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ABSTRACT BOOK



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VERBAL PRESENTATIONS

Lead (Pb) Contamination of Pitcher Pump systems in coastal Madagascar: Health implications for sustainable self-supply

David Akers, University of South Florida

Additional Authors: Michael MacCarthy; Jeffrey Cunningham; Jonathan Annis; James Mihelcic

Access to safe water supply--a major determinant of public health--is less than 50% in Madagascar, and access to piped, treated water remains out of reach financially for many in the urban and peri-urban areas where available. The Self-supply option of the Pitcher Pump has been meeting the need for household water in coastal areas of Madagascar since the early 1960s and has proven a sustainable option for many households. These pumps make use of leaded components in the construction, however, which may pose a health risk for heavy metal intoxication and therefore cause the water to be unsafe for drinking and cooking. This study assesses the potential for lead (Pb) leaching from Pitcher Pump systems into water at levels of health concern. The objectives of this study are to assess Pb concentrations in water drawn from Pitcher Pumps, to determine the relationship between various factors and the Pb levels, to make a preliminary assessment of public health implications of Pb contamination, and to offer informed recommendations to reduce the likelihood of consuming contaminated water. A field study was undertaken to measure concentrations of dissolved Pb in water from Pitcher Pumps under recently flushed and first-draw pumping conditions at 18 households in the city of Tamatave, Madagascar. Variables potentially affecting Pb leaching were determined including pump age, depth to the well screen, pump manufacturer, season of sample collection, and basic water quality indicators. Sampling campaigns were conducted three times over the course of eight months. Time-release case studies were also carried out at two households to determine the time scale over which the Pb concentration in stationary water reaches equilibrium with the Pb-containing system components. Pilot studies of iron (Fe)-for-Pb substitution of select pump system components were carried out at the same two households to attribute the major contribution of Pb leaching to one set of parts and to assess one strategy for decreasing dissolved Pb concentrations. Finally, the Internal Exposure Uptake Biokinetic Model for Lead in Children (IEUBK Model) of the US Environmental Protection Agency (EPA) was employed to estimate realistic blood lead levels (BLLs) in children under five years of age, based on Pb concentrations measured in the water. Of the 18 pumps sampled, 15 produced at least one sample exceeding the World Health Organization (WHO) provisional guideline of 10 µg/L dissolved Pb in water. Specifically, 67% of all samples showed concentrations above 10 µg/L under first-draw pumping conditions. Flushing the pumps prior to use decreased the Pb levels significantly ($p < 0.0001$), with only 35% of samples exceeding the provisional guideline. Under flushed conditions, the median Pb concentration in pumped water was 9 µg/L, down from 13 µg/L at one hour of inactivity. No statistically significant correlations were observed between measured Pb concentrations and factors like the season of sample collection, pump age, manufacturer, or water quality indicators like pH or temperature. Under first-draw conditions, the concentration of Pb in water increased with increasing duration of pump inactivity, until equilibrium was reached with the leaded pump components. For two pumps, substitution of Fe valves for Pb greatly decreased Pb concentrations in the water, from 37-100 µg/L and 7-24 µg/L down to 3-4 µg/L and 2-8 µg/L, respectively. Model-predicted geometric mean BLLs in children range from about 2-8 µg/dL, in some instances exceeding the Centers for Disease Control and Prevention (CDC) guideline for an elevated BLL (5 µg/dL), depending on the exposure concentrations. This study finds that water provided by Pitcher Pump systems in Madagascar frequently exceeds the WHO provisional guideline value for safe consumption under first-draw conditions, and may do so even after flushing the pumps. The Pb concentrations measured in the field have the potential to elevate BLLs in children under five to levels implicated in serious health issues. Leaching of Pb into the water is therefore an issue of concern for users of the Pitcher Pump systems in Tamatave, and likely for other areas served by this technology. Flushing the pumps before water collection generally reduces Pb levels in the water. These results suggest that most of the Pb leaches from pure Pb check valve weights at the mouth of the pump, and consequently, a substitution of Fe weights on the valves greatly reduces Pb concentrations and the probability for exceeding the WHO provisional

guideline. Relatively simple operational changes on the part of the pump manufacturers and the pump users might, therefore, help to ensure the continued sustainability of Pitcher Pumps in eastern Madagascar.

A farm to fork risk assessment for the use of wastewater in agriculture in Accra, Ghana

Prince Antwi-Agyei, London School of Hygiene and Tropical Medicine (LSHTM)

Additional Authors: Sandy Cairncross; Anne Peasey; Kelly Baker; Jeroen Ensink

The use of wastewater in agriculture is on the increase in Ghana as a result of rapid urbanisation, water scarcity, and the high cost associated with treating urban wastewater. The use of wastewater holds clear benefits to farmers, but also poses serious risks to farmers and consumers of wastewater irrigated produce. The relative importance of wastewater irrigation in disease transmission is however unclear as past studies have shown that post harvest activities can play an important role in produce contamination too. In the period from October 2012 to August 2013 irrigation water, farm soil, produce and ready-to-eat salad samples were collected, and analysed for the presence and concentration of *E. coli*, adenovirus, norovirus, and helminths. Produce samples were collected from field, market, and at food stalls. A membrane filtration culture-based method was used to determine the prevalence and concentrations of *E. coli*. Helminth ova concentrations in water, soil and on produce were determined using a flotation-sedimentation technique, while virus analysis was done using Quantifast RT-PCR and PCR. Questionnaires were administered to study participants, which included farmers, market and street food vendors, public consumers of street food, produce buyers at markets and chefs at hotels and restaurants. In addition critical exposures associated with microbial quality of produce were assessed through observations. The microbial results showed that at least 81% of irrigation water sources in both seasons were contaminated with *E. coli* exceeding recommended levels for irrigation of salad crops. Over 80% of produce and salad samples were contaminated with *E. coli*, with average concentrations ranging from 0.8 to 3.8 log *E. coli*/g produce. Ready-to-eat salads from street food vendors were found to be the most contaminated (3.9 log *E. coli*/g). Farm produce had significantly higher levels of contamination than market produce in the dry season but not in the rainy season. Key risk factors identified for produce contamination were source of irrigation water, farm soil and use of poultry manure at the farm level. The method reported for cleaning salad crops, irrigation water, farm soil and type of farm produce were also found to influence street vendor microbial quality. Results further showed widespread use of poultry manure among farmers with a 60% and 99% prevalence in the rainy and dry seasons respectively, potentially causing higher levels of contamination than irrigation water. At markets, observations revealed that although two-thirds of vendors reported to have washed their vegetables before sale, wash water was found to be contaminated. Hygienic display of produce at markets was also poor, as 45% of vendors sold their produce in the open and without any protection from environmental contaminants. At least 87% of street vending sites were dusty, while 20% had their salads uncovered for an average time of close to 100 minutes. 67% of vendors who were observed to have prepared salad onsite did not wash their hands before preparation. The results of this study suggest that, farm level contamination and post-harvest contaminants both may play significant role in influencing produce quality. This association is, however, partly influenced by seasonality. There is therefore a need to manage risk factors at all domains with priority attached to the farm level. At the farm level, banning or restricting the use of untreated wastewater, or better still adoption of crop restriction remains the greatest security in ensuring food safety. However, without alternative water sources, these measures are unlikely to be feasible as it will deprive farmers and vendors of their livelihood. In the interim and considering the absence of alternative water sources, farmers are recommended to practice good agricultural practices that will limit produce contact to soil or sediments. These could include controlled fetching of irrigation water and the use of watering cans fitted with caps. Similarly, restrictions on the use of poultry manure might not be implementable in the short term but farmers should ensure that manure is well composted before use as soil amendment. Due to the challenges in the uptake and implementation of effective farm level protective measures, post harvest interventions are needed to further reduce microbial

levels in produce. At markets, vendors should practice hygienic display of their produce. Washing of produce should be done under running potable water, or by the use of multiple batches of potable water. Apart from environmental and personal hygiene and effective salad treatment, street food vendors should prepare salad in small quantities to meet customer inflow, and to prevent contamination due to inadequate storage and inappropriate temperature. Apart from buffet, salads at hotels and restaurants should also be prepared based on customer request, or be refrigerated until ready to serve.

The effects of watershed land cover and precipitation on fecal contamination in surface waters

Javier Arce-Nazario, University of Puerto Rico at Cayey

Additional Authors: Nicolle Lebrón; Jennifer Paredes

Fecal contamination in surface water is a serious health threat, and increases the cost of water treatment. This study analyzes the effects of both watershed composition and precipitation on the concentration of fecal contamination in surface waters. From June 2013 to April 2014, water was sampled at fifteen sites in the La Plata River Watershed, and tested for the presence of coliphages and enterophages using novel microbiological techniques. This microbiological composition data was compared to the watershed composition, determined using GRASS GIS hydrotools, and to precipitation values measured by pluviometers. The analysis shows that microbiological presence is affected by both watershed composition and precipitation, and that these factors interact. Precipitation typically increased the presence of phages in streams. Water from regions with a higher concentration of houses and farmland showed higher levels of phages compared to forested watersheds. Water from watersheds from highly urbanized regions showed a much higher numbers of enterophages, compared to coliphages. Water from watersheds with farms resulted in higher levels of coliphages relative to enterophages. Daily precipitation increased the concentration of phages in the water. These results suggest a preliminary framework for analyzing how water quality varies as a result of environmental and social factors.

Impact of sanitation coverage on neighborhood-level fecal contamination in Accra, Ghana

Kelly Baker, Emory University

Additional Authors: Habib Yakubu; Dorothy Peprah; Clair Null; Kate Robb; Joseph Ampofo; George Armah; Christine Moe

Improved access to safe, clean toilets can reduce human fecal contamination in the environment by preventing open defecation, and by installing barriers between human feces and public resources. Capture and containment of human feces by toilets should reduce the amount of fecal contamination in the environment. However, proper treatment and disposal of septage is an equally important and often neglected component of the sanitation chain. In cities in developing countries, the lack of designated sewage holding and treatment facilities results in direct disposal of large quantities of untreated waste into the environment. Little is known about how effective improvements in sanitation coverage are at preventing contamination, given open defecation within a population and a lack of septage management. We hypothesized that neighborhoods with lower sanitation coverage may have disproportionately higher neighborhood-level contamination. This study explored the impact of moderate versus low neighborhood-level sanitation coverage on fecal contamination in the public domain in a city lacking an overall municipal septage treatment system. The Sanipath study was conducted in 4 neighborhoods of urban Accra, Ghana, a city lacking a municipal septage containment and treatment system. Most septage was emptied directly into open drains or the ocean, and open defecation was common due to low levels of sanitation access. Half of the compounds in the neighborhoods of Alajo (58%) and

Shiabu (47%) had a toilet, while sanitation coverage in Bukom (6%) and Old Fadama (1%) was low. Daily use of public latrines was reported by 67% of residents in Alajo, 45% in Shiabu, 65% in Bukom, and 78% in Old Fadama. Samples representing different types of community-level fecal exposure routes were collected in each neighborhood, including drain water, piped drinking water, soils from public areas and raw market produce. Concentrations of fecal contamination in these samples were assessed by measuring *E. coli* by membrane filtration of serially diluted samples and enumeration of colonies on BBL® MI Agar. Geometric mean concentrations of *E. coli* in drain and drinking water, and on raw produce were compared between the 4 neighborhoods using One Way ANOVA, and by nonparametric ANOVA for soil samples. Mean *E. coli* CFU/100 mls of drain water was similar ($p=0.19$) in Alajo ($n=25$, mean 1×10^9 , Standard Deviation (SD) 3×10^9), Shiabu ($n=24$, mean 1×10^{10} , SD 3×10^{10}), Bukom ($n=18$, mean 6×10^9 , SD 2×10^{10}), and Old Fadama ($n=20$, mean 7×10^8 , SD 2×10^9). Although mean *E. coli* CFU/100 mls of piped water was slightly higher in Old Fadama ($n=30$, mean 5×10^1 , SD 2×10^2) than in Alajo ($n=36$, mean 0.8×10^0 , SD 0.2×10^0), Shiabu ($n=28$, mean 2×10^0 , SD 6×10^0), and Bukom ($n=22$, mean 1×10^0 , SD 2×10^0), the difference was not significant ($p=0.11$). Mean *E. coli* CFU per item of raw produce was similar ($p=0.23$) in Alajo ($n=23$, mean 4×10^4 , SD 1×10^5), Shiabu ($n=18$, mean 6×10^3 , SD 2×10^4), Bukom ($n=18$, mean 1×10^5 , SD 2×10^5), and Old Fadama ($n=23$, mean 1×10^5 , SD 3×10^5). A significant difference ($p=0.002$) was observed between the mean *E. coli* CFU/gram of soil collected from the four neighborhoods. Soil in Old Fadama ($n=51$, mean 8×10^3 , SD 2×10^4) was significantly more contaminated than in Alajo ($n=67$, mean 1×10^3 , SD 6×10^3) and Shiabu ($n=42$, mean 1×10^3 , SD 5×10^3), but not Bukom ($n=37$, mean 2×10^3 , SD 9×10^3). Our data suggest that municipal-level failure in sanitation service creates high concentrations of fecal contamination across a city, regardless of compound-level coverage level in individual neighborhoods. Higher levels of compound-level sanitation coverage did not reduce the risk of exposure to general fecal contamination from community-level resources in an environment where animals freely roam and where human feces is openly discarded. Soils in the poorest urban slum of Old Fadama were more contaminated, but this is unlikely to be caused by sanitation coverage level since Old Fadama has similar levels of compound-level sanitation coverage as Bukom. This neighborhood had the only public bucket latrines, and the drainage system was also poor compared to Bukom. Residents in Old Fadama reported flooding more often, with longer duration, and over a larger geographical area. Notably, although contamination levels in soils were significantly higher in Old Fadama, this difference was marginal (1 logarithmic unit) and may not translate into real differences in exposure, infection and disease rates in humans. Improved sanitation coverage may be more effective at reducing the amount of human feces in the environment. Forthcoming analysis of Norovirus GI/GII and human Adenovirus concentrations in these samples will better distinguish between general and human fecal contamination and allow comparison of human feces contamination by neighborhood sanitation coverage level.

Improving Lives through Sharing Water Point Data

Brian Banks, Global Water Challenge (GWC)

Around the world, as many as 1.8 billion people lack access to safe water. This challenge is exacerbated by failures in the water sector, resulting in high rates of non-functioning water points. In response to this challenge, governments, NGOs, donors and individuals are increasingly collecting data on the functionality of water points. Unfortunately, there is no effective way to share this flood of incoming data as it is being collected by a multitude of stakeholders in a variety of formats. Costly information gathered is too often used once, by one user before it is left inaccessible on organizational servers, in dusty reports and in proprietary monitoring systems. Not only is this one-time use of data inefficient in a sector with scarce monitoring resources, but it dramatically limits the opportunity for those addressing water challenges to learn and improve from one another. The Global Water Challenge (GWC) realizes the value of data in understanding the water access landscape and recognizes that water point mapping is growing in popularity as a tool for monitoring and evaluation of water access projects. With these realities in mind, GWC has evaluated the feasibility of sharing monitoring data for improved sector practice. Through a pilot study of publicly-available water datasets, nearly

250,000 data points across twelve datasets and nine countries were harmonized using an initial draft data exchange standard. The success of the pilot initiative affirms the feasibility of and need to scale up these initial activities. Building on lessons learned in pilot development, GWC will facilitate a discussion throughout the global water sector to support the collaborative development of a framework for sharing water point data. Once this framework is developed from the sector-wide discussion, it will be used to harmonize diverse datasets. Beginning in May 2014, GWC will conduct a review of attributes documented in various organizations' monitoring activities. It is expected that this review will lead to a baseline data exchange standard. Sector engagement, through webinars, expert interviews and in-person discussions, to review the baseline standard will lead to a widely accepted data exchange standard that will enable sector-wide data aggregation. GWC will leverage the opportunity of the University of North Carolina - Chapel Hill Conference to present the Beta version of the Data Exchange Standard. This builds directly on the WASH Monitoring Exchange presentation made in 2012 at the UNC Water and Health Conference. GWC will discuss the process undertaken to develop the Data Exchange Standard, clarify next steps, demonstrate the standard's added value to the sector and solicit feedback for continued improvement.

Water Safety Plans: Institutional conditions for implementation and potential added value to US drinking water regulations

Rachel Baum, The Water Institute

Additional Authors: Urooj Amjad; Jeanne Luh; Jamie Bartram

Background: Water Safety Plans are a preventive drinking water risk management approach that is applied from source to tap. They have been implemented either voluntarily or mandatorily in over fifteen countries worldwide, with documented benefits. Studies have shown that countries which have implemented WSPs have observed increases in drinking water quality regulatory compliance, improvements in microbiological water quality, decreases in incidences of clinical cases of diarrhea, and better asset management leading to potential financial gain. Despite these potential benefits, WSPs have had limited application in the US. Objectives: The objectives of this study are to: (1) determine the institutional conditions in which water safety plans (WSPs) are implemented, and (2) examine the potential added value of WSPs to the United States (US) national drinking water legislation and regulations. Methods: We examined the ability and willingness of water utility managers to implement WSPs in North Carolina, defined as operational, managerial, and financial. Using an ethnographic and grounded theory approach, we conducted twelve semi-structured interviews. A comparative analysis between US drinking water regulations and WSP steps informed an analysis of the similarities and differences between them, and identified how WSPs complement drinking water regulations in the US. Findings: Results show the following reasons for utilities' inability or unwillingness to implement WSPs: lack of sufficient time and resources, lack of clear comparative advantage of WSPs in relation to other hazard management plans, lack of buy-in from water operators or town managers, no clear responsibility of who could lead the implementation or in which practices it would naturally fit, and lack of ideas about the usefulness and relevance. The results from the comparative analysis show that the largest gaps between US regulations and WSPs are in team procedures and training, risk assessment and prioritization, and management procedures and plans. The study contributes to understanding conditions for water utilities to adopt new practices, how WSPs could be adapted for various utility needs, and how drinking water quality management may benefit from voluntary, preventive initiatives.

Conditions for Making Sodium Hypochlorite in a Developing Country While Avoiding Inorganic Disinfection By-Products

Mike Bellamy, Northwest Missouri State University

Chlorination is an attractive disinfection option in a developing country such as Haiti for several reasons. One is that large volumes of water can be treated for little cost. A second is that water that has been chlorinated can have residual disinfectant present. This may help prevent recontamination of the water if it comes in contact with unwashed hands or a contaminated storage container. A third is that test kits are readily available to measure the concentration of free chlorine in treated waters. Testing treated waters for the presence of multiple pathogens is time-consuming. It also requires trained users and specialized equipment. Consequently, it is much easier to test for the presence of residual chlorine than it is to test for the absence of pathogens. Some organizations working in developing countries use commercial bleach to chlorinate water. However, commercial bleach breaks down fairly rapidly. It is possible to unwittingly dose water with unacceptably high levels of the toxic disinfection by-products chlorate and perchlorate. A solution to the problem of bleach breaking down to form toxic disinfection by-products is to make bleach on-site and use it right away. Sodium hypochlorite (bleach) can be made easily by passing a solution of sodium chloride in water over different types of electrode materials. The process is referred to as on-site generation (OSG) of sodium hypochlorite. Several organizations make relatively inexpensive equipment that can be used to make hypochlorite in developing countries. However, care must be taken when using this equipment since the same electrodes used to make hypochlorite will also make chlorate and eventually perchlorate. Industrially, chlorate formation is avoided when making hypochlorite by controlling factors such as the concentration of the salt solution, pH, temperature, flow rate, type of electrode material, and current applied to the electrodes. However, it is not always easy to control reaction parameters in a developing country. The budgets of projects in developing countries are often very limited. In addition, certain chemical reagents and equipment may not be available. However, if the OSG equipment is first tested in a laboratory, reaction parameters can be identified that are reproducible in a developing country that will produce hypochlorite while minimizing the formation of chlorate and perchlorate. At one site in Haiti, trained workers have been able to consistently chlorinate water to within 1 or 2 ppm while avoiding disinfection by-products.

The interaction of deworming, improved sanitation, and household flooring and soil-transmitted helminth infection in rural Bangladesh

Jade Benjamin-Chung, University of California, Berkley

Background: Mass drug administration (MDA) with deworming is commonly used to control soil-transmitted helminths (STH). In Bangladesh, MDA takes place in schools twice annually. However, there is evidence that reinfection often occurs rapidly among a large proportion of those treated. The delivery of chemotherapy in combination with sanitation and flooring might sustainably reduce the burden of STH in the long run. The objectives of this study were to: 1) estimate the prevalence of STH infection among children and women of childbearing age in rural Bangladesh, 2) estimate associations with deworming, hygienic latrines, and finished floors and STH infection, 3) explore potential interactions between these exposures, and 4) estimate associations between cluster-level exposures and cluster-level STH prevalence. **Methodology:** We conducted a cross-sectional survey of 1,655 households to assess deworming in the prior six months, access to hygienic latrines, and household floor material. Field staff collected 1,795 stool samples among a stratified sample of children 1-4 years, children 5-14 years, and women 15-49 years in rural Bangladesh. We detected and quantified *Ascaris*, hookworm, and *Trichuris* ova in stool samples using mini-FLOTAC. We used log linear regression to estimate prevalence ratios adjusted for potential confounders (age, sex, wealth, mother's age, mother's education, sub-district). We assessed interaction on the additive scale using the relative excess risk due to interaction (RERI) as well as on the multiplicative scale. We estimated the association between cluster-level STH prevalence and coverage of each exposure of interest using cubic smoothing splines with 95% confidence bands. **Results:** 32% of individuals were infected with at least one STH; 9% had multiple infections. *Trichuris* was most common, infecting 21% of the study population. 26% of children 1-4 years, 40% of children 5-14 years, and 30% of women 15-49 years had an STH infection. Less than 2% had a moderate or high intensity STH infection. The adjusted prevalence ratio (aPR) for reported deworming in the past six months was 0.60 (95% CI 0.46, 0.80) for

Ascaris, 0.91 (95%CI 0.60, 1.39) for hookworm, and 1.02 (95% CI 0.84, 1.24) for Trichuris. The aPR for hygienic latrines was 0.88 (95%CI 0.65, 1.19) for Ascaris, 0.75 (95%CI 0.44, 1.25) for hookworm, and 1.00 (95%CI 0.80, 1.24) for Trichuris. Living in a household with a finished floor was associated with lower STH prevalence for Ascaris (aPR=0.52; 95% CI 0.30, 0.90) and hookworm (aPR=0.44; 95% CI 0.15,1.29) and was not associated with Trichuris prevalence (aPR=1.00; 95%CI 0.80, 1.24). We found a consistently greater protective association across helminths for combined deworming, sanitation, and floor exposures in comparison to individual exposures. For example, for Ascaris, the aPR was 0.63 for deworming alone, 0.97 for hygienic latrine access alone, and 0.44 both. The RERI was -0.43, indicating that the joint aPR was closer to the null than the sum of the individual aPRs; however, the RERI was not statistically significant (95% CI -2.40, 0.48). Cluster-level STH prevalence was unassociated with cluster-level deworming, finished flooring, and improved sanitation coverage. Conclusions: We found that STH infections were prevalent among school-aged children despite targeting by school-based MDA for the last five years; they were also prevalent among pre-school aged children and women of childbearing age in the same community. There was evidence that individuals who took deworming and had access to hygienic latrines and finished flooring in their household had a lower STH prevalence than those who only took deworming. While measures of interaction were not all statistically significant, our results suggest a possible synergistic interaction between deworming, improved sanitation, and finished flooring. In contrast to what we would expect based on mathematical modeling studies, we found no association between cluster-level STH prevalence and the percentage of households in a cluster with each exposure. Our results support further exploration of STH control efforts combining deworming, improved sanitation, and finished flooring.

Effect of Community Led Total Sanitation intervention on Diarrheal diseases and other hygienic behaviors in Households, southern Ethiopia

Hunachew Beyene, Addis Ababa University

Additional Authors: Wakgari Deressa

Diarrheal disease has been one of the major public health challenges especially in developing countries. Access to improved water sources, sanitation, and hygiene promotion has been the best weapon to reduce the health impact of diarrheal diseases. Community Led Total Sanitation (CLTS) approach through promotion of behavior change and awareness of health and hygiene aspects has been regarded as one of the simple solution to reducing disease burden. With the understanding of this concept the ministry of health of Ethiopia has adopted CLTS to be implemented in the country through the Health Extension program. Recent reports reveal that using CLTS as a promotion tool, many rural kebeles (kebeles are the smallest administrative unit in Ethiopia) in many parts of the country have been declared to be Open Defecation Free (ODF). However, various researchers reported that the prevalence of diarrheal disease and poor hygienic practices are still common in many parts of the country and in the study area. The present study evaluated the effect of the CLTS intervention by comparing the magnitude of diarrheal disease in children less than five years of age and improvements in other hygiene behaviors in households living in ODF and Non ODF kebeles. This cross-sectional study was conducted between July 1- August 15, 2013 in 8 rural kebeles of Sidama zone, Southern Ethiopia of which 4 are from ODF and the remaining 4 are from non-ODF kebeles. A total of 1939 under five children between the ages of 6 and 59 months in 1677 households were included in the study. Household data was collected using structured and pretested questionnaire. Trained health professionals who had sufficient understanding of the subject collected the data. Ethical approval was obtained from the Institutional Review Board of Addis Ababa University, and permission was obtained from the regional health bureau. In addition a total of 8 Focus Group Discussion (FGD) was also conducted in the 8 kebeles. The 2 weeks prevalence of diarrhea was 497(25.6%) with no difference in prevalence between ODF and non-ODF villages. In principle, in ODF kebeles, all households are supposed to have a latrine. However, the coverage was found to be only 79.4%. The coverage in the Non-ODF kebeles was 59.1%. Nearly all of the latrines were simple pit type, and 489 (39.2%) are not hygienic. And 93.3% of the latrine

owners didn't have hand washing facilities. Among the latrines, 414 (24.8%) had some sort of problems, of which 272 (56.4%) were collapse of the pits. Among the 414 households with latrine problem, 58.2% are found in the non ODF kebeles. The logistic regression analysis indicated that latrines in the ODF kebeles were more hygienic than those found in the non ODF kebeles (OR=1.485, 95% CI, 1.158-1.896). However, the latrines constructed were not improved as compared to those found in the non-ODF villages (OR=1.44, 95% CI, 1.10-1.88). In terms of child feces disposal, those who live in ODF places dispose properly as compared to those who live in non ODF areas (OR=2.4, 95%CI 1.959, 2950). Among the latrine owners 1162 (93.3%) are very happy or moderately happy with the latrine they were using. However, 1645(94%) of the latrine owners have explained their interest to adopt more improved latrine type than the current simple pit latrine; among these, 66.8% mentioned that they can afford to adopt. In the qualitative study, it was revealed that sustainability of latrine structure is a big problem. The participants mentioned that the average life time of a latrine in many places is 6 months as the wooden slab decomposes with the soil and flooding. Strong logs are no more available due to deforestation, and buying them (if available) has been unaffordable for most of the villagers. From this study it can be concluded that, there has not been reduction in the incidence of diarrhea due to the CLTS intervention. In addition the accelerated campaign resulted in mass construction of non improved latrines. However, there have been improvements in hygienic practices in the ODF villages. It is a lesson that the government need to provide affordable and sustainable sanitation options which are resilient to environmental effects, and interventions also need to be targeted on certain behaviors.

Hygiene assessment of decentralized sanitation nutrient recovery: Pathogen occurrence and inactivation during urine nitrification

Heather Bischel, Ecole Polytechnique Fédérale de Lausanne

Additional Authors: Ariane Schertenleib; Tamar Kohn

Having reached the Millenium Development Goal of reducing the number of people without access to basic sanitation services within its country borders, South Africa now aims to achieve universal access to sanitation services. Aggressively pursuing this goal, the eThekweni Municipality of Durban installed over 80,000 urine-diverting dry toilets since the early 2000s at households in peri-urban regions of the city. Currently, urine from these toilets is typically diverted from households into soak pits. However, approximately two thirds of phosphorus and 80% of nitrogen in human excrement are contained in the urine fraction of human excreta and could be recycled for agriculture either directly or in a processed form such as the stabilized nitrogen- and phosphorous-rich fertilizer produced from urine nitrification. Little systematic evaluation regarding the pathogenic health risks and microbial treatment efficacy of urine nutrient recovery processes has been conducted. Source-separated urine contains fecal pathogens as a result of cross-contamination of collected urine with fecal matter. This project assesses the presence of human viruses in urine storage tanks throughout Durban and evaluates the pathogen inactivation performance of urine nitrification moving bed biofilm reactors (MBBRs). While urine diversion and nutrient recovery have typically been implemented as grassroots or community-driven initiatives, the magnitude of the UDDT installation in the eThekweni Municipality will allow an evaluation of the potential for urine nutrient recovery processes at scale. A hygiene evaluation is particularly important in a large-scale urban or peri-urban setting in which urine storage times are reduced and fertilizer production rates are high. The presence of human viruses whose transmission pathway is the fecal-oral route was evaluated urine storage tanks installed in three regions of Durban using reverse transcription multiplex PCR and real-time PCR. This analysis expands upon previous work in which fecal bacteria, including *Clostridium perfringens*, *Aeromonas* spp., *Shigella* spp., and *Vibrio* spp., were detected in the source-separated urine. Each urine tank contains a composite of source-separated urine from approximately one hundred nearby households, thus yielding a mixture of pathogens in the fertilizer source material. Of the 9 virus targets, JC Polyomavirus was ubiquitous in the urine tanks, while Adenovirus and Rotavirus were detected in about one third of the samples.

JC Polyomavirus may be a useful indicator of urine contamination for a future health assessment. Hepatitis A virus, hepatitis E virus and Norovirus GII were also detected. The persistence in stored urine and low infective dose of human viruses points to the need to control these contagions in the production and use of urine as fertilizer, especially in the potentially high user-material contact scenarios likely in decentralized peri-urban urine collection and processing schemes. Inactivation of pathogens was evaluated in batch MBBRs that are used to stabilize volatile ammonia in urine. A gram negative bacterium, a gram positive bacterium, and bacteriophage were used as indicators of pathogenic viruses. Reactor conditions were modified to evaluate modes of inactivation. Whereas bacteriophage ΦX174 and MS2 remained infective following urine nitrification, *Salmonella typhimurium* and *Enterococcus* spp. were inactivated in the batch systems. However, inactivation occurred at rates roughly equivalent to or slower than those expected for bacteria in unprocessed stored urine, where uncharged ammonia serves as an inactivating agent. Nitrification reactor biological communities did not adapt to inactivate bacteriophage MS2 during continuous input of MS2 over more than 60 days in a flow-through nitrification reactor. Thus nitrification as a fertilizer production process remains insufficient as a standalone technology for the sanitisation of source-separated urine.

'A Child is also a Teacher': Exploring the Potential for Children as Change Agents in the Context of a School-based WASH Intervention in Rural Eastern Zambia

Sara Bresee, Emory University

Additional Authors: Justin Lupele; Bethany Caruso; Jessica Sales ; Sarah Fry ; Matthew Freeman

Background: Access to water, sanitation and hygiene (WASH) at school has been shown to improve health of pupils and increase school attendance. Interventions that target the school can also serve as an entry point to improve WASH access at home. Using the school - an established and trusted source of knowledge - as a means of information dissemination, is especially pertinent in rural settings where other techniques to engage communities might not be as effective. However, few school-based WASH programs use systematic or evidence-based approaches to promote dissemination of knowledge and practice. There is limited research on using school pupils as agents of change and the mechanisms by which pupils can influence their parents and siblings. In the context of a school-based WASH program, SPLASH, funded by USAID/Zambia and managed by USAID/WASHplus, we sought to explore the potential for children to be change agents for behavior change and technology adoption in their households. The study aimed to: 1) describe behavior, cultural norms, and attitudes towards sanitation and hygiene of primary school pupils within Eastern Zambia; 2) understand how pupils were able to take WASH information home to their parents and families; and 3) identify who children and parents considered to be trusted sources of information and key avenues for message dissemination. Methods: We employed qualitative methods in order to gain a richer understanding of the attitudes and norms surrounding children as change agents in the form of a two-phased study at five different SPLASH schools. During phase 1, we conducted 2 focus group discussions (FGD) with 16 pupils, one with girls and one with boys, and interviews with teachers who serve as the school's WASH coordinators. Pupils drew pictures, which they used to discuss their normative school and home WASH environments and behaviors, and the differences. Pupils were also asked to role-play to show how they would speak to or teach a family member about WASH. At the end of phase one, we gave the pupils a homework assignment that consisted of two sheets of paper containing pictorial WASH related tasks. One was an instruction sheet on how to make a tippy-tap while the other showed the dangers of open-defecation and drinking unsafe water. We returned for phase two at the same schools and conducted two more FGDs with the same pupils to assess their attitudes and opinions of carrying out the assignment. We also conducted 5 FGDs with a total of 39 pupils' mothers. Mothers were posed questions related communication behaviors with their children and their impression of the WASH behaviors and technology discussed by children. Data were analyzed using verbatim transcriptions and translations from the local language to English using grounded theory methodology. Results: Most pupils reported safe sanitation and hygiene behaviors at school

and, due to a high perceived risk of disease, wanted to practice these behaviors at home. Pupils discussed a desire to alter their environment to have safe sanitation, however they did not feel they had the agency to be able to influence this change. They reported negotiating with their parents (namely a male household head) to influence the construction of home latrines. As for hand hygiene, pupils discussed being able to build tippy-taps to increase hand washing. In addition, pupils regularly remind their parents and siblings to wash their hands. Pupils also reported demonstrating how to use toilets and tippy-taps with their younger siblings. Pupils used the pictorial homework assignment to aid in discussion of sanitation and hygiene. They reported that having a piece of paper allowed for their families to trust and easily understand the information they were trying to teach. Mothers were receptive towards receiving WASH information from their children, this was due to the value they placed on their children's education, previous exposure to sanitation and hygiene information and an existing desire to change. Conclusions: We found considerable evidence that children can serve as effective change agents when provided discrete tasks with simple instruction. Pupil and parental perspectives were similar in regards to a child's physical, mental and social capacity to be able to build tippy-taps and latrines. This study has implications for specific programmatic guidelines for school-based WASH. First, school-based WASH interventions should leverage the pupil's ability to influence the home through pictorial homework assignments and technology instructions to create hand washing technology and latrines at home. Second, pupils should be encouraged to speak to their families about sanitation and hygiene but their physical and social abilities should be taken into account. Rather than assuming dissemination from schools to home, the specific mechanisms by which children can influence their parents and other children should be explored in Zambia and elsewhere.

User Preferences and Willingness to Pay for Household Water Treatment in Rural Tanzania

Zachary Burt, University of California at Berkeley

Additional Authors: Robert Mussa; Yolanda Mbatia; Veritas Msimbe; Joe Brown; Thomas Clasen; Hamisi Malebo; Isha Ray

MOTIVATION Where piped and treated water is not an option for reasons of cost and logistics, household water treatment and safe storage (HWTS) is a potentially cost-effective way to help vulnerable populations achieve the health benefits of safe water. HWTS has the potential to reduce mortality and morbidity; in particular to prevent stunting and promote healthy mental development in children (Fewtrell et al, 2005). In Tanzania, however, an estimated 69% of rural households do not treat their water before drinking (Malebo et al 2007); increasing rates of HWTS in Tanzania would therefore go far in reducing mortality and morbidity. **PROJECT DESCRIPTION** This study aims to identify the HWTS with the greatest potential for long-lasting and wide-range adoption. With this goal in mind, we estimated the price levels for potentially appropriate HWTS technologies/methods for rural areas. Specifically, the HWTS methods we examined were:: 1) Chlorine treatment alone (WaterGuard Liquid or WaterGuard Tablets), 2) Chlorine treatment with flocculation (PUR or re-packaged PUR [takasa maji]), 3) Filtration (Siphon or Ceramic Pot Filters), and 4) Boiling. Every household received one HWTS from each of the four categories over the course of the study. Working in a total of four villages from two villages from each of two different districts, we conducted a census of each village and used this to randomly select 150 participants from each village. All participants evaluated one of the HWTS from each of the four categories, over the course of four consecutive evaluation rounds, each round lasting a minimum of five weeks. The order in which the HWTS were assigned was randomized at the household level. At the end of each round we collected user preference data and at the end of all four rounds we collected WTP data. **RESULTS** By the end of the round, 80 - 90% of study participants in Geita and 80 - 97% of those in Kisarawe reported using their assigned HWTS in the previous two weeks. Women were the primary operators of HWTS. Looking at the user preferences, adoption rates were highest for boiling and the pot filter in both districts. Of the households that used the pot filter, 59% ranked it as first or second best overall, in Geita, and 58% in Kisarawe. PUR, WaterGuard Liquid and WaterGuard Tablets were all strongly disliked in Geita; WaterGuard Liquid and WaterGuard Tablets were less often rejected

in Kisarawe. PUR was strongly liked in Kisarawe, a much different outcome than in Geita, which may have been due to the much higher prevalence of turbid water in Kisarawe than in Geita. The results of the willingness to pay (WTP) analysis using simulated auctions revealed that for PUR the median bid was half its retail price and for WaterGuard Liquid and WaterGuard Tablets the median bid was roughly 1/3 the retail price (the median representing what 50% of the participants are willing to pay). Since the filters were durable household products their bid prices were much higher, but the average and median bids represented only a smaller percentage of the retail price (e.g., the median bids for the siphon filter and the pot filter were 7% and 11% of their retail prices, respectively). **RECOMMENDATIONS** According to our observations, none of the retail HWTS tested for this study has a greater potential for scale up in current circumstances than boiling. Boiling does not require financial expenditure when using gathered bio-fuel, and therefore the (financial) price and the WTP is the same: zero. Boiling is the most accessible option available to the largest number of households within our study population; no supply chain would need to be built in order to supply this HWTS to rural households. Yet, boiling is not without costs; gathering fuel and heating the water requires time, and although most of the participating households had outdoor kitchens, for those that had indoor kitchens, burning wood is associated with a higher risk of respiratory diseases (Smith et al. 2000). Although it is hard to say whether people preferred boiling more than the pot filter, at the very least the pot filter was a strong rival. Therefore, it is the recommendation of the research team that if either price reduction or subsidies, or a combination of the two, were to be made available, then the pot filter would likely have good potential for scale up in rural Tanzania. We estimate that in order to reach approximately half of the targeted rural household, the combination of subsidies and price reductions needed would total around Tsh 40,000 (US\$ 27) per filter. In addition, if PUR, or a similar sachet product which provided both flocculation and disinfection, were to be made available at a price of around Tz Sh 100 or less per packet (the median price in Kisarawe), this might allow for successful scale up in rural communities with access to predominately turbid water sources.

Impact of a school-based WASH program on diarrhea, respiratory infection, absenteeism and presence of blood antibodies for infectious disease: new approaches and results from Mali

Anna Chard, Emory University Rollins School of Public Health

Additional Authors: Victoria Trinies; Howard Chang; Matthew Freeman

Background: The impact of improvements in water, sanitation, and hygiene (WASH) on the reduction of enteric and neglected tropical diseases among children and adolescents is well supported. However, health impact evaluations of WASH interventions in low-resource settings are limited by the existing, and often biased, expensive, or laborious methods and tools used to measure diarrheal and NTD incidence. The aim of this study is to pilot a novel, objective method for evaluating the impact of school WASH improvements on enteric and neglected tropical diseases incidence among pupils in Mali through blood antibody analysis of dried blood spots (DBS) using a Luminex assay. This method was developed and tested by the CDC, but has yet to be employed for school-age children and integration of this method into WASH trials is still limited. Compared to other methods to collect biological evidence of infection such as stool analysis and venipuncture, DBS are advantageous for conducting research in low-resource settings because they can be stored at ambient temperatures for up to 100 days, even in tropical climates, and require only basic training for study staff to perform collection. **Methods:** We randomly selected 20 of 916 beneficiary schools of a comprehensive school-based WASH program (intervention), and matched them with 20 control schools that had not received any WASH improvements. In each school, 20 pupils in grades 1-6 were randomly selected for participation in the study, for a total of 800 participants. Each student underwent a pupil interview, which addressed school and home WASH access and behaviors and a one-week recall of school absence and diarrhea. Capillary blood in the form of dried blood spots (DBS) was collected from each student. Using a Luminex multiplexing assay, we will analyze the DBS for blood antibodies for *Cryptosporidium* (3), *Giardia* (6), *Toxoplasma*, ETEC, *Salmonella* LPS Group B and D (2), norovirus

(2), *E. histolytica*, *Campylobacter*, cholera, Filariasis, *Strongyloides*, *Babesia microti*, trachoma, *Plasmodium*, cysticercosis, *Schistosoma*, dengue, Rift Valley Fever Virus, and Chikungunya virus. Results: Data will be analyzed after the completion of data collection in May 2014. We will employ random effects logistic regression analysis, with data clustered at the school level, to assess the impact of the school WASH program on the presence or absence of select blood antibodies. Results from this pilot study will be used to address several additional research questions. We will assess the feasibility of using the Luminex multiplexing assay to detect incidence of the aforementioned enteric and neglected tropical diseases among school-aged children, which is a novel age range for this approach. We will identify the leading pathogenic causes of enteric and neglected tropical diseases among school-aged children in Mali. We will also compare self-reported diarrhea against biologic evidence of infection with diarrheal agents. Conclusions: Few WASH impact evaluations employ methods to collect biological evidence of enteric and neglected tropical disease infection. We expect that these results will provide objective measurements of disease incidence among school-aged children, which will inform our understanding of the impact of school-based WASH programs. We will also gain a greater understanding of the incidence of various enteric and tropical diseases in Mali, which can help inform future intervention strategies. Furthermore, this research will assess the feasibility of using a novel approach to objectively evaluate school WASH impacts that can be used in resource-poor field settings.

The impact of a rural sanitation programme on health in Orissa, India: a cluster-randomized, controlled trial

Thomas Clasen, Rollins School of Public Health, Emory University

Additional Authors: Sophie Boisson; Parimita Routray; Belen Torondel; Marion Jenkins; Matthew Freeman; Jeroen Ensink; Wolf-Peter Schmidt

India accounts for a quarter of the 2.5 billion people without access to improved sanitation, two-thirds of the 1.1 billion practicing open defecation and a quarter of the 1.5 million deaths annually from diarrhoeal diseases. The Government of India's Total Sanitation Campaign (TSC) is the largest effort globally to improve sanitation in rural communities. We undertook a cluster-randomized, controlled trial to assess the effectiveness of a rural sanitation intervention under the TSC to prevent diarrhoea, child malnutrition and soil transmitted helminth infection. 100 rural villages in Orissa, India were selected for participation in the study. We enrolled households with a child <4 years or a pregnant woman at the time of enrolment. Following a baseline survey, 50 villages were randomized to the intervention arm and underwent latrine promotion and construction in accordance with the TSC; control villages received no intervention. Following the implementation period, we collected and assayed stool samples for soil-transmitted helminths (STH) and provided deworming tablets to assess the rate and intensity of reinfection; we also measured the height of children <2 to assess HAZ. Thereafter, we visited study participants 7 times over 18 months, collecting self-reported diarrhoea prevalence for children <5 (primary outcome) and all members of the household as well as weights for children <5. At endline, stools were again assessed for STH infection and children <2 were weighed. In sub-samples of households, we also assessed faecal contamination of household water supplies, hands of child caretakers and sentinel toys given to children and monitored the density of synanthropic flies that can serve as mechanical vectors of faeces. We assessed latrine coverage and use throughout the study villages with spot checks at mid-line and end-line of the surveillance period. The intervention increased mean village-level latrine coverage from 9% to 63% in intervention villages compared to an increase of 8% to 12% in control villages. 63% of households with any latrine reported using them. Health surveillance data was collected from 1437 households with children under 5 in the intervention arm (1919 <5s, 10014 individuals overall), and 1465 (1916 <5s, 10269) in the control arm. The intervention had no effect on diarrhoeal disease among children <5 in intervention villages (period prevalence ratio 0.97, 95%CI: 0.83-1.12) or all ages (1.02, 95%CI: 0.88-1.18). Neither did it impact HAZ for children under 2, WAZ for children <5, or the prevalence or egg count of STHs. There was no evidence that the intervention impacted contamination of household drinking water, hands or sentinel toys, or impacted density of flies in food

preparation areas. Latrine construction and use was sub-optimal in intervention villages, it was not below levels commonly achieved under the TSC. While latrine ownership may offer other benefits, including convenience, dignity and safety, our results suggest that sanitation interventions that still leave large portions of village populations practicing open defecation may not impact transmission of faecal pathogens or achieve gains in health outcomes.

Investigating the impact of household water treatment and fuel use on drinking water quality and indoor air pollution in rural China

Alasdair Cohen, University of California, Berkeley

Additional Authors: Isha Ray; John (Jack) Colford; Yong Tao; Jeff Romm

BACKGROUND: HWT IN CHINA Rosa and Clasen (2010) calculated that an estimated 1.1 billion people practice household water treatment (HWT) worldwide, with over half boiling their water. However, because they could not find data in English, this estimation excluded China. A follow-up "Letter to the Editor" (Yang et al., 2012) cited a 2009 article by authors at the Chinese Center for Disease Control & Prevention (Chinese CDC) which provided an estimate of 600 million Chinese using HWT, bringing the actual global total to approximately 1.7 billion. Hitherto, almost nothing about HWT in China has been published in English (and what data there is in Chinese journal articles and government reports is rather limited). China is investing heavily in rural drinking water infrastructure but approximately 300 million rural Chinese still lack access to safe water, and most of China's approximately 700 million rural residents regularly boil their water (Zhang et al., 2009). While boiling inactivates pathogens, fuel combustion contributes to respiratory ailments via indoor air pollution in rural China (Zhang and Smith, 2007), and fuel harvesting and combustion contribute to environmental damage. **PROJECT DESCRIPTION** In order to improve access to safe water, reduce exposure to indoor air pollution, and potentially improve environmental health, researchers at the University of California Berkeley and the Chinese CDC collaborated on an innovative research project to understand the relationships and drivers between water-related behaviors and beliefs, drinking water quality, fuel use, and poverty in rural China. Given the relatively paucity of data on HWT in China (even after consulting Chinese sources), we sought to understand the prevalence of HWT use in rural China (boiling and other), HWT's impact on water quality, and any relevant and predictive socio-economic factors. For those households that boil their drinking water, we sought to examine the likely health and environmental impacts. This is the first rigorous study focused specifically on HWT in rural China (in addition to addressing these specific issues, our work will also help Western academics and practitioners gain a better understanding of the state of HWT in rural China). **SAMPLE SIZE & METHODS** During the summer of 2013 we collected data from 450 households across 15 villages in Guangxi Province using a geographically stratified cross-sectional design. The Multidimensional Poverty Assessment Tool (www.ifad.org/mpat) surveys were used to collect demographic and poverty-related data alongside purpose-designed survey questions about drinking water practices and preferences, fuel use, boiling behaviors, household ventilation, etc. Drinking water samples were collected from every household and analyzed for microbial contaminants, and physicochemical analysis was conducted for each village's primary drinking water source/s. Data collection was repeated in a subset of villages during the 2013-2014 winter to address seasonality, and remote temperature sensors (on kettles and pots) were used to corroborate household responses about boiling frequency and duration. **RESULTS & IMPACT** Our analysis and modeling (taking into account the potential benefits for human health, well-being and cost-effectiveness) will help us understand the contexts in which the promotion of non-boiling HWT in rural China may be advisable, as compared to the status quo. The Chinese CDC is planning to scale up our research design to two other provinces and will use our results to help draft rural water policy recommendations. These findings may also be relevant for other countries with relatively high rates of water boiling in rural areas (e.g., Mexico, Vietnam). **REFERENCES** -ROSA, G. & CLASEN, T. 2010. Estimating the Scope of Household Water Treatment in Low- and Medium-Income Countries. The

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An evaluation of teacher-facilitated community-led total sanitation from Ethiopia

Jonny Crocker, The Water Institute at UNC

Additional Authors: Jamie Bartram

Community-led total sanitation (CLTS) is the national approach to addressing rural sanitation and hygiene in Ethiopia. CLTS in Ethiopia is primarily facilitated by Health Extension Workers (HEWs), who are stationed approximately two to every kebele (~6000 people) across the country. HEWs are tasked with 15 focus areas in addition to CLTS, thus CLTS has not reached many parts of the country, and CLTS efforts are often not sustained. Teachers are promising alternative CLTS facilitators, as there is overlap between teaching and facilitating skills, and there are more teachers per kebele than HEWs. Additionally, teachers are already engaged and are active members of their kebeles with a vested interest in improving the health and well-being of their students. The Water Institute at UNC in partnership with Plan International performed a rigorous evaluation of teacher-facilitated CLTS in two regions of Ethiopia. This study used a quasi-experimental design in which kebeles were manually selected from two regions and assigned to teacher- or conventional-CLTS. Manual assignment was done in a manner to approximately match baseline household latrine ownership, kebele size, and number of teachers per kebele. This study took place in six kebeles in Ethiopia. In four kebeles (112 villages), Plan Ethiopia trained 80 teachers who then facilitated CLTS over the next year. In two kebeles (50 villages), Plan Ethiopia implemented conventional CLTS, which included training six HEWs and the kebele cabinet, then supporting them in facilitating CLTS over the next year. Household surveys were administered by an independent contractor to 2284 randomly selected households at baseline and to 2209 of the same households after one year of implementation had been completed (75 households were lost to follow-up). Household surveys covered a range of topics including basic household characteristics, attitudes and perspectives, water and sanitation indicators, and interactions with other community members and community leaders. Teachers were able to successfully facilitate CLTS within their kebeles, though increases in household latrine ownership occurred slower than in conventional-CLTS. Teachers face unique challenges to facilitating CLTS, including time constraints due to their primary responsibility of teaching, and gaining recognition and approval from district administration, community leaders, and community members. The results of this study indicate that teachers are effective facilitators of CLTS, and with support to overcome initial barriers, they may be able to accelerate sanitation and hygiene progress within Ethiopia.

Results from the Sustainability Check: The Influence of Technical, Social and Financial Factors on Community-Managed Hand Pump Sustainability in Rural Mozambique

Kristen Downs, University of North Carolina at Chapel Hill

Additional Authors: Jessica Pearlman; Samuel Godfrey; Matteus van der Velden; Jamie Bartram

Due to the poor long-term performance of rural water supplies--particularly community-managed boreholes with hand pumps--in Sub-Saharan Africa over the last few decades, there has been increasing attention from

development practitioners, donors and researchers to understand the factors that affect their sustainability. Many empirical studies that have aimed to understand sustainability have been limited due to difficulties measuring performance over time and/or the institutional, technical, financial, social and environmental factors that may influence sustainability. This study uses three years of annual post-construction monitoring surveys ("the Sustainability Check") from the One Million Initiative, a large scale rural water and sanitation joint program in Mozambique to analyze technical, social, and financial factors influencing the sustainability of a random sample of hand pumps (n = 51, 74, 80 by year) in nine districts of Mozambique for 2011-2013. We use a combination of ordered logistic regression, binary logistic regression, and negative binomial count models to model sustainability for three outcome variables: level of water flow (WF), frequency of breakdowns (BRK), and repair time for the last repair (RT). While water point functionality over time has often been used as a proxy for sustainability in past studies (e.g. Foster, 2013), there was insufficient variation in this sample to use functionality as a dependent variable due to the high proportion of functional water points (80%, 90%, 93% by year). For each outcome, models were run for four sets of independent variables: (1) technical factors: frequency of preventive maintenance, training of maintenance committee members, presence of a routine maintenance kit, type of agreement with mechanics for large repairs, distance to spare parts; (2) social factors: frequency of water committee meetings, training of management committee members, proportion of women on committee; (3) financial factors: fraction of households paying tariff, update frequency of financial records, quality of financial records, percentage of planned tariffs paid; and (4) a final combined model with all factors. In the final models, the presence of a routine maintenance kit and percentage of households contributing tariff were found to positively influence ($p < 0.05$) several outcomes of hand pump sustainability (WF, BRK, RT). Preventive maintenance frequency (BRK) and the percentage of the planned tariff paid (WF, BRK) appeared as significant in multiple models, although these have impacts in the opposite direction from what is theoretically expected, suggesting that tariff collection and maintenance is performed in response to problems with the hand pump. Other predictors such as the quality of financial records (WF, BRK), training of management (BRK) and maintenance (RT) committee members, committee meeting frequency (BRK), and agreements with local mechanics (BRK RT) appear to be critical only for specific outcomes. Finally, the findings from this analysis suggest that technical and financial factors have a stronger relationship with measures of hand pump sustainability than the social indicators. This study reinforces the results of similar studies (Foster, 2013; Whittington et al., 2009) that technical expertise, spare parts (the routine maintenance kit), and tariff collection are important and suggests that there is a core set of indicators that can be measured for monitoring sustainability. References: Foster, T. (2013). ES&T, 47(21), 12037-12046. Whittington et al. (2009). Water Policy, 11(6), 696-718.

Attitudinal factors associated with latrine construction, use, and maintenance in Odisha, India

Robert Dreibelbis, University of Oklahoma

Additional Authors: Matthew Freeman; Rachel Chase; Marion Jenkins; Parimita Routray; Thomas Clasen

Background: While often grouped under the larger terminology of "adoption," the decision to construct a latrine, consistent use by all family members, and maintenance are distinct behaviors driven by a constellation of factors including: community conditions, family demographics, individual roles and responsibilities, as well as specific attitudes towards latrine construction and use. While a small number of studies have investigated these attitudinal factors related to latrine construction, few have quantified these factors in a rigorous, replicable manner and fewer still have extended their research to include use and maintenance of sanitation systems. The purpose of our research was to identify and measure attitudinal factors related to sanitation practices in Odisha, India and assess the relationship between these attitudes and construction, use, and maintenance of sanitation systems. Methods: Scale Development: A total of 47 key phrases and concepts were identified from the focus-group discussions on sanitation attitudes and adapted into a survey instrument consisting of binary

agree/disagree statements. Mokken scaling procedures were iteratively applied to identify emergent sub-scales based on the clustering of participants' response patterns in two rounds of survey data collection (n = 120 & 500). These emergent scales were broadly organized into two groups. One group contained sub-scales that reflected generalized attitudes towards latrines and defecation practices; we refer to the sum of these individual sub-scales as our general scale. The second group consisted of sub-scales that reflected individual experiences or preferences towards existing sanitation infrastructure. We refer to the sum of these sub-scales as our experiential scale. Scale assessment: Final scales were included in endline data collection for a cluster-randomized trial assessing the impact of the Total Sanitation Campaign on child health outcomes (n = 2,153; 1,139 control / 1,338 intervention). The general scale was administered to all households; the experiential scale administered in those households with a latrine. Scale values were calculated by summing the number of yes/no response that favored latrine construction or use. Regression models with cluster-specific random effects were used to compare scale values against predetermined behavioral outcomes: latrine ownership, latrine use, and latrine maintenance. Results: Twenty agree/disagree questions emerged from our analysis that corresponded to 7 latent, data-driven factors. Four of these comprised our general scale: attitudes towards open defecation (4 questions); descriptive norms related to latrine use (4 questions), injunctive norms related to sanitation (2 questions); and attitudes towards feces and fecal matter (2 questions). Three factors comprised our experiential scale: attitudes towards the current latrine owned by the households (4 questions), the perceived convenience of latrine use (4 questions), and attitudes towards sharing sanitation within the immediate family (2 questions). We focus our analysis results on the general scale and its relationship with latrine uptake. Among all respondents, 43% had a latrine at the time of data collection (17% among controls; 65% among intervention). Average value for the general scale was 5.2 (SD: 2.5; possible range 0 - 12). After accounting for intervention status, we found a 46% increase in the odds of latrine ownership for every 1-point increase in the general scale (OR: 1.5, 95% CI: 1.4 - 1.5). This translates to a 6% increase in the marginal probability of latrine ownership for each additional point on our scale. Similar results were found when analysis was stratified by intervention status. Among the sub-scales included in our general scale, attitudes towards open defecation (OR 1.5; 95% CI: 1.4 - 1.7), descriptive norms regarding sanitation (OR: 1.7; 95% CI: 1.5 - 1.9), and attitudes towards feces (OR 1.3, 95% CI: 1.1 - 1.5) were associated with latrine ownership. Injunctive norms regarding sanitation did not have an independent association with latrine ownership (OR: 1.0; 95% CI: 0.9 - 1.2). Conclusions: Our research outlines a process through which locally relevant, contextually specific factors related to behavioral outcomes can be identified and quantified. Our emergent scales are an important step towards the development of standardized scales related to sanitation adoption in India. We identify specific factors that are associated with latrine uptake independent of participation in large-scale behavioral interventions such as the Total Sanitation Campaign. Behavior change approaches that focus on changing attitudes towards open defecation, establishing norms related to latrine use, and changing attitudes towards storing feces on private property may see larger gains in latrine adoption. Future analyses will explore the association between our scales and latrine use and maintenance.

Outcome Based M&E: Using the Water Service Ladder Framework in the Lazos de Agua (Water Links) program

Susan Dundon, Millennium Water Alliance

In 2013, the Millennium Water Alliance (MWA) presented at the UNC Conference on the launch of a new program in Latin America, "Water Links" (more commonly known by its Spanish name "Lazos de Agua"), to provide WASH services to over 110,000 of the most marginalized populations in Mexico, Guatemala, Honduras, Nicaragua and Colombia. The innovative monitoring and evaluation framework for this program is built upon the water and sanitation ladder frameworks developed by the WHO and recently championed by the IRC. As described last year, MWA and its six NGO implementing partners are using this framework to assess the level of water service provided in participating communities and analyzing the impact that providing various levels of WASH services has across a number of important indicators. The water service level ladder quantifies service

into categories from sub-standard, to basic, to high using a series of cumulative factors including water quantity, quality, accessibility and reliability. The different interventions being implemented on the ground across the five countries provide a variation of water service levels (basic, intermediate and high), providing a unique data set to generate evidence of the impact of providing varying service levels in differing contexts. By working as a consortium of NGOs, the MWA Latin America Program is able to assess different delivery and treatment technologies across rural settings in multiple contexts, all within the same framework with common indicators. While last year's presentation highlighted the key goals of the program and the process of designing and implementing a multi-country, multi-partner M&E system, this year's presentation will focus on the results from the program's baseline data collected in 2013 and first round of monitoring data, to be collected in May 2014. Baseline data was analyzed according to the program's framework M&E framework with special attention paid to quantifying the baseline water service levels in each country for adequate comparison of program monitoring and post-program evaluation. Data was collected using the program Akvo FLOW on cellular telephones in 1009 households scattered across 109 communities in 20 municipalities located in 7 states within the five countries. Demographic data was analyzed as well as each of the four variables in the water service level ladder which were analyzed both individually and cumulatively. Only approximately one quarter of the households surveyed had access to >100L of clean water daily. Less than 20% of the sample reported having a household water connection inside the house (only 14% during the dry season); another almost 20% reported a household connection on the property though not inside the house. 56% of households reported water collection duties, with an average distance of between 100m to 1000m (mean: 300m in the rainy season and 384m in the dry season) to the source, or an average round trip time of 19 minutes in the rainy season and 28 minutes in the dry season. Time and energy spent collecting water is time that cannot be dedicated to productive and income generating activities, directly effecting the household economies. 54% of water points were reported as 95% reliable (functioning 11-12 months per year), though in Guatemala 96% of water points functioned only 5-6 months per year. 45% of families reported using between 21 and 50L of water per person per day - sufficient to meet only the most basic needs. Over 80% of the entire sample used less than 50L of water per person per day. When this data was integrated into the water service level ladder and results were viewed cumulatively, only 2% of the baseline population was considered to have a high level of water service. These indicators and others, such as use of multiple water sources, health, and economic variables will be presented from both the baseline data collection exercise as well as the first round of monitoring data collection (6 months to 1 year post baseline). This program is funded by Coca Cola Latin America and the FEMSA Foundation.

A prospective cohort study of risks associated with beaches in Brazil

Joseph Eisenberg, University of Michigan

Additional Authors: Claudia Condé Lamparelli; Kristen Pogreba-Brown; Marc Verhougstraete; Maria Inês Zanoli Sato

INTRODUCTION The association between exposure to contaminated recreational water and disease has been studied since the 1950s. Epidemiologic studies in the US and UK have demonstrated higher rates of gastrointestinal, respiratory, and skin illnesses in swimmers compared to non-swimmers at recreational waters. These studies focused primarily on beaches in developed areas dominated by point source pollution and has led to the creation of worldwide standards for risk criteria (WHO 2003; USEPA 2012). Additional studies conducted in New Zealand, Egypt, Hong Kong, Australia, Israel, France, Canada, and The Netherlands yielded similar findings (Pruss 1998). The developing world, including South America, is underrepresented in the scope of global recreational water quality epidemiological studies. These areas rely on water quality criteria developed on other continents with relatively little information known about their local applicability. In this manuscript we describe a large cohort study performed at five urban beaches near Sao Paulo, Brazil. The aim of this project was to compare rates of highly credible gastrointestinal illness (HCGI) among swimmers and non-swimmers and to

evaluate whether there was a dose-response relationship among swimmers based on water quality measures. Furthermore, we investigate whether sensitive populations (children and elderly) are at higher risk. These analyses lay the foundation for localized QMRA. **METHODS** At baseline of the prospective cohort study, 23235 participants were interviewed at five Brazilian beaches. Triplicate beach water samples were collected once daily at each beach on days when initial interviews were conducted and assayed for fecal coliforms, *E. coli*, and enterococci using defined substrate technology. Follow-up telephone interviews were conducted 10 days later to determine the onset of specific symptoms. Cases reporting vomiting or diarrhea or stomach ache plus nausea were classified as NGI cases (consistent with the current definition used by the USEPA). Cumulative incidence (per 1000 individuals) and Odds Ratios (OR) of health outcomes (NGI, diarrhea, nausea, vomiting, and fever) were calculated for three age groups (0-10, 11-19, and 20+) at the five beaches. Dose-response models were created for each beach using the maximum likelihood estimation to fit the data to a Beta-Poisson distribution ($P=1-[1+C/N50(21/\alpha-1)]^{-\alpha}$). Where N50 is the number of organisms required to infect 50% of the population, C is the dose, and α represents pathogen survival probabilities (derived from the model). **RESULTS** In total, 150 water samples were collected over 10 days (five weekends) at five beaches. Enterococci ranged from 1.2 to 1.8 (log MPN/100 ml) with a geometric mean of 1.37. *E. coli* ranged from 1.6 to 2.4 (log MPN/100 ml) with a geometric mean of 1.82. Of the 23,235 enrolled individuals, 16,637 successfully completed the follow-up interview (72% response rate) which included 14,010 individuals entering the water that day (9,456 of which usually submerge their heads and 5,844 tend to swallow water). Other initial survey data collected included sand contact at the beach (n=11,943), eating food prepared on the beach (n=11,909), and exposure to pool water in previous week (n=6,212). Pooled beach data found the odds of NGI by age group after entering the water to be OR=1.34 (0-10), OR=0.98 (11-19), and OR=1.12 (20+). Overall NGI OR for all beaches when exposure included only entering the water was 1.59 (95% CI 0.97-1.57) but increased to 2.57 (95% CI 2.05-3.23) when sand contact was included as an exposure. Among individuals that entered the water and usually swallowed water, a dose-response relationship was observed for NGI, where illness was positively related to enterococci concentrations ($\alpha=0.10$; N50=1893). **DISCUSSION** This study demonstrated a Beta-Poisson distributed dose-response relationship between enterococci and NGI in swimmers and non-swimmers. However, we also found water exposure to be one of many factors influencing illness risk at beaches. Sand contact had higher NGI OR compared to entering the water alone; indicating that exposure to sand may increase the risk of reporting NGI. Furthermore, this study demonstrated that NGI risk is not equal across the defined age groups, with the risk of NGI highest in the youngest age group. Other factors potentially influencing NGI risk at Brazil beaches include food consumption and time spent at the beach. Our results, distinct from the USEPA and UK data, should be used when developing regulations in Brazil. The results of this study indicate that a universal recreational water quality standard is not adequate for all geographical locations and a local risk assessment is required to inform local regulations. Both developing and developed countries will benefit from local QMRA and beach criteria development.

The sanitation ladder, and sharing facilities; what constitutes an improved form of sanitation

Jeroen Ensink, London School of Hygiene and Tropical Medicine

Additional Authors: Josephine M L Exley; Faraji Abdelahi; Lauren d'Mello Guyett

With over 50 pathogens transmitted in excreta access to adequate sanitation is of key importance to public health. Nonetheless in 2000 42% of the world's population, some 2.6 billion people, lacked access to basic sanitation. In order to address this shortfall sanitation was added in 2002 to part three of the seventh United Nations Millennium Development Goal (MDG), which aims "to halve, by 2015, the proportion of people without sustainable access to basic sanitation". Most recent surveys estimate that 2.4 billion people are still lacking access to basic sanitation, and the MDG sanitation target is unlikely to be met by 2014. Moving up the rungs of the ladder is assumed to result in an improvement in the hygienic quality of the facility, and consequently a

reduction in health risks for users. However, there is little evidence to substantiate this claim, or what actually constitutes a hygienic latrine. The current definition of improved sanitation does not include anything regarding actual use, quality of the facility, cleanliness, or maintenance. It is therefore likely to include forms of sanitation that are not kept clean or are in a general state of disrepair, and hence unable to protect users' health. This has led some commentators to suggest that the current figures of people with access to adequate sanitation are significantly overestimated. A technology-based classification system allows comparisons in data across time and countries but inherently it presumes that the system is context-free - one size fits all. In fact the appropriate choice of technology might be place dependent. Potentially a simple pit latrine without a slab is suitable for a dispersed low-income rural area whilst in a densely populated urban area with a reliable water supply a low-cost sewerage system might be more appropriate. The threshold of latrines shared by two, or more families being classified as unimproved is also arbitrary, as there is no reason to presume that a facility shared between two, or more households presents a greater threat to health, than one used by a single household; especially when considering that one large household might contain more people than two or three smaller households together. Work conducted in Bangladesh found that the use of public and shared facilities lead to substantial improvements in child health, while a survey in Tanzania observed no difference in diarrhoea prevalence between children with access to an improved, or unimproved form of sanitation. The objective of the research to be presented was to identify key management, use and design characteristics that were associated with unhygienic latrines. With the aim of helping to refine the JMP definition as to what constitutes an improved form of sanitation. For this over 1,000 different sanitation facilities, ranging from private to shared facilities and representing different rungs on the sanitation ladder were inspected and sampled in Tanzania from April 2013 to April 2014. Collected samples included swaps of key points of hand contact within facility like: door handles, walls and floors, for the presence of *E. coli* ii) soil analysed for the presence of soil transmitted helminths in and around the sanitation facility and iii) the type and number of filth flies in each latrine. The first results of the survey showed that latrines without a slab were significantly more contaminated than latrines with a slab, but that the level and the number of people sharing a facility did not play a role in the hygiene level of the sanitation facility.

Upgrading a Piped Water Supply from Intermittent to Continuous Delivery: Impact on Waterborne Illness in Urban India

Ayşe Ercumen, UC Berkeley

Additional Authors: Benjamin Arnold; Emily Kumpel; Zachary Burt; Isha Ray; Kara Nelson; John Colford, Jr.

Background: The United Nations Millennium Development Goals (MDGs) target to halve by 2015 the proportion of the world population without access to improved sources of drinking water. Among improved sources, piped water on premises is considered the highest category. However, MDGs are based on the type and location of water sources with no consideration of water quality. Incorporating measures of water quality into how we define safe water access is one of the central discussions around the post-2015 Sustainable Development Goals (SDGs). Despite being widely considered the gold standard for water access, the presence of a piped connection gives little information about the quality, quantity and frequency of water delivery. Piped water is supplied intermittently in the vast majority of cities in low-income countries. Intermittent delivery of piped water can lead to waterborne illness through contamination of water in pipelines or during household storage, use of unsafe water sources during intermittencies, and limited water availability for hygiene. **Methods:** We conducted a matched cohort study in Hubli-Dharwad, India to provide the first rigorous large-scale study of the impact of upgrading from intermittent to continuous supply on waterborne diseases. We used multivariate matching to match intermittent and continuous supply areas. We followed 3922 households with children <5 years over 15 months to collect data on the caregiver-reported prevalence of diarrhea, blood/mucus in stool and highly credible gastrointestinal illness (HCGI) in children <5 years; death of a child <2 years in the household; and

typhoid fever, hepatitis, or cholera in any household member. Findings: In continuous supply areas, there was a 42% reduction in the percentage of households with at least one case of typhoid fever (CIR = 0.58, 0.41-0.78). Our results also suggested a 49% reduction in the percentage of households with death of a child <2 years (CIR = 0.51, 0.22-1.07), and modest reductions in the prevalence of diarrhea (PR = 0.93, 0.83-1.04) and blood/mucus in stool (PR = 0.78, 0.60-1.01) in children <5 years. In pre-specified subgroup analyses, child diarrhea was more prevalent and the reductions more pronounced in below-median wealth households, with an 11% reduction in the prevalence of diarrhea (PR = 0.89, 0.76-1.04) and 37% reduction in the prevalence of blood/mucus in stool (PR = 0.63, 0.46-0.87). Discussion: The upgrade to continuous supply significantly reduced the incidence of typhoid fever and appeared to reduce child mortality and diarrheal illness. The impact was larger among below-median wealth households. Notably, the practice of storing drinking water was maintained in continuous supply households even after the upgrade in supply, and point-of-use contamination during storage may have attenuated the health benefits from the continuous water supply. Our findings suggest that, although having a piped connection on the premises is considered a benchmark for adequate water access, intermittent provision of water through these pipes - the dominant method of water supply in low-income country cities - is associated with a significant burden of waterborne illness.

Determinants of water point functionality from a longitudinal study of four districts in northern Ghana

Michael Fisher, UNC Chapel Hill

Additional Authors: Kate Shields; Kaida Liang; Jamie Bartram

Recent research has shown that at any given time, 30 percent of water points in sub-Saharan Africa may be non-functional. When water points fail, households may resort to unimproved sources including surface water. Previous studies have suggested that in addition to age and technical factors, multiple "software" factors such as tariff collection, technical support, and the presence of a functioning water and sanitation committee are strongly associated with water point functionality. What is less clear is which of the modifiable factors affecting functionality represent the greatest opportunities for improvement and action on the part of implementers and policymakers, and how monitoring efforts can be improved to better track these factors. Based on preliminary results from a multi-level longitudinal study in the Northern region of Ghana, we explore determinants of water point functionality. We explore both "hardware" and "software" factors associated with water point functionality, including water point type, year of construction, number of users, management structure, technical support, and access to spare parts. We further explore water and sanitation committee finances, training and activities to assess the efficacy and impact of these committees. Using these data we expand upon a model of rural waterpoint functionality in which the average functionality rates of water points reflect dynamic equilibria between routine breakdowns and repairs, with the rate of repair depending on community resources and technical capacity, waterpoint management structure, and other factors. The balances of these equilibria have the potential to affect multiple health-relevant outcomes, including reversion to unimproved sources and the quantity of water collected at the household level. Multi-level logistic regression models and other tools are used to evaluate the relative contributions of key factors to functionality. Implications for WaSH implementation and monitoring are explored.

Pro-poor tariff design: Does it exist? Investigating the relationship between income and water use and its impact on tariff performance.

David Fuente, The University of North Carolina at Chapel Hill

Additional Authors: C. Nauges; Xun Wu; Dale Whittington

Policy makers often express concern about the affordability of water and wastewater services, especially for the poor. This concern is often used to justify keeping water prices low and for implementing an increasing block tariff (IBT), which typically includes a "lifeline" block that provides customers the first increment of water (e.g. 0 to 10 m³ per month) at a low volumetric price, or even free. While the use of the IBT is arguably well intentioned, it typically falls far short of meeting its objectives in developing country contexts for a number of reasons. First, the poorest residents of a city typically do not have a piped water connection and therefore cannot benefit from use-based subsidies delivered through the tariff. Second, there are number of reasons that poor households may use more water than wealthier households. For example, income and household size may be inversely related, poorer households may on-sell water to neighbors who do not have private connections, and poorer households are more likely than wealthy households to obtain water from shared connections. While these factors have prompted a long standing debate among scholars about whether the IBT is appropriate in many less developed country contexts, the IBT has become the most common tariff structure implemented by water utilities across the globe. Indeed, nearly 50% of utilities in the Global Water Intelligence (2011) tariff survey implemented an IBT and 86% of utilities included in the World Bank's African Infrastructure Country Diagnostic implemented an IBT (Banerjee et al 2010). Policy makers find the IBT attractive in part because of the widespread belief that low income households use less water than wealthier households. However, this is an empirical question that is context dependent. In this paper, we use Monte Carlo analysis to simulate the performance of three revenue-neutral tariff structures: a uniform price, an increasing block tariff, and a volume differentiated tariff. In particular, we specify hypothetical, yet realistic, water use and income distributions and then examine how the three tariff structures perform with respect to subsidy targeting under different assumptions on the strength of the correlation between water use and income. In the base case of our analysis we assume that three tariffs do not generate sufficient revenue to cover costs, a common situation in many developing country contexts. We extend this analysis using a multi-period model to examine the performance of the three tariff structures when the hypothetical utility implements prices that achieve full cost recovery under each tariff. Preliminary results indicate that the relative performance of the tariff structures is heavily influenced by the strength of the correlation between income and water use, particularly under full cost recovery pricing scenarios. Our analysis reaffirms that in many contexts the water tariff, and in particular the IBT, performs poorly with respect to subsidy targeting. Additionally, our analysis highlights the importance of understanding the empirical relationship between income and water use, a relationship that has been largely overlooked in the water pricing and tariff design literature.

A mathematical model of herd protection from sanitation

James Fuller, University of Michigan School of Public Health

Additional Authors: Joseph Eisenberg

Many interventions to combat infectious diseases provide some form of indirect protection to individuals not receiving the intervention. This herd protection has been shown empirically with vaccines, insecticide treated bednets, and deworming drugs. Sanitation interventions have the potential to provide herd protection to nearby households by preventing environmental contamination. Using a mathematical model of enteric pathogen transmission, we show how different sanitation interventions can provide different levels of herd protection. We also show how classical epidemiologic approaches will underestimate the total benefit of sanitation, highlighting the need for special study designs.

Performance, Use, and Sustainability of Decentralized Water Filtration Systems in Hospitals in Honduras and Ghana

Marisa Gallegos, Center for Global Safe Water at Emory University

Katharine Robb; Ledor Sira-Idee Igboh; Samantha Lie Tjauw; Christine Moe

The 2015 Sustainable Development Goals include a provision to "provide universal access to safe drinking water in health centers." Currently, an estimated 46% of healthcare facilities in the developing world have access to an improved water source. In recognition of the need to increase safe water access, the General Electric Foundation (GEF) donated decentralized water filtration systems (DWFS) to 4 district-level hospitals in Honduras in 2009-2011 and 6 district-level hospitals in Ghana in 2004-2006. Research is needed to assess the barriers to improved safe water access in healthcare facilities and to identify sustainable interventions. The objective of this study was to evaluate water quality, the use of safe water, and the sustainability of safe water access in healthcare facilities with DWFS donated by the GEF. More broadly, this evaluation is an important first step in the assessment of barriers and the development of mitigation strategies to attain universal and sustained safe water access in healthcare facilities. The Center for Global Safe Water at Emory University (CGSW) developed a metric to assess sustainability using four domains: technical feasibility, on-site capacity, accountability, and institutional engagement. Water quality, interview data, and observations formed the inputs for the sustainability metric. Water quality was evaluated for *E. coli*, total coliforms, *Pseudomonas aeruginosa*, and chlorine residual. A mixed-methods approach was used to collect interview data on knowledge, attitudes, and practices regarding water use and barriers to safe water access. Observations were conducted on water infrastructure and maintenance. The data were used to score each hospital from 0 to 4 in each sustainability domain. The scale was designed such that a score of 2 indicated meeting minimum criteria for an enabling environment for sustainability in a given domain. Each domain contributed equally to an overall sustainability score between 0 and 4. Over the course of the evaluation, over 300 samples were tested for *E. coli*. Despite onsite treatment, 77% of samples in Honduras and 61% of samples in Ghana met international drinking water guidelines. Water infrastructure problems, frequent bypassing of the filtration system, improper preparation of chlorine solution, and inadequate maintenance, frequently resulted in poor quality water at the point of use within the hospitals. Results from interview data collected in 2013 showed that despite the variable quality of tap water, it is used for a variety of drinking, hygiene and medical purposes. In Honduras, 24% of staff drink tap water versus 5% in Ghana. Tap water was used for reconstituting and giving medications by 23% of clinical staff in Honduras and 14% in Ghana. While 19% of staff in Ghana use tap water for wound care, no staff in Honduras reported using tap water for wound care. A common barrier to the use of safe water is lack of knowledge about the quality of water from various sources. The baseline sustainability evaluation conducted by the CGSW in Honduras in 2012 found that two of four hospitals met or exceeded the criteria for an enabling environment for the sustainability of the DWFS. Over the course of one year, capacity strengthening and infrastructure improvements were completed at each site. Following the 2013 sustainability evaluation, three of four hospitals met or exceeded the minimum criteria for sustainability (a score of 2 in each domain). The average sustainability score for hospitals in Honduras increased from 2.1 and 2.5. In Ghana, the baseline sustainability evaluation conducted in 2013 found that none of the hospitals met the basic criteria for an enabling environment for sustainability of the DWFS. The average sustainability score for hospitals in Ghana was 1.4. The follow up sustainability evaluation in Ghana will be completed in the summer of 2014. Barriers to sustainability were substantial in the domains of technical feasibility and on-site capacity. Common challenges included: frequent power outages, insufficient and unreliable water supplies, substandard and poorly maintained piped water infrastructure, limited access to parts and supplies necessary for water treatment, infrequent or improper maintenance, insufficient oversight from hospital leadership, and high staff turnover. Despite improved water sources and on-site treatment systems at each of the hospital sites, there exist persistent challenges to consistent safe water access and use. These findings help focus the efforts of the GEF and the hospitals to improve the impact and sustainability of DWFS through targeting specific domains. Furthermore, the findings contribute to the evidence-base for promoting safe water in healthcare facilities as a priority within the global water sector.

Determinants of purchasing flood resistant toilets: A household study of the most vulnerable populations in areas of Pikine and Guédiawaye, two main suburbs of Dakar, Senegal.

Anna Gamma, EAWAG

Additional Authors: Jennifer Inauen; Hans-Joachim Mosler

Objectives: This study explored the behavioral factors, which explain the commitment and the willingness to pay for the purchase of flood resistant toilets in Pikine and Guédiawaye, two main suburbs of Dakar, Senegal. The absent sanitation services in the suburbs of Dakar and the regular floods during the rainy season pose a serious health risk on this vulnerable population and especially children are prone to morbidity and mortality due to infectious diarrheal disease. **Methods:** Structured face-to-face interviews were conducted with the decision makers or family members of the decision maker who think that they could influence the decision maker with regard to the purchase of flood resistant toilets. 392 households were interviewed with a questionnaire who took the RANAS model (risk, attitude, norm, ability, self-regulation) into account (Mosler, 2012). A multiple linear regression was carried out to reveal factors predicting the commitment to buy a flood resistant toilet and by a logistic regression the willingness to pay was analyzed. **Results:** The results showed that feeling committed to buy a flood resistant toilet is mainly related to not being proud about the current type of toilet in the household (affect pride), the perceived vulnerability and the social and personal norms. The willingness to pay is mainly related to the fact not to like the current toilet type in the household, the recovery self-efficacy to save money after having stopped saving money and the feeling of commitment to buy a flood resistant toilet. **Conclusion:** Behavior change strategies to change the influential psychological factors will be designed, to increase in a first step the commitment to buy a flood resistant toilet, which is crucial for having a positive willingness to pay; in a second step, behavior change strategies to alter the willingness to pay will be developed.

Factors associated with pupil latrine use: If you build it, they will come and why

Joshua Garn, Emory University

Additional Authors: Michael Kramer; Carolyn Drews-Botsch; Matthew Freeman

Background: Little empirical data exist on how the type, design, conditions, and cleanliness of school latrines affect pupil latrine use. The purpose of this study was to characterize how various school sanitation conditions are associated with latrine use. **Methods:** We conducted a longitudinal assessment in 60 primary schools in Nyanza Province, Kenya, using structured observations to measure both latrine conditions and latrine use during the 30 minute morning break. We used piecewise multivariable logistic regression to model the association between pupil to latrine ratio and latrine use (pupil used a latrine or not during the break). We used this model to predict the increase in latrine use given the theoretical addition of one latrine at a school, and assuming an average school size and a variety of initial pupil to latrine ratios. We used multivariable negative binomial regression to model the association between different latrine facility characteristics and the count of uses at specific facilities. **Results:** We observed a piecewise association between increasing pupil to latrine ratio and decreasing pupil latrine use, with a natural breakpoint (change in slope) at a pupil to latrine ratio of 25:1 ($p < 0.01$ for both slopes). The predicted relative increase in the odds of latrine use from adding one latrine is: 53% in a school with a starting pupil to latrine ratio of 150:1 (odds ratio (OR)=1.53 95% CI: 1.30,1.79), 15% in a school with a starting pupil to latrine ratio of 75:1 (OR=1.15 95% CI: 1.09,1.21), 7% in a school with a starting pupil to latrine ratio of 50:1 (OR=1.07 95% CI: 1.04,1.10), 12% in a school with a starting pupil to latrine ratio of 25:1 (OR=1.12 95% CI: 1.06,1.17), and 4% in a school with a starting pupil to latrine ratio of 15:1 (OR=1.04 95% CI:

1.02,1.06). In the facility specific analysis, pupils preferred to use newer latrines over older latrines (incidence rate ratio (IRR)=1.14, 95% CI: 1.02, 1.28), and also preferred ventilate improved pit latrines (IRR=1.17, 95% CI: 1.02, 1.34) and urinals (IRR=2.02, 95% CI: 1.62, 2.52) over prefabricated plastic latrines (IRR=0.68, 95% CI: 0.54, 0.86) and traditional pit latrines (referent). Latrine dirtiness was a deterrent to latrine use for girls (IRR=0.83, 95% CI: 0.70, 0.98), but not for boys (IRR=0.98, 95% CI: 0.86, 1.12). An increased number of latrines in a block (a group of conjoined latrines) was associated with increased use at that block, although the increase in use was not proportional to the block's added capacity (IRR for two doors =1.10, 95% CI: 0.93,1.30; IRR for four doors=1.75, 95% CI: 1.429, 2.15; IRR for six or more doors=2.52, 95% CI: 1.92, 3.32; one door was used as the referent). Conclusions: This study provides insights into many factors that potentially affect latrine use, and could lead to a better allocation of resources for school sanitation, with the end goal being to improve pupil's health and educational outcomes.

Effect of a food hygiene intervention (Safe Food, Healthy Child Campaign) on mother's food hygiene behaviours in Nepal: An exploratory trial

Om Prasad Gautam, London School of Hygiene and Tropical Medicine, UK

Additional Authors: Valerie Curtis

Background: Inadequate food hygiene probably causes a substantial proportion of gastro-enteric infections among infants and young children globally and may contribute to undernutrition. One estimate has 70% of diarrhoea in developing countries caused by pathogens transmitted through food. However, most of what is known about food-borne infections in low-income settings is based on expert opinion and biological plausibility. Food hygiene has been neglected both in research and in programming in low income settings. Simple, easily replicable and feasible and effective food hygiene interventions are needed. **Methods:** A cluster randomized, before-after study with control study was conducted in rural hill settings of Kavre district, Nepal, between October 2012 and December 2013. Eight clusters were selected using inclusion and exclusion criteria. 30 households with a mother having a child aged 6-59 months were recruited from each cluster (altogether 239 households). After collecting socio-demographic information and baseline outcomes measurement, the eight clusters were then randomized into 4 intervention and 4 control (no intervention) groups. **Design of the intervention:** A food hygiene behaviour change package was designed using the Evo-Eco theory of behaviour change on the basis of detailed formative research and pretesting. A motivational food hygiene promotion package was designed to be implemented to change five key prioritized behaviours such as i) cleanliness of serving utensils before serving cooked/stored food, ii) handwashing with soap by mothers before feeding child and before eating food by child, iii) proper storage of cooked/leftover food in a container with tight lid, iv) thorough re-heating of stored/leftover food before serving, v) water/milk treatment before offering to child. The campaign employed motivational themes such as "nurture", "disgust", "affiliation" and "social respect" as a driver of behaviour change for each event and also changed the physical, biological and social settings. Campaign utilized various innovative and creative tools and activities such as storytelling, video-clip demonstration, kitchen makeovers, eye dangles, use of 3D flip charts, games such as child life, puzzles, folk songs and hot potato games, demonstration such as glo-germ, disgusting pictures, baby bib, competitions such as 'clean kitchen', 'ideal mother', 'safe food hygiene zone', public commitment, social/public pledging etc. The interventions were delivered through six community/group events followed by six HH visits organized by trained community health volunteers. **Outcome measurement:** The primary outcomes were measured by direct observation of the five key food hygiene behaviours in all HHs (119 control, 120 intervention HHs) from eight clusters both during baseline and follow-up. Measurement was done 45 days before (baseline) and 45 days after (follow-up) the intervention. **Results:** The observed key food hygiene behaviours (combined effect of all key food hygiene behaviours) were rare at baseline in both the intervention (1%) and control clusters (2%). The intervention achieved an increased prevalence of food hygiene behaviours in the intervention arm (43% vs. 1%,

differences 42%, $p=0.010$). After 3 months key behaviours were more common in intervention than in the control arm (43% vs. 2%; differences 41%, $p=0.020$). The intervention appeared to be equally effective in improving all five behaviours and in all clusters with few variations. Conclusion: it is possible to change multiple food hygiene behaviours using interventions employing with emotional motivators, and changing the settings for behaviour. This offers a proven simple and scalable food hygiene promotion intervention package which can be delivered through any health, WASH, and nutrition programme in low income settings. Funding: Funded by SHARE Consortium and co-funded by WaterAid

Water, Sanitation and Hygiene in Haiti: Past, Present and Future

Rick Gelting, CDC

In 2010, Haiti endured a massive earthquake and the start of the largest cholera epidemic in modern history. These events, especially the cholera epidemic, brought increased attention to the water, sanitation and hygiene (WASH) situation in Haiti, which has the lowest rates of access to improved water and sanitation infrastructure in the western hemisphere. This presentation will examine the history of the WASH sector in Haiti, considering factors that have influenced WASH conditions in the country in the past. The presentation will then discuss the current situation since the earthquake and subsequent cholera epidemic, and the responses to those events. Those responses have included efforts to improve service of urban piped water systems and improve sewage disposal sites. Rural Departmental Units (known by their French acronym URDs) have also been established to manage WASH services and infrastructure in each of Haiti's 10 Departments. Recognizing that piped water services will not reach many Haitian communities in the near future, the National Directorate for Potable Water and Sanitation (known by its French Acronym DINEPA) is also developing a national strategy to promote household water treatment and storage (HWTS). In addition, DINEPA, in conjunction with partners, has created a rural WASH workforce by training and deploying 264 water and sanitation technicians to work in every commune outside of the metropolitan area around the capital of Port-au-Prince. In closing, the presentation will suggest some actions to help bring about long-term WASH improvements for the future. The "National Plan of Action for the Elimination of Cholera in Haiti 2013-2022," developed by the Ministry of Health and Population, DINEPA and other partners, includes a WASH component that outlines several elements critical to eliminating cholera, including: * Investing in WASH programs, including water and sanitation infrastructure and hygiene education, with a special emphasis on sanitation * Coordinating the WASH Sector * Building or augmenting capacity within Haitian government institutions at all levels to manage WASH investments and also to operate and maintain WASH infrastructure and sustain hygiene improvement efforts Because the current WASH situation has evolved over decades due to limited attention and resources, it will take a long term, sustained effort with coordination of the sector by the government of Haiti and large scale investment from multiple partners to improve the situation.

Demand Estimation with Strategic Complementarities -- the Case of Sanitation in Bangladesh

Raymond Guiteras, University of Maryland

Additional Authors: Ahmed Mobarak; James Levinsohn

Poor sanitation is widely believed to contribute to serious health problems in the developing world. Despite the availability of relatively inexpensive hygienic latrines and intensive efforts to promote adoption, rates of open defecation and non-hygienic latrines remain high, especially in South Asia. The epidemiology of disease transmission provides one potential explanation: if neighbors practice poor sanitation, investing in a toilet in isolation may not generate any health gains. This strategic complementarity may give rise to multiple equilibria,

with a community stuck at a low-adoption equilibrium due to coordination failure. To measure the importance of this channel, we conduct a large-scale randomized controlled trial in rural Bangladesh that introduced, in turn, joint information sessions, joint commitments, and subsidies to induce communities to invest in toilets. We randomly vary both individual inducements to invest in toilets and the proportion of the community that is subsidized. The multiple dimensions of randomization and the design of the intervention permit identification and estimation of a structural model of interdependent demand. We also collect rich social network data, which, combined with the randomization, allows us to estimate the direction and nature of network effects. We distinguish epidemiological spillovers from social learning by randomly varying the identity (social position) of the individuals receiving early subsidies. We find that individual households are more likely to invest in sanitation when a greater proportion of their neighbors receive subsidies. These spillovers are present regardless of the degree of social connectedness of the household that receives the early subsidy, which suggests that the disease transmission mechanism accounts for at least part of the spillover effect. Interdependent decisions appear to explain part of the puzzle of low adoption of welfare-improving products and behaviors in developing countries, which implies that community-level (rather than individual-level) interventions may be a useful marketing strategy.

Modelling of the co-treatment of fecal sludge in anaerobic WWTP systems

Yonas Hagos, UNESCO-IHE

Like other cities in Africa, in Adama town, Ethiopia, septic tanks and pit latrines are the most common on-site sanitation systems. Only 30% of the fecal sludge from these on-site sanitation systems are collected and dumped in to stabilization pond located 9.4km west of the city. The fate of the rest is imposing problems in the environment and public health. The poor design and construction of the stabilization pond results odor problems in the surrounding and there are often complains by the communities residing nearby. In addition; the effluent from the pond joins the river course downstream and the communities downstream uses this polluted water for different purposes such as washing and agricultural activities. This high pressure imposed leads the Municipality to look for other options. On the other hand, the Ministry of Education (MoE) of Ethiopia is currently building 15 wastewater treatment plants (WWTP) in 13 universities across the country on which one of them is the Adama Science and Technology University (ASTU) WWTP, Adama, Ethiopia. In order to verify the design data used for the design of the ASTU WWTP, first detailed chemical analysis were conducted followed by a detailed COD and TN fractionation of the WW from the university and the faecal sludge from pit latrines and septic sludges. Then, the possibilities of the co-treatment of the faecal sludges with ASTU wastewater in the ASTU WWTP were assessed using Bio-Win process simulation 3.1. A detailed characterization using standard methods (APHA 1995) of the ASTU WW and FS from pit latrines and septic tanks were conducted in ASTU chemistry laboratory. As a result, the average flow rate and COD concentration were found to be 1480 m³/d and 698 mg/l for high activity period and 156 m³/d and 925 mg/l for low activity period, respectively. From the fractionation of the COD and TN the mean biodegradable COD fraction of the WW was found 74.5 ±1.5%. Similarly, the biodegradable COD fraction of the pit and septic sludges were found to be 50±8% and 35±1%, respectively. To assess the feasibility of the co-treatment of the faecal sludges with ASTU waste water in the ASTU WWTP, dynamic simulations of various scenarios were done using Bio-Win process simulation 3.1. The simulation results show that 128 m³ (16 tankers/day) of pit sludge or 224 m³ (28 tankers/day) of septic sludge; which are 7.5% and 13% of the average daily flow of the WW of ASTU, respectively, could be co-treated without exceeding the effluent standards. Apart from that, a combination of 128 m³ (16 tankers/day) of septic sludge and 80m³ (10 tankers/day) of pit sludge or combination of 96 m³ (12 tankers/day) of septic sludge and 96 m³ (12 tankers/day) of pit sludge which are 7.5%, 4.6%, 5.6% and 5.6% of the average daily flow of the WW of ASTU respectively were found feasible to be co-treated without affecting the effluent criteria. Finally, this research verifies that, a considerable amount of FS could be treated and improves the sanitation

Keywords: Pit latrines, Septic tanks, characterization

Selection of easy to collect candidate measures of handwashing with soap for inclusion in routine population-based surveys

Amal Halder, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b), Dhaka, Bangladesh

Additional Authors: Abul Kasham Shoab; Mahbub-Ul Alam; Aftab Opel; Probir Ghosh; Monirul Alam; Fiona Ward; Hrachya Sargsyan; Khairul Islam; Stephen Luby; Leanne Unicomb

Background: Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) are useful sources of nationally representative data on water, sanitation and hygiene facilities and practices. These surveys collect data on the spot check indicator - 'presence of handwashing location with water and handwashing agent'. Whether this adequately reflects practices and adequacy of facilities is not clear. Currently, five-hour structured observation is the method of choice for estimating actual handwashing practice, despite limitations of reactivity to the presence of an observer. However, this method is not practical for large scale surveys. The objective of this study was to select candidate questions and spot check observations for future DHS and MICS in Bangladesh and elsewhere to estimate handwashing with soap. **Methods:** To select candidate handwashing measures, structured observation data collected in 2012 from a health impact assessment of a UNICEF-DFID supported sanitation, hygiene education and water supply intervention in Bangladesh (SHEWA-B) were used to compare proxy handwashing indicators collected through personal interviews and spot checks. These included five indicators from questions in face-to-face interviews and seven from spot check observations. The candidate indicators were: recall of handwashing education messages; reported critical times to wash hands with soap or with water alone; reported purchase of separate soap for handwashing; observed child and caregiver hand cleanliness; observed child and caregiver handwashing demonstrations using soap and water; observed availability of handwashing location(s), locations that included a handwashing device, locations stocked with water and handwashing agents; and observed post-defecation handwashing location different from that for food related events. We determined proxy indicators that were associated with observed handwashing with soap after fecal contact events because the number of observations where hands were washed with soap for other critical times such as before food handling events were few (<3%) compared to fecal contact events (27-36%). To assess the association between observed handwashing behaviors and proxy indicators, we calculated cluster adjusted multivariate odds ratios including wealth scores as a potential confounder using generalized estimating equations. To determine which proxy indicators, alone and in combination, estimated the best observed handwashing practice we constructed different models with combinations of significantly associated proxy variables. Later on to determine the model of best goodness of fit we used likelihood ratio test technique and compared the model of combination of all proxy indicators with other models those did not include the combination of all proxy indicators. We used the Bangladesh National Hygiene Survey data collected in 2013 from 2500 households from 100 random geographic clusters to determine the distribution of candidate proxy indicators and their combinations on a nationally representative population. **Results:** In the multivariate analysis, controlling for wealth and cluster effect, we detected that three of the twelve proxy indicators from the SHEWA-B data were associated with observed handwashing with soap after fecal contact events: 1) presence of a handwashing location with water and soap/ash (OR: 4.2; CI: 2.4, 7.4), 2) respondent recall of at least two critical handwashing times (OR: 2.8; CI: 1.6, 5.2) and 3) mothers' hands appeared clean (OR: 1.8; CI: 1.0, 3.1). Among models of combinations of these variables, the one that included all three variables gave the best goodness of fit. Households with all three indicators were more likely to be observed washing hands with soap after fecal contact (exposed 33%, non-exposed 6%; OR=10, $p<0.001$). Among households surveyed in the National Hygiene Survey, 52% had handwashing location with water and soap/ash; 33% of respondents recalled at least two critical handwashing times and their households had handwashing location with water and agent; 26% of respondents' hands appeared clean and their households had handwashing location with water and agent, and 18% had all three indicators. **Conclusion:** To estimate observed handwashing with soap, a combination of three

easy to collect variables as part of a survey that includes environmental spot checks can be considered. Candidate indicators include observed presence of handwashing location with water and soap, observed respondent hand cleanliness and ability to recall at least two critical handwashing times. These indicators could be incorporated into nationally representative surveys such as DHS or MICS in Bangladesh and elsewhere.

PERFORMANCE COMPARISON OF MICROBIAL SOURCE TRACKING ASSAYS IN BANGLADESH AND KENYA

Angela Harris

Additional Authors: Amy Pickering; Michael Harris; Leanne Unicomb; Clair Null; Stephen Luby; Jennifer Davis; Alexandria Boehm

This study assesses the effectiveness of several microbial source tracking (MST) assays for detecting and distinguishing human, ruminant, and avian fecal contamination in urban and rural Bangladesh, as well as rural Kenya. Comparing the sensitivity and specificity of MST assays across geographic locations provides insight into the dominance and stability of source-specific genetic targets in the gut microbiome of animal and human hosts. To utilize MST assays in a new geographic area, it is suggested that a 'local' validation study be conducted as the prevalence of the source-specific markers can vary geographically based on diet and evolution. However, the scale of 'local' has not been defined, and this study offers insight into this issue. Additionally, the results of this study can inform recommendations for which MST assays should be used to characterize environmental fecal contamination in the study areas, where proper management of human and animal waste is lacking. Fecal specimens were collected from households in the Mirpur community in urban Dhaka, Bangladesh; in rural Mymensingh district in Bangladesh; and in the rural Western Province of Kenya. Samples were collected from humans (n=50), goats (n=60), cows (n=60), sheep (n=19), dogs (n=17), chickens (n=60), and ducks (n=35). In each study area, five composite samples were created for each source type from 2-4 individual fecal donors. The composite samples were made into fecal slurries using molecular grade water. Fecal indicator bacteria (FIB), *E. coli* (EC) and enterococci (ENT), were enumerated using membrane filtration (MF) and growth on selective media (mEI and MI media, Difco) in Kenya and a most probable number (MPN) method (Colilert and Enterolert, IDEXX, Westbrook, ME) in Bangladesh. For molecular processing, the fecal slurry was filtered using membrane filtration, and DNA was extracted from the filter. The following MST Taqman qPCR assays were performed on the DNA extracts: GenBac3 (general fecal marker), HF183 Taqman (human-specific), BacHum (human-specific), HumM2 (human-specific), BacCow (ruminant-specific), Rum2Bac (ruminant-specific), and BacR (ruminant-specific). An avian SYBR green assay termed GFD was also performed. Generally, FIB concentrations per gram of wet feces were similar across animal sources and between the study areas. However, there was some variation observed in the FIB levels in feces. For instance, across all study areas, cow feces had significantly lower concentrations of EC and ENT than chicken feces ($p<0.05$). Depending on the study area, cow feces also had significantly lower levels of FIB than human, duck, and dog feces ($p<0.05$). Goat feces also had lower levels of FIB than feces from dogs and chickens ($p<0.05$). The mean concentrations of FIB by animal source did not vary between the study areas ($p<0.05$) except for goat and human feces. *E. coli* concentrations in goat feces were different between Kenya and the study sites in Bangladesh. Human feces in Kenya had lower levels of ENT than in rural Bangladesh, and goat feces in Dhaka, Bangladesh had lower levels of ENT than in Kenya. The samples from rural Kenya and Bangladesh are currently in the molecular processing phase, but results of the MST validation for Dhaka, Bangladesh have been assessed. The performance of an assay is determined by calculating the sensitivity (SNS) and specificity (SPC) based on the presence/absence of the marker in target and non-target source feces. The BacHum assay is the most sensitive human assay (SNS=60%, SPC=65%), but slightly less specific than the HF183 Taqman (SNS=40%, SPC=70%) and HumM2 (SNS=40%, SPC=75%) human assays. Non-target amplification of the human-specific markers occurred in goat, duck, and chicken feces. The Rum2Bac and BacR ruminant targets were only detected in cow and goat feces (SPC=100%), making them both more specific than the BacCow assay (SPC=33%), whose target was detected in duck and chicken feces. The ruminant assays

were all 100% sensitive. The avian assay was detected in all of the chicken and duck fecal composites; however, the avian target was also detected below the range of quantification (ROQ) in cow and human feces (SPC=93%). Complete results on the validation of the MST assays from all study sites will be presented. This study provides recommendations for which molecular MST assays can be used to detect and distinguish human, ruminant, and avian fecal contamination in our study areas. Additionally, our results compare MST assay performance between two continents (Asia versus Africa) and between urban and rural settings. Comparison of the validation results across geographic sites offers insight into the robustness of the assays and understanding the scale at which geographic variation in the gut microbiome of animals can influence the applicability of molecular microbial source tracking methods.

Safe Drinking Water Act health-based standards compliance among community water systems serving tribes in the United States, 2010 - 2012

Korie Hickel, The Alaska Native Tribal Health Consortium

Additional Authors: Chris Dankmeyer; James Temte; Troy Ritter

Introduction According to the U.S. Environmental Protection Agency (EPA), from federal fiscal year (FY) 2010 to 2012, 15.5 % of tribal community water systems did not meet Safe Drinking Water Act (SDWA) compliance with health-based standards, in contrast to 9.3% of non-tribal community water systems. Full compliance with SDWA health-based standards requires that a drinking water system has no maximum contaminant level (MCL) or treatment technique (TT) violations. The EPA definition of a "tribal" community water system (CWS) is a public water system that is located on the Navajo Nation or on an Indian Reservation and the EPA has primacy for its compliance. However, this definition excludes many CWSs that are currently providing water to tribal communities, categorizing them as "non-tribal" systems. For example, the State of Alaska has SDWA enforcement primacy in Alaska, a state that is home to 229 federally recognized tribes, most of which reside in tribal communities that are not on Indian Reservations. Therefore, the CWSs that serve them would not be captured in the EPA SDWA compliance estimates for tribal CWSs. The objective of this investigation was to determine the true health-based standard compliance status of tribal CWSs in the US. Our hypothesis was that the actual proportion of tribal CWSs complying with SDWA health-based standards is different from the 15.5% reported in the SDWIS database by the EPA. Determining a more accurate compliance rate will more clearly define public health risks and inform resource allocation.

Methods First, a more inclusive definition of a tribal CWS was developed to include all CWSs that serve a tribal community where 50% or more of the population belongs to a federally-recognized American Indian or Alaska Native (AI/AN) tribe. This expanded definition differs from the one used by the EPA, because it relies on a community's demographics, as opposed to primacy jurisdiction and Indian reservation boundaries. For consistency, the definition of a CWS remained the same as the EPA definition: a CWS is a public water system that supplies water to the same population year-round. We then reviewed the Safe Drinking Water Information System (SDWIS) pivot tables from FY 2010-2012 and, using the EPA's tribal CWS definition, determined the percentage of CWSs in and out of compliance with health-based standards for all non-tribal CWSs in the U.S. and for tribal CWSs. We analyzed this data for each year and as an aggregate over the study period. Next, we applied the expanded definition of a tribal CWS in Alaska, identified applicable CWSs, and worked with the EPA and the State of Alaska Drinking Water Program to obtain their compliance history with SDWA health-based standards from FY 2010-2012. We then calculated SDWA health-based standards compliance rates for "non-tribal" CWSs and tribal CWSs using the expanded definition. Results According to EPA definitions, from FY 2010 to 2012 the aggregate percentage of CWSs with a health-based violation was 9.3% among non-tribal CWSs and 15.5% for tribal CWSs. Using our expanded definition of a tribal CWS, we identified 183 CWSs that primarily serve tribal communities in Alaska and were not included in the EPA definition of a tribal CWS. Of the 183 CWS identified, 29.3% had a health-based violation during the FY 2010-2012 period. The addition of the Alaska data increased the percentage of tribal CWSs with a health-based

violation from 15.5% to 18.3% and reduced the percentage of non-tribal CWSs with a health-based violation from 9.3% to 9.2% when removed from the non-tribal category. Discussion The data presented here confirm our hypothesis that the actual proportion of tribal CWSs complying with SDWA health-based standards is different from the 15.5% reported by in the SDWIS database by EPA. Expanding the definition to include all CWSs that serve communities mostly comprised of tribal members, and not just those in Navajo Nation or those for which EPA has primacy, provides a more complete and accurate picture of SDWA compliance and public health risks among tribal populations. We recommend that the expanded definition of a tribal CWS be used when collecting, analyzing and interpreting SDWA compliance data for US tribes. We also recommend that data for tribal CWSs be made easily accessible within, or in addition to, the SDWIS database. This will make it easier to identify the health-based risks of CWSs serving tribal communities. It is important to note that the disproportionate rates of compliance and provision of safe drinking water reveal that tribal members may have a greater health risk from their publicly provided water than the non-tribal U.S. population. Further research needs to be done to determine if other CWSs outside of Alaska meet our expanded definition of a tribal system and qualify for inclusion into our dataset.

HappyTap: Aspirational handwashing device commercialization in Vietnam

Ai Huynh, WaterSHED

Additional Authors: Geoff Revell

In many developing countries, handwashing with soap offers huge potential for improved public health due to its effectiveness as a barrier against a variety of important diseases such as diarrheal disease, respiratory infections, trachoma, and others. Achieving a sustainable and scalable market-driven solution to enable consistent handwashing would be significant: a systematic review of observational and experimental studies cited reductions in diarrhea of 48 percent for handwashing with soap. Despite its effectiveness, consistent practice of handwashing is poor in rural Vietnam (36% of people reported washing hands after defecation; 23% before eating; and 19% before preparing food). Efforts to change handwashing behaviour on a large scale have had little sustained impact. In Vietnam, recent hygiene awareness interventions implemented by the World Bank's Water and Sanitation Program (WSP) and the Vietnam Women's Union reached over 16 million people, but little or no significant change was found in handwashing practice. Even so, hygiene campaigns implemented in Vietnam have cumulatively resulted in a high level of knowledge and awareness about the importance of handwashing. While hygiene promotion may be insufficient to change behaviour, evidence suggests that the presence of dedicated handwashing equipment is associated with the practice of handwashing, and that convenient access to soap and water at critical times may be a key determining factor in the consistent practice of handwashing. WSP and WaterSHED worked with IDEO, an American design firm, to conduct a user-centred design process that emphasized rapid prototyping and adequate field testing. The design team realised that rural people aspired to own products with high aesthetic value; they did not want to project the image that they were poor. The main alternative handwashing device promoted by NGOs was the Tippy-Tap, a makeshift handwashing solution made using an old container (e.g. can or jug) suspended above the ground. The solution, dubbed HappyTap, was designed to be an aspirational product that gives households an easy way to incorporate handwashing with soap into daily routines, thus bridging the gap between knowing and doing. The design sought to reflect the right mix of aesthetic appeal, functionality, durability, and affordability. WaterSHED carried out test-marketing in two provinces of southern Vietnam to validate assumptions about the product price, distribution strategy, and ultimately the marketability of the device. Women at organized group events were shown various presentations about the HappyTap, and their feedback on various aspects was recorded and analysed. In particular, the research team focused on collecting data that could inform price setting, promotional messages development, product attributes, and effective distribution channels (aka the 4 Ps). A priority was to develop an understanding of the consumer response to a variety of potential marketing

concepts. WaterSHED tested various messages and communication tools in group settings meant to approximate the sales event venue. There was a significant variance in stated willingness-to-pay based on the messages used and the quality of the presentation (USD 2.50 to 25). Villagers commonly cited "protecting family health" as a motivator to purchase, but they were much more likely to pay if the product met their aesthetic expectations. Group events also revealed a strong effect of momentum: if initial consumer feedback was positive, the overall response would likely be positive as well. The resulting product was branded, Tien Loi, which translates to "convenience" - an important selling point. On the supply side, manufacturers and distributors of plastic housewares in Vietnam are generally inexperienced in the development of new products. WaterSHED's research indicated that they are mostly demand-responsive and have a low appetite for innovation and risk. In order to foster a sustainable market, WaterSHED is currently implementing a two-pronged strategy: i) leading a limited-time promotional campaign that leverages existing hygiene behavior change campaigns and will reach over 125,000 people through direct sales; and ii) directing generated demand to the growing network of retailers and distributors in order to stimulate their supply response. The HappyTap market development strategy is based on WaterSHED's pioneering sanitation marketing program in which the promotion of unsubsidized market transactions requires that NGO facilitators progressively exit the market as their roles are succeeded by the private and public sectors. The long run aim of the HappyTap commercialization project is to create a dynamic commercial market in Vietnam for handwashing devices in which businesses can earn an attractive return, consumers are empowered, and in which the gains from large scale behaviour change programs are cemented with consistent, practiced behaviour.

Structured observation to measure water treatment behavior in low-income communities in Dhaka, Bangladesh

Kaniz Jannat, International Center for Diarrheal Disease and Research, Bangladesh

Additional Authors: David Levine; Stephen Luby; Raymond Guiteras; Leanne Unicomb

Much of the burden of diarrheal disease in low-income countries is preventable through improvements in sanitation, water quality, and hygiene. Households participating in interventions that include water treatment with liquid chlorine or boiling report lower rates of diarrhea. However, rates of both are often low -even when the chlorine is provided for free. This study assessed the usefulness of structured observation to learn more about behaviors and social interaction related to safe water. We examine structured observation for water treatment behavior because several studies have found that rates of handwashing with soap are far lower measured with structured observation, more closely reflecting usual practice than with self-reports. We enrolled 418 compounds from low-income neighborhoods in Dhaka, Bangladesh. Compounds are groups of single-room households, usually with a small, centrally-located courtyard with shared water source, toilet and kitchen. Field intervention specialists delivered messages about safe water during a courtyard meeting at enrollment and two weeks subsequently. They also discussed disinfecting water with liquid chlorine, guidelines on its use and provided free hardware for four months that included two 15L reservoirs with a spigot, reservoir stands and a wall-mounted liquid chlorine dispenser. Two months after enrollment field staff visited compounds and conducted structured observation. They first looked for the supplied reservoirs and evidence of regular use (defined as water visible inside the reservoir). For the next five hours they noted the source, subsequent treatment and usage of any collected water. They also observed water consumption behavior and social interactions relating to safe water. Each observation was conducted between 7 a.m. and 12 noon. Six weeks later field workers administered a survey to two randomly-selected households per compound. The survey asked about self-reported water treatment practices. At least one of the provided reservoirs was in use at 60% of compounds (249/418). A total of 5,238 water collection events were observed among the 418 compounds. A small minority of these included water collected from the supplied reservoir (148/5238, 3%); for the remainder of events the water was collected directly from the source. Of the 5238 water collection events, equal

proportions of men (30/1129; 3%) and women (118/4109; 3%) collected chlorinated water from the reservoirs. Residents stored source water for drinking on 852 occasions, of which it was seen treated on 474 (56%) occasions. Among the 852 events of water storage for drinking, households were observed to boil in 42% (n=355) or chlorinate in 14% (n=119) of cases. However, during the survey 36% (300/826) respondents reported that they used chlorine for treating drinking water. Of the 474 water treatment events observed during structured observation, 24 (5%) were conducted by men who were less likely to boil (n=11, 46%) than chlorinate. Women treated water on 454 occasions and boiled water on 344 (76%) of those. We observed 101 drinking events. For most of these we could not confirm the treatment status of the water consumed (n=70), 12 events were assessed as chlorinated water consumption, six as boiled water consumption and 12 where source water was consumed without any treatment. During the total observation period of 2090 hours there were two occasions when someone was seen reminding a fellow compound member to use safe water, on four occasions someone was observed praising the use of safe water and on three occasions someone was criticizing lack of safe water. Water treatment behaviors could be measured using structured observation, which provided additional information on treatment and drinking practices compared to self-reported behaviors from surveys. Health messages and provision of a free water treatment method was not enough to change habitual practice, with boiling remaining the predominant treatment method. Gender differences in water handling and treatment method preferences were detected. The intervention has shown no impact on creating peer pressure among these less cohesive urban compound-based communities. Conducting a small number of observations of water handling and drinking practices early in development of interventions can provide insights that could be used to refine behavioral change communication messages appropriate for the community.

Effect of latrines on human fecal contamination and exposure in the public and domestic domains of disease transmission in rural India: Application of microbial source tracking techniques.

Marion (Mimi) Jenkins, University of California, Davis

Additional Authors: Mitsunori Odagiri; Alexander Schriewer; Miles Daniels; Pravas Misra; Pinaki Panigrahi; Thomas Clasen; Stefan Weurtz

With over 600 million mostly rural people practicing open defecation in India and over 500,000 children under age five dying each year from diarrhea, improved sanitation is clearly necessary to reduce exposure to enteric pathogens. In the context of a large cluster randomized controlled sanitation trial in rural Odisha, India to measure the health impact of household latrines, human fecal contamination and exposure in intervention and control communities was measured and compared using microbial fecal source tracking (MST) methods based on host specific genetic markers of Bacteroidales, an abundant gut microorganism of the order bacteria. MST is an emerging approach to discriminate and quantify human from other animal sources of fecal contamination. The goals of this study were to (1) measure levels of total, human and animal fecal contamination in the public (local community water sources) and the domestic household (stored drinking water, hands) domains of fecal-oral disease transmission, and (2) compare observed levels of total and human fecal contamination in the two domains between intervention and control villages for a better understanding of pathways by which latrines reduce exposure in rural India. In each intervention (n = 30) and control (n = 30) village, one 20-L sample each was collected from improved (two public deep and two private shallow tube wells for drinking, n = 209) and unimproved (two public ponds for bathing and hygiene activities, n = 94) community water sources along with domestic domain samples in 5 to 6 households per village, comprising 300-mL of stored drinking water (n = 348), and hand rinses of mothers (n = 349) and children (n = 346). Sampling occurred during the monsoon seasons of 2012 and 2013 following completion of latrine construction activities in intervention villages. Public and domestic domain samples in each village were collected during a single morning visit, with each randomly selected pair of spatially proximate intervention and control villages visited on two successive days, to minimize geographic and temporal confounding. After concentration by filtration, total-, human-, and ruminant-

associated markers were measured using quantitative PCR assays validated in India. Our results show that despite relatively high detection rates of total Bacteroidales in the public domain (55 to 100%), human-associated markers were rarely detected (1 to 5%). In contrast, detection rates of human-associated markers were significantly higher in the domestic domain (18 to 21%) while total Bacteroidales detection rates were lower (53 to 70%). We will present detailed results on the levels of human fecal markers, and the effects of latrines at community and household scale on human fecal contamination and exposure via routes in the public and domestic domains of disease transmission in study communities.

Do decentralized community treatment plants provide clean water? Evidence from Andhra Pradesh

Marc Jeuland, Duke University

Additional Authors: Marcella McClatchey; Subhrendu Pattanayak

In poor and emerging market economies, most households obtain water for household consumption from sources of variable quality and safety located outside the home, with important negative consequences for health (WHO 2012; Shaheed et al. 2014). In part owing to such concerns, there are also a growing number of highly advanced, community-level drinking water treatment facilities in locations where piped in-house water systems are nonexistent or unreliable. These systems typically utilize combined technologies such as advanced filtration with ultraviolet disinfection, or reverse osmosis. And while these methods are known to be highly effective for the removal of pathogens and other water contaminants, there is no rigorous evidence on whether sophisticated community-level treatment systems deliver water quality, health, or other benefits to households that source water from them. This paper utilizes a quasi-experimental approach by combining (a) the construction of plausible counterfactual groups of communities with and without community water systems (CWS) and (b) a difference-in-difference methodology to examine impacts on households of these highly advanced systems. Under this model, treatment households could choose to visit the centrally-located CWS to purchase water in 20 liter quantities using approved containers; the fees collected then served to cover operation and maintenance costs and to repay loans for the capital investment provided by external donors. At the outset, 25 communities selected into the CWS program were matched with 25 non-CWS control villages in the same region using a number of characteristics obtained from village census, including the basic water supply alternatives. In each village, approximately 55 households were randomly selected for inclusion in a baseline survey. Balance checks using baseline data do not reveal significant differences across treatment and control arms of the evaluation design. Midline and endline surveys were conducted in 2008 and 2011 following installation of CWS infrastructures. Counter to initial expectations, we find low rates of sourcing water from these facilities (~10% in 2008, declining to about 6% by 2011), and correspondingly little evidence of average benefits to households living in treated villages. Users of CWS water are positively selected: these user households report somewhat higher income, are more educated, have more young children, and are less likely to believe that the government should pay for water supply improvements. Relative to nonusers and households in the control villages, we observe increases in the number of regular drinking water sources used (by roughly 1 source on average) and in monthly expenses on drinking water (by about 40 Rs., or roughly \$0.80 per month), which suggests that households did not make a switch to exclusive sourcing of drinking water from the more expensive CWS. At the same time, users invest in significantly less in-house water treatment, have somewhat higher rates of contamination with *E. coli* in their household drinking water containers, and report higher rates of child diarrhea, than control households. These findings are robust to standard difference-in-difference regression as well as several specifications that utilize propensity score matching to pair CWS users in treated communities with observationally similar households in untreated communities. Overall, these findings offer two lessons. First, CWS users end up scoring worse in terms of behaviors and outcomes related to water quality presumably because of compensatory behavior linked to the 'prevalence elasticity of demand for prevention behaviors' (Pattanayak & Pfaff, 2009). This substitution between private and public (e.g., CWS) behaviors

complicates plans and interventions to deliver clean water and thereby eradicate water borne diseases. Second, for this and other reasons, we must be cautious in declaring that high-tech community water treatment facilities are better than existing water supplies for households facing drinking water problems.

Monitoring drinking water quality in a nationally representative household survey: the Ghana Living Standards Survey

Rick Johnston, World Health Organization

Background: The Ghana Living Standard Survey (GLSS) is a routine survey implemented by the Ghana Statistical Service. The sixth GLSS survey, implemented in 2013/14, covered 18,000 households throughout the country. A new drinking-water quality module was implemented in the survey, which included on-site testing of water quality at 20% of households and 6.7% of water sources. **Methods:** Simplified and robust field test equipment, which do not require electricity, were used for on-site water quality measurement. Both 1 mL and 100 mL samples were tested for *E. coli*, using membrane filtration (Millipore Microfil) and enzyme growth media (Nissui Compact Dry EC). A 50 mL sample was tested for arsenic (ITS Econo-Quick). A subset of samples were cross-checked in reference laboratories. Internal consistency checks were also applied to ensure data quality. Supervisors and Editors from 30 teams were trained in the testing methodology. During fieldwork, teams would conduct interviews in 15 households per Enumeration Area; three of these households were randomly selected for water quality testing, and the drinking-water source of one of these households was visited and tested. In all, 3,600 household and 1,200 source samples were tested. **Results:** Little arsenic contamination was noted, though a few problematic areas were identified. *E. coli* levels were significantly higher in household samples than at sources. Half of drinking-water sources met the government guidelines of <1 CFU *E. coli*/100 mL, but only 28% of household water samples met this standard. Approximately 12% of sources, and 25% of household samples contained high levels of contamination (>100 CFU/100 mL). Water quality was generally better in urban areas, and among households using "improved sources" of drinking water, following the definitions of the WHO/UNICEF Joint Monitoring Programme. Water quality was best among those reporting use of sachet water or water piped into the dwelling, yard, or plot. Water stored in the household was five times more likely to be contaminated when stored in open containers, compared to covered containers. However, water from closed storage containers was 37% more likely to be contaminated than household water collected directly from sources. **Discussion:** Quality control measures were essential to ensure data reliability, though it was difficult to ensure that cross-check samples reached laboratories and were processed within time limits. Survey results have identified groups at greater risk, including rural populations and those using certain types of drinking-water sources. These findings can inform the sector and support more targeted interventions, for example of household water treatment and safe storage.

Norovirus Contamination in Accra, Ghana and Infection Risk Associated with the Practice of Urban Agriculture

Amy Kirby, Center for Global Safe Water, Emory University

Additional Authors: Han-Hsuan Tsai; Habib Yakubu; Katherine Robb; Pengbo Liu; Amy Kirby; Peter Teunis; Kelly Baker; Christine Moe

BACKGROUND: Noroviruses (NoVs) are the major cause of nonbacterial gastroenteritis worldwide. The vast majority of human NoV infections are due to viruses from genogroups I and II (GI and GII). NoVs are primarily transmitted via the fecal-oral route and can survive for long periods in the environment. In addition, NoVs are resistant to many common disinfectants, which increases the importance of good sanitation practices for

controlling environmental exposure to NoV. However, data on NoV contamination levels in the environment, major exposure pathways, and the corresponding risk of NoV infection is limited, particularly in low-income urban settings. **METHODS:** Environmental samples were collected from a variety of public domains associated with the sanitation infrastructure in Accra, Ghana in order to investigate NoV GI and GII contamination in the environment. Samples were screened for the presence of NoV GI and GII using real-time RT-PCR, along with an internal control to detect PCR inhibitors that may be present in the samples. The magnitude of NoV contamination in presumptive positive samples was determined by quantitative real-time RT-PCR (RT-qPCR) using NoV GI or GII standards. Inhibited samples were diluted prior to quantification. The data on NoV GI and GII concentrations in irrigation water samples were used to conduct Quantitative Microbial Risk Assessment (QMRA) to investigate the potential risk of NoV infection among urban farmers who unintentionally ingest NoV-contaminated irrigation water. **RESULTS:** Septage samples from public latrines were the most frequently contaminated samples with the highest mean virus concentrations (GI: 41% positive, 3.8×10^6 GEC/mL; GII: 52% positive, 1.4×10^6 GEC/mL). NoV was detected less frequently in samples collected from public drains, flooded areas, irrigation water, ocean water, and farms (5-15% of each sample type were positive for GI or GII), and the virus concentrations in positive samples were 1-6 logs lower than that detected in septage. Irrigation water had high concentrations of NoV (GI mean: 1.2×10^5 GEC/mL; GII mean: 2.9×10^5 GEC/mL), but the virus was only detected in 10% of samples. None of the samples collected from food vendors, produce markets, schools, or nurseries were positive for GI or GII NoV. PCR inhibition was detected in 19% of samples screened for NoV. QMRA analysis estimated the average probabilities of NoV GI and GII infection for farmers who irrigate their crops daily are 0.28 and 0.42, respectively, for a seven-day period. **CONCLUSIONS:** NoV GI and GII are present in Accra and can be found throughout the urban environment at high levels. Urban agriculture was implicated as a primary mode of NoV exposure, especially during irrigation of crops. Farmers are at especially high risk for NoV infection because of their daily contact with highly contaminated irrigation water.

MFU/100ml: New Measurement Parameter for Rapid Enzymatic Monitoring of Fecal-Associated Indicator Bacteria in Water

Juri Koscheltnik, VWM GmbH

Additional Authors: Markus Epp; Wolfgang Vogl; Marija Zunabovic; Maximilian Lacker

Microbial water quality is generally assessed by the presence of fecal-associated indicator bacteria. Coliforms and *E. coli* have traditionally been used as indicators based on the assumption that there is a direct relationship between the concentration of indicator bacteria and the potential health risks involved. There is a wide variety of microbiological and biochemical methods available for testing the microbial quality of water through these indicator microorganisms. Microbiological cultivation methods estimate the number of bacteria in water samples as amount of Colony Forming Units in 100 ml (CFU/100ml) or as a Most Probable Number of bacteria in 100 ml (MPN/100ml). There are growing amount of molecular methods allowing qualitative and quantitative detection of indicator bacteria without the need for cultivation. These methods are primarily based on the identification of specific genetic markers or antigenic determinants as well as on the measurement of specific metabolic activity in fecal-associated bacteria. Although there is no clear correlation between microbial counts and the number of genomic copies or catalytic activity of specific enzymes in analyzed water samples, the measurement units should be clearly designated. On the one hand, the measurement results of genetic markers identification, expressed in GC/100ml (GC = Genome Copies) or CCE/100ml (CCE = Calibrator Cell Equivalent) are already defined and generally accepted. On the other hand, the specific enzymatic activity of beta-D-glucuronidase in fecal indicator bacteria has been analyzed for many years, but the measurement parameter is still not quite suitable for quantitative analysis. The amount of product released by catalytic cleavage of substrate in certain period of time (usually expressed in pmol/min/100 ml or in nM/min) significantly depends on the measurement conditions (buffer composition, pH, temperature) and the chosen substrate. In this work we are introducing a novel parameter: enzymatic activity of beta-D-glucuronidase expressed in Modified

Fishman Units in 100 ml of water sample (MFU/100ml). This new parameter gives a value which is completely independent on the measurement procedure and therefore is applicable for quantitative comparative studies. All necessary calibrations, various comparison tests as well as field trials were performed using fully automated measurement device (VWM ColiMinder) capable to detect enzymatic activity of beta-D-glucuronidase above 0.0005 MFU/100ml in freshwater within less than 20 min without sample pretreatment. In preliminary monitoring tests a fluctuation of fecal contamination in surface water could be continuously tracked with a previously impossible time resolution giving insights into development and abatement of microbial water pollution.

A study of drivers for latrine take-up in rural Cambodia

Phyrum Kov, World Bank

Additional Authors: Priya Lall; Claire Chase; Susanna Smets; Yeng Lun; Virak Chan; Sophea Pov; Veasna Toeur

Rural sanitation coverage in Cambodia remains lowest compared to other countries in the region. The coverage in 2011 was only at 22% with almost three quarters of the population in rural areas openly defecating. Over the past years, a number of interventions have been introduced to Cambodia in order to help accelerating progress in rural sanitation. Among the many programs introduced, sanitation marketing program have been implemented since 2009 through various organizations. The experience from sanitation marketing program indicates that latrine take-up in communities, i.e. the rate of sales of latrines, is not uniform. In some areas the take-up of latrines has been slow, while other communes (lowest level of Cambodia government's administration) have reached much higher levels of coverage in a relatively short period of time. This study therefore is trying to understand the factors or drivers contributing to latrine take-up in rural areas where sanitation marketing activities have been carried out. The results of the study will help guide policy and optimize sanitation programming to improve sanitation service delivery models for rural households in Cambodia. The combined dataset from two big sanitation marketing programs were used, namely WaterSHED's Hands-Off sanitation marketing program and iDE's Sanitation Marketing Scale-Up (SMSU) program covering 13 provinces out of 24 provinces. The combined dataset covers the sales data in the commune, the data on latrine producers and their sales agents. From the two programs, the data of 381 communes where sales were made over the period of 2012 were selected for the study. The study also used the data from the government's routine monitoring system, the Commune Database and ID Poor database, which provides information on commune characteristics and demographics that may explain latrine take-up in the commune. In the study, the latrine take-up rate in a commune is defined as the sales per month per 100 households without a toilet at baseline. This measure is used as it reflects well the market potential in the commune. On average, the latrine take-up rate in a commune is 0.28%, meaning that out of 1000 households without a toilet at home, nearly three households per month purchased latrine. The analysis of the take-up rate is conducted at the commune level due to the data availability, reliability and simplicity's sake. The study is largely quantitative, while qualitative analysis is also conducted, where relevant, to explain some of the intangible factors that may be associated with the latrine take-up. According the descriptive analysis, there may be variety of factors that affect the latrine take-up in a commune. These factors can be categorized into three: (1) commune level factors which relate to commune's demographics, infrastructure and composition of leadership; (2) demand level factors which relate to demand creation activities and overall exposure to market environment; and (3) supply level factors which associate with the latrine producers' characteristics and their distance to the commune. Multivariate regression analysis was used by constructing the model with variables around the three main factors identified above. A number of iterations were conducted for the regression analysis to construct a plausible model that best explains the latrine take-up rate. Moreover, the regional fixed effects were also added to the model to capture unexplained variance. The results of the multivariate analysis showed that latrine take-up is positively associated with the number of latrine sales agents in the commune, the income-generating occupation of people in the

commune, the exposure to the market, and the population density. It is also noted that the poverty rate in the commune did not have plausible relationship with the take-up rate. When only commune level factors are included in the model, the proportion of female commune councilors also explains the take-up rate in that particular commune. These results suggest that strengthening sales function could be key to improve the latrine take-up in a commune. Having strong local government leadership in enabling the private sector to operate in the communes is also necessary in enhancing sales function. Last but not least, capitalizing on the female members of the commune council, such as the focal point for Commune Committee for Women and Children, is also key to increase the latrine take-up rate.

Tracking district budgets for sustainable rural water services in Ghana and Uganda

Tyhra Kumasi, IRC/CWSA

Additional Authors: Valérie Bey; Jeske Verhoven; Joseph Abisa; Marieke Adank; Stef Smits

Sustainable water service delivery requires strong links between policy, planning, budgeting and resources allocation and use. In many countries however, like in Ghana, these links are weak at the district level. District plans and budgets are also often predominantly focused on construction of new water facilities (CapEx) and include limited recurrent expenditure. For instance, in Ghana, capital maintenance expenditure (CapManEx) and expenditure on direct support (ExpDs) are the responsibility of the District Assembly but, are often not fully planned and budgeted for on a systematic basis. In Uganda, the main funding for district local governments is received from the national level in the form of the District Water and Sanitation Conditional Grant (DWSCG); guidelines provided to the districts as regards to spending of this grant specify that not less than 70% should be spend on CapEx and up to 8% on CapManEx, leaving only a few percent to ExpDS. The thinking behind the adoption of life cycle costing by districts is that an increase of allocation and disbursement of funds for recurrent expenditure of water services will result in longer life-spans of water facilities, followed by increased functionality and ultimately in improved levels of service. Triple-S operates in Ghana and Uganda with the aim of developing innovative solutions for improved water services and support sector processes and reforms for their incorporation into sector operative framework. The project seeks to provide better understanding of the Service Delivery Approach (SDA) and the tools, processes and cost required to institutionalise and scale-up. Triple-S has field tested a methodology developed by WASHCost for costing sustainable Water, Sanitation and Hygiene services by assessing life-cycle costs (LCC) and comparing them against levels of service provided. The objective of the study presented in this paper was to examine whether in Triple-S pilot districts, between 2010 and 2013, the total budget for water service delivery has increased and whether budgeting, allocation and disbursement of funds for rural and small town water services has shifted from predominantly CapEx towards an increase in CapManEx and ExpDS.. Apart from funding from the central and local governments, other sources of funding for WASH activities in the districts was tracked. Prior to tracking of the plans and budgets districts staff in Ghana were also trained on the life cycle cost approach to ensure that they plan and budget comprehensively. Quantitative data has been collected in both Ghana and Uganda. Data analysis is currently underway in Uganda and the results will be ready by the time of writing the full paper. For Ghana, results for instance in Akatsi district show that although there has been a shift in focus from CapEx to ExpDs and CapManEx, it is not consistent over the years and exclusively reliant on donor funds. There was also marginal improvement in budgetary allocations for WASH service delivery in the districts with fair distribution among the existing and new infrastructure. In both countries it is almost the first time that the budgets have been tracked from the local government level; when previous local budgets tracking have been undertaken, these examined total budget and total expenditure but not disaggregated per cost component. It is expected that this study will enable the districts to have a comprehensive picture of investments from local governments and other stakeholders showing total budgets, expenditure but also disaggregation per cost components in terms of CapExp, CapManEx and ExpDs. This information is vitally important for district WASH staff, enhancing their planning and budgeting processes and

making a case for more allocation for under budgeted cost components. It is anticipated that the study will institutionalise the concept of LCC and trigger national discussions on the realistic cost of supporting the provision of sustainable water services as well as on how the shortfall in the cost can be covered by stakeholders in order to improve sustainable WASH service provision in both countries.

What can monitoring data tell us about water safety in sub-Saharan Africa?

Emily Kumpel, Aquaya Institute

Additional Authors: Rachel Peletz; Mateyo Bonham; Ranjiv Khush

Monitoring for Safe Water (MfSW) is a three-year applied research program that began in 2012 to understand why regulatory requirements for microbial water quality monitoring in sub-Saharan Africa do not ensure the adequate collection and use of microbial water quality data. Through this program, we have collected records of more than 50,000 microbial indicator test results in drinking water from 20 water utilities and 16 public health surveillance agencies in nine countries (Benin, Ethiopia, Ghana, Guinea, Kenya, Senegal, Tanzania, Uganda, and Zambia). Regulatory monitoring data can be used to assess whether drinking water in these agencies' jurisdictions is free of microbial contamination and to compare the quality of different sources. However, there are challenges in interpreting these data, including ensuring data quality and understanding how representative the tests are of water sources populations are drinking. Through this program, we collected 44,000 tests for fecal indicator, 45,000 tests for free chlorine, and 23,000 tests for turbidity from logbooks between 2001-2013 from institutions that applied to the MfSW program. Additionally, through the MfSW program, 26 institutions currently submit microbial water quality data monthly. Previous analyses of monitoring data have relied on the Rapid Assessment of Drinking-Water Quality (RADWQ) study (Bain, 2012; Onda, 2013); availability of raw data directly from surveillance agencies and utilities through this program allows a more detailed analysis of data based on sampling as employed by monitoring agencies. Preliminary results presented in this abstract are based on 8,000 microbial tests from 17 institutions in six countries that expanded their testing program through MfSW and sent at least one month of data as of April 2014. We define microbiological contamination as a positive fecal coliform, *E. coli* or H₂S test. A total of 7% (n= 2522) of samples from piped networks were collected by water supplies in five countries were positive for fecal indicator bacteria. Half of schemes (n=26) did not have any positives, with one scheme having a maximum of 17% of samples positive for fecal indicators. 35% (n= 1753) of piped network samples did not meet minimum guideline of >0.2 mg/L free chlorine. Free chlorine concentrations were significantly correlated with presence of fecal indicator bacteria (p<0.01, Wilcoxon rank-sum): only 1% of samples with a free chlorine residual (>0.2 mg/L) were positive for fecal indicators, compared to 10% of those without free chlorine residual (<0.2 mg/L). Only 1% of samples (n= 2283) did not meet recommended <10 NTU. Public health surveillance agencies tested a wide range of drinking water sources. 43% of all drinking water samples (n= 5089) were positive for fecal indicator bacteria. 81% of samples from sources classified as unimproved (n=961) were positive for fecal indicators compared to 19% of samples from improved sources (n=2608). Samples from sources classified as improved were collected predominantly from piped networks (52%) and boreholes (25%), with the remaining samples from improved springs, wells, and handpumps. Most samples collected from sources classified as unimproved were collected from groundwater, specifically open wells (41%), unspecified wells (28%), handpumps (14%), and unimproved springs (11%), and the remaining from carts or bottled water. Improved wells and springs had significantly fewer samples positive for fecal indicators than unimproved wells and springs, respectively (p <0.01; chi-squared) In addition, we will discuss whether the sources tested through these monitoring programs are representative of water sources populations drink (as measured through census data) and discuss how the MfSW program has affected the geographic reach and representation of monitoring data in the partner institutions. We will also present the results of checks on data quality. References Bain, R., Gundry, S., Wright, J., Yang, H., Pedley, S., & Bartram, J. (2012). "Accounting for water quality in monitoring access to safe drinking-water as part of the Millennium Development Goals: lessons

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A methodology to assess correct and consistent use of household water treatment products: case studies from Haiti and Nicaragua

Daniele Lantagne

Additional Authors: Anna Murray; Natalie Wilhelm; Julie Napotnik

Background Worldwide, an estimated 780 million people drink water from unimproved sources and an estimated 1.2 billion more drink contaminated water from improved sources. Household water treatment and safe storage (HWTS) is one intervention promoted to accelerate the health gains associated with safer drinking water. Correct and consistent use of HWTS products is critical; research has associated inconsistent HWTS use with diarrheal disease, and has shown occasional exposure to contaminated water can diminish health benefits from HWTS interventions. Current methods used to evaluate HWTS options include: laboratory efficacy to establish pathogen removal; randomized, controlled trials (RCTs) to document disease reduction; and field water quality testing to determine effective use. A WHO toolkit for monitoring and evaluating HWTS programs provides indicators to evaluate HWTS uptake; however, no indicator or methodology is provided for assessing long-term correct and consistent use. In Haiti, a non-governmental organization (NGO) distributes a two-bucket water filter system to households. Filter users add a large sodium dichloroisocyanurate tablet (Aquatab) to a top bucket, then disinfected water passes through a 1-micron nylon filter and activated carbon filter into a bottom bucket, where users add a small Aquatab for residual disinfection. In Nicaragua, the Newton-San Juan del Sur Sister City Project (NSJSSC) distributes biosand filters (BSFs): household filters that employ sand and gravel as the filter media. To use, users simply pour water into the top of the filter. Tufts University worked with the Haitian NGO and NSJSSC to evaluate programmatic improvements to training and filter design, respectively. Data collected also provided information on correct and consistent HWTS use, which is presented herein.

Methods A baseline questionnaire establishing demographics, water use habits, and water quality parameters was verbally-administered to participant households. After baseline, BSFs were distributed to 82 families in four Nicaraguan communities; Haitian filters were distributed to 304 families in two Haitian parishes. Unannounced follow-up household visits occurred 1-2 weeks, 2 months, and 6-8 months after distribution. Each visit included: 1) a verbally-administered questionnaire addressing users' knowledge of product use/maintenance, water treatment and drinking habits, product satisfaction, and product technical issues; 2) observation of current filter use; and 3) water quality testing. For Haitian filters, free chlorine residual (FCR) of untreated water, and water in top and bottom buckets was measured with a LaMotte rapid DPD kit. Acceptable FCR ranges were 0.2-0.6 mg/L for bottom, and ≥ 1.5 mg/L for top bucket water samples. For the BSF, three samples (untreated; direct filter effluent; and stored, treated water) were collected in WhirlPak bags, transported to a field laboratory, and analyzed for *E. coli* and total coliform using membrane filtration with m-ColiBlue24 media. Acceptability was quantified using three survey questions: self-reported filter use, future plans to use the filter, and if the user reported liking the water taste. Consistent use was evaluated by observed presence of stored, treated water. Correct use was technology dependent. Correct Haitian filter use depended on answers to a series of filter usage questions, and acceptable FCR in top and bottom bucket samples. Correct BSF use was considered as households with low risk *E. coli* contamination in stored drinking water (<10 CFU/100 mL). Results and Discussion Acceptance and consistent use in both programs was high: over all visits, $>82\%$ of Haitian and $>92\%$ of BSF users reported using filters, planning to continue use, and liking the taste of filtered water. Overall, 88-97% of BSF and 78-82% of Haitian filter users had water in their filters at each visit. Correct use was lower: among Haitian filter users, 45-58% knew all steps, 32-37% had FCR in both water samples, 9-19% had acceptable FCR in both water samples, and 7-11% both knew all steps and had correct FCR. Among BSF users, 32-58% had

stored drinking water with <10 CFU *E. coli*/100mL. Only 1% of Haitian households demonstrated consistent, correct use (acceptable FCR at all three visits). Of the BSF households with water quality data at all 3 visits (29 households), only 3% had low risk microbiological contamination at all visits. Recommendations This methodology presents an approach to evaluating correct and consistent use of HWTS products, and can be adapted to particular technologies and study lengths. It addresses user acceptance, correct use, and product effectiveness over time. These results also highlight the disparity between laboratory efficacy data, RCT results, self-reported user data, and objective indicators; and the need to understand the impact of inconsistent HWTS use on user health.

Understanding psychological factors determining water treatment practices for the prevention of Cholera in Chad

Jonathan Lilje, EAWAG: Swiss Federal Institute of Aquatic Science and Technology

Additonal Authors: Hans-Joachim Mosler

Background: Cholera is globally on the rise with an estimated 3-5 million cases each year. The disinfection of drinking water via chlorination is one effective means to reduce the vulnerability and thus morbidity of individuals due to water-borne diarrheal diseases in developing countries. In order to efficiently promote a behavior change towards the usage of water disinfectants in a preventative effort, it is however necessary to account for the local populations' attitudes and current habits. Based on a factorial behavior model (RANAS; Mosler, 2013) derived from health psychological theory, intervention strategies can be developed systematically addressing important psychological factors with the goal of a sustainable change in behavior. Methods: A representative household survey was carried out in the period between Nov. 2013 and April 2014 in South-Western Chad, a region which has been struck by Cholera in a cyclic manner during the last decades. In order to assess psychological determinants for the promotion of water treatment behavior, structured interviews were conducted with the child-care givers in 1000 households along the Chari and Logone rivers in the Lake Chad basin. The RANAS model (Mosler, 2013) was then applied to determine which psychological dimensions should be addressed in the effort of designing an effective behavior change intervention. Results: By comparing means to the respective scale maximum (scales from 0 to 5) as well as analyzing differences between groups of performers and non-performers, we identified relevant factor blocks for intervention. The perceived vulnerability for diarrheal diseases as well as the perception of social norms encouraging the use of water disinfectants revealed high intervention potentials for future behavior change campaigns. These two factors were generally weakly developed within the study population (scale means around 2) and also revealed high differences between households who already perform water treatment in comparison to non-performers (effect sizes $d = 0.9$). Discussion: In the local context of the Chadian population, the two psychological dimensions of individual risk perception for diarrheal diseases and the strengthening of social norms in favor of water treatment should be addressed. The RANAS model (Mosler, 2013) serves as guide to identify appropriate intervention strategies which can subsequently be tailored to the specific situation. The perception of individual vulnerability should be addressed during information campaigns where relevant facts and risk information are communicated leading to a positive knowledge transfer about diseases and the protective function of water treatment. Social norms can be influenced during public commitment events and strengthened by highlighting existing norms that are already in favor of water treatment practices.

mWASH: Introducing new indicators for improved monitoring of water, sanitation, and hygiene at the national level

Luke MacDonald, Johns Hopkins University Global Water Institute

Additional Authors: Easmon Otupiri; Timothy Julian; Sara Marks; Kellogg Schwab

Introduction: Existing data at the national level leave many gaps for water and sanitation planning purposes. To address these gaps, the Johns Hopkins University mobile Water, Sanitation, and Hygiene (mWASH) study is an ongoing national survey examining new indicators of WASH issues in 5 countries (Ghana, Democratic Republic of Congo, Ethiopia, Uganda, and Kenya), with a planned roll-out in 8 additional countries. This study is designed for rapid turnaround of periodic national surveys (every 6 months) that provide new insight and depth on WASH issues. In contrast, many existing surveillance tools like the Demographic and Health Survey (DHS) occur once every 5 years in participating countries. mWASH is one component of the multi-sector Performance Monitoring and Accountability 2020 (PMA2020), which also includes a module on access to family planning services. Ghana was the first PMA2020 country to complete data collection. Results from the first round of data collection in Ghana are highlighted here. **Methods:** The mWASH platform consists of female resident enumerators living and working in randomly selected clusters which are statistically powered to provide national estimates, with subnational estimates available in some countries. Enumerators collect household and health care facility interview data using mobile phones equipped with ODK software. In Ghana, 100 enumerators collected data in 100 randomly selected clusters, interviewing 42 households per cluster and 6 service delivery points per cluster, resulting in an unweighted de jure (all usual household members) population sample size of 15,891 in round 1, with the ability to disaggregate by urban and rural, and by wealth quintile. The mWASH study examines: the use of multiple water sources for multiple purposes; seasonal and daily reliability of water services; prevalence of open defecation; management of child feces; time spent collecting water for all women ages 15-49; productive uses of water; and the presence and conditions of hand washing stations in households and health care facilities. This is an improvement over other national-level surveys which typically focus on one source for drinking and one source for other purposes, do not specifically track child feces management, and do not consider the prevalence of open defecation outside of households where open defecation is the main sanitation practice. **Results:** In Ghana we find that that 32.9% of the population lives in households that rely on one water source, whereas the rest of the population live in households that use two or more sources. Wealth is directly related to the number of household water sources; wealthier households use more water sources than poor households. By examining households' regular use of all water sources, mWASH found that 21.7% of the population regularly drinks water from unimproved sources, which is greater than the 16.7% of the population reporting use of an unimproved source as the main drinking water source. Examining a new mWASH indicator on prevalence of open defecation reveals that 34.7% of the population regularly practices open defecation at home or at work, as compared to 25.9% of the population living in households that report open defecation as the main practice. As many as one third of all piped water users report that their water source is unpredictably intermittent. These results suggest that the new mWASH indicators can better capture nuanced household WASH practices to inform policy at the national and regional levels. Thus, the mWASH study helps better articulate the gap in reliable access to safe water and gaps in sanitation practices. In future rounds of data collection, PMA2020 seeks to expand the list of participating countries and increase depth on WASH issues by including new questions.

A Systems Approach to Climate, Water and Diarrhea in Hubli-Dharward, India

Jonathan Mellor, Yale University

Additional Authors: Kara Nelson; Zach Burt; Ayse Ercumen; Emily Kumpel; Julie Zimmerman

Recently published estimates indicate that climate change might increase diarrhea incidence by 22-29% by the end of the century[1]. This impending crisis might undermine much recent work carried out in the WASH sector which has improved the livelihoods of millions. Although evidence suggests that climate change will exacerbate diarrheal disease rates, there is a great deal of uncertainty surrounding studies conducted to date. This is

because diarrhea is caused by a myriad of pathogens many of which show seasonal trends. Furthermore, all-cause diarrhea incidence shows a positive relationship with temperature, but a more complex relationship with precipitation in many regions. This is why the recent IPCC Fifth Assessment Report highlighted the need for improved multidisciplinary approaches to better understand the mechanisms and complexities of climate-induced diarrheal disease transmission. Some important shortcomings of prior epidemiological studies include the following: - Epidemiological studies of climate change impacts simply correlate short-term seasonal weather patterns to disease rates. - WASH systems in developing countries are complex systems with a plethora of pathogen transmission pathways that must be fully integrated to accurately predict disease rates. - Most previous studies are highly localized and do not rely on climate models to study long-term impacts. Those that do take a more global approach use overly simplified assumptions. Such correlational approaches have very limited ability to inform intervention efforts to help impoverished communities adapt to climate change and cannot be generalized to other climates or cultures. Therefore, the goal of our project is to develop a mechanistic systems approach that incorporates the many facets of the complex climate and WASH system to establish relationships between climate change and diarrheal disease rates under future climate scenarios. As part of our broader project, we report on the development of our transdisciplinary agent-based computer model to study the linkages between climate change, water and diarrheal disease rates in Hubli and Dharwad India. An agent-based model is comprised of agents who live in an environment and follow programmed behavioral rules. Our agents are households and children who live in the twin cities of Hubli and Dharwad, India. The model was informed and developed through a collaborative effort between the University of California, Berkley and Yale University's Climate and Energy Institute. We first gathered 15 months of local weather, water quality, water usage, WASH practices, disease incidence and diarrhea etiology data from the region. The front end of our model is a stochastic weather simulator that utilizes 15 global climate models and 2 emission scenarios to simulate how rainfall and temperature will change on a daily basis until the year 2100 in the Hubli-Dharwad region. The water quality and quantity available to residents on a given model "day" depends on the simulated day's weather and is based on field data. The propensity for a modeled child to get sick then depends on an integrated Quantitative Microbial Risk Assessment (QMRA) model. We calibrated the QMRA model using seasonal diarrhea etiology and morbidity estimates from the region. We then integrated a bootstrap method to simulate the intrinsic uncertainty and heterogeneity of the dose-response model parameters for different children. Confounding variables include water quantity, hand-washing and the presence of improved sanitation. The benefits of our approach are as follows: - Our mechanistic approach allows us to develop and prioritize scientifically derived adaptation strategies. - We can quantitatively link different climate model and greenhouse gas emissions scenarios with diarrhea incidence over arbitrarily long time periods. - We can explore the complex climate and WASH system dynamics, rank risk factor importance, identify tipping points and test a broad range of counter-factual scenarios. - Our modeling approach is modular and easily expandable such that new datasets can be easily integrated to study climate impacts in other regions or even on a continental scale. - Scenarios can be modeled quickly and easily in silico which has obvious cost and ethical benefits. Our results indicate that anthropogenic climate change will have a serious effect on diarrhea incidence in the region. However, adaptation strategies including the provisioning of improved water supplies, household water treatment and improved sanitation can largely mitigate the worst effects of climate change. 1. Kolstad, E. W. & Johansson, K. A. Uncertainties associated with quantifying climate change impacts on human health: a case study for diarrhea. *Environmental Health Perspectives* 119, 299 (2011).

Assessing the Effectiveness of German Development Bank (KfW) Projects: Evaluation Ratings or Project Indicators?

Laura Metzger, Swiss Federal Institute of Technology (ETH) Zurich

Additional Authors: Isabel Günther

Abstract In this study we quantitatively analyze what influences the performance of 150 drinking water projects that were financed by a large bilateral donor, the German Development Bank (KfW). Unlike other related cross-country studies, which rely on subjective donor evaluation ratings, we use more direct and objective measures of project performance that are based on the change in safe drinking water supply provided to the target group before and after the project. Furthermore, we use sector specific project design variables in order to explain the variation in project performance. To our knowledge, we are the first to consider sector specific project design variables, next to sector unspecific project management variables, in a cross-country study on project aid effectiveness. **Motivation of the study** The body of literature that assesses the effectiveness of project-based aid, from a cross-country perspective, is small and the available evidence is concentrated on World Bank aid (see e.g. Isham and Kaufmann, 1999; Kilby, 2000; Dollar and Levine, 2005; Dollar and Levine, 2005; Guillamont and Laajaj, 2006; Denizer et al., 2013). Most quantitative cross-country studies we are aware of, either use (World Bank) evaluation ratings or economic rates of return to measure project or program performance. Both indicators have drawbacks. Evaluation ratings are subjective assessments of project performance, a feature that limits their interpretability and individual comparability. Economic rates of return focus on resource use efficiency and do not directly measure aid effectiveness. Moreover, most studies aggregate projects of heterogeneous sectors and do not sufficiently discriminate between different types of aid. The studies on WB aid we are aware of measure project performance either in the form of economic rates of return (Isham, et al., 1997; Isham and Kaufmann, 1999; Kilby 2000) or in the form of ex-post project evaluation ratings (Denizer et al. 2013; Dollar and Levine, 2005; Guillamont and Laajaj, 2006). Ex-post evaluation ratings are closer to our concept of aid effectiveness than economic rates of return (ERR). ERR result from cost-benefit analyses of project-based investments and focus on capital productivity and resource use efficiency. Ex-post evaluation ratings, by contrast, reflect the extent to which individual projects achieved their sought-for development goals (Denizer et al., 2013). This latter description also applies to KfW's evaluation ratings. However, using evaluation ratings to analyze aid effectiveness is problematic. First, the ratings are not standardized (with respect to how they are generated) and therefore not comparable across donor organizations. Second, the ratings are probably not even comparable within an organization, because they rest on an evaluator's subjective assessment of project performance. Lastly, evaluation ratings are usually composed of sub-ratings that capture different aspects of project performance. These sub-ratings ratings are, in turn, based on project specific indicators. Even with good knowledge about a donor's rating process and the project specific information that is relevant to it, it is still difficult to pin down how a rating is generated and what it comprises exactly. Against this background, our study seeks to address two key issues of related cross-country studies on project-based aid. First, in contrast to previous studies, we define more direct and objective project performance indicators. These measures are based on the change in safe drinking water supply provided to the target group before and after the project. Second, we consider a broader range of project-level variables: in addition to sector unspecific project management variables, we include and analyze sector specific project design variables, which are usually in the focus of micro-level studies. **Results** Our results indicate that KfW's evaluation ratings are best explained by project management variables, while the water supply indicators are best explained by project design variables. Moreover, we find that key explanatory variables affect the performance of projects differently, depending on whether performance is measured with KfW's evaluation ratings or the change in water supply for the target group. These differences cannot only be ascribed to the fact that the water supply indicators are more narrowly defined than the evaluation ratings, in the sense that the latter take into account other concerns (like sustainability) while the former are missing that perspective. The deviance in results leads to different conclusions, and potential policy recommendations, about the factors that positively influence the achievement of desired development goals.

Efficacy of a Solar Sanitation System to Reduce E. coli and C. perfringens spores in Latrine Waste in Kenya

Jennifer Murphy, Centers for Disease Control and Prevention

Additional Authors: Emily Woods; Andrew Foote; Hana Lokey; Newton Wamola; Lilian Waiboci; Wilson Gumbi; Nina Marano; Barry Fields; Ciara O'Reilly; Eric Mintz; Vince Hill

In 2012, 64% of the world's population, and only 30% of the population in sub-Saharan Africa, had access to improved sanitation facilities. The population lacking access to fecal sludge management services is likely much higher. This glaring deficiency results in increased exposure to infectious fecal waste and elevated rates of morbidity and mortality from diarrheal illness. In the developing world, diarrhea is the second leading cause of death among children less than 5 years old. Past interventions for diarrheal disease prevention have focused primarily on water treatment and hygiene, but studies suggest that improvements in sanitation can yield equal or greater reductions in rates of diarrhea in young children. The need for research on low-cost, effective methods for collection and treatment of fecal sludge is urgent and well-recognized. Solar sanitation is an inexpensive and effective form of waste treatment that thermally inactivates microorganisms in fecal sludge. An innovative solar waste treatment technology that uses a parabolic reflector to concentrate solar energy was constructed and pilot-tested using latrine waste from households in Naivasha, Kenya. We evaluated the efficacy of treatment over time by measuring inactivation of *E. coli*, a fecal indicator bacterium, and *C. perfringens* spores, a heat-tolerant spore-forming bacterium that may serve as a proxy for *Ascaris* eggs. Core samples of fecal sludge were taken from two locations (center and edge) within treatment containers before treatment and after 3 and 6 hours of treatment. We also monitored temperature fluctuations at various points within containers throughout treatment times. Core samples were mixed and submitted to dry weight analysis and to an elution step to aid in removal of microorganisms from biosolids. The elution supernatant was then diluted and assayed for *E. coli* using IDEXX Colilert QuantiTray/2000 and for *C. perfringens* spores using heat-inactivation of vegetative cells followed by the 5x3 Most Probable Number Iron Milk Medium method. Back-calculation provided estimates of *E. coli* and *C. perfringens* spores per dry weight of biosolids in order to determine log reductions over time. Maximum temperatures in the solar waste treatment containers ranged from 56-116°C at edge locations and 57-95°C at center locations. In both locations, maximum temperatures were almost always achieved between 3 and 6 hours of treatment time. When maximum temperatures were above 73°C, *E. coli* reductions ranged from >4.1->8.3 log₁₀ at 6 hours; when maximum temperatures were below 57°C, *E. coli* reductions were <2.1 log₁₀. When maximum temperatures reached >95°C, *C. perfringens* spore reductions ranged from 2.4->5.0 log₁₀ at 6 hours; results at lower temperatures were variable, with log reductions ranging from <1.8->5 log₁₀. Average liquid content of biosolids in the solar waste treatment containers decreased slightly, from 73% initially to 69% at 6 hours, suggesting that microbial inactivation was not due to desiccation. These results indicate that this solar waste treatment technology rapidly achieved high temperatures (within 6 hours) capable of achieving substantial reductions of *E. coli* (up to >8.3 log₁₀) and *C. perfringens* spores (up to >5.0 log₁₀). Studies are currently underway to evaluate this solar waste treatment technology in a refugee camp setting and to better characterize the time-temperature relationship of microbiological inactivation within the system.

Fouling in hollow fiber membrane microfilters used for household water treatment in Honduras

Anna Murray, Tufts University

Additional Authors: Mario Goeb; Barbara Stewart; Catherine Hopper; Jamin Peck; Carolyn Meub; Ayse Asatekin; Daniele Lantagne

Background: Membrane filtration is an emerging technology used in many applications; including biomedical, food service, wastewater, and drinking water treatment. The largest obstacle to filter performance in all

applications is membrane blockage, or fouling. Fouling is caused by organic, inorganic, and bacterial constituents, and leads to loss of membrane permeability, observable by a decline in the water flow rate coming through the filter. Membrane fouling can be reversible, where material retained in a cake layer on membrane surfaces is removable by physical backwashing processes; or irreversible, where physical interventions are insufficient and alternative methods such as chemical cleanings are needed to recover performance. The Sawyer PointOne Filter (PointOne) is a hollow fiber membrane microfilter recently promoted for HWT in developing countries. It consists of hollow fibers bundled in a U-shape inside a plastic casing. Users attach the PointOne in-line with a delivery hose to a 20-liter bucket. Water flows by gravity into the casing inlet, through the 0.1 micron porous fiber walls into the hollow fiber membrane tubes, and exits into a second storage container. Sawyer recommends pre-treating turbid source water, backwashing the filter with a syringe and clean water when flow slows (the only recommended maintenance), and advertises filter lifespan as over 10 years. The PointOne is efficacious at removing bacterial (>6-log reduction) and protozoal (>5-log reduction) organisms that cause diarrheal disease. However, field effectiveness data has found bacterial contamination in 18-54% of tested filter effluent water in studies ranging from 3 months to 3 years of use. The non-governmental organization Pure Water for the World (PWW) distributed 200 PointOne filters in Honduras. After 23 months of use, PWW found several filters had reduced turbidity and bacterial removal efficiencies. Six of these poorly-performing filters were removed from homes and examined in laboratories at University of Maine and Tufts University to investigate why their performance had declined. Methods: The six filters removed from the field and one new filter were investigated in the laboratory by: 1) filtering sterile water and testing filtrate for turbidity and bacterial presence to establish the presence/absence of bacterial contamination within the filter; 2) cleaning filters according to manufacturer instructions obtained by calling Sawyer (soaking in warm water and vinegar, and backwashing) and testing for total coliforms, fecal coliforms, and *Escherichia coli* (*E. coli*) in sterile water filtrate; 3) imaging membranes from one used, cleaned filter and one new filter with scanning electron microscopy (SEM); and 4) performing elemental analysis of both new and used membrane surfaces by energy dispersive spectroscopy (EDS) to identify elemental constituents of the fouling layer. Results and Discussion: Sterile water filtrate from uncleaned filters removed from the field after 23 months of use had turbidity of 144 - >200 nephelometric turbidity units and bacteria counts of 13 - >200 colony forming units. After cleaning according to manufacturer instructions, sterile water effluent was positive for total coliforms, but negative for fecal coliforms and *E. coli*. SEM analysis of the cleaned, used filter identified pore blockage on the exterior membrane surface and particles on the inner surface of the hollow fibers, and visual inspection revealed possible broken membrane fibers. EDS analysis identified oxygen, silicon, aluminum, iron and lead on the outer surface, as well as calcium, potassium and magnesium, suggesting a thick fouling layer composed of heavy metal oxides and organic matter. These results indicate irreversible fouling, for which removal by physical backwashing procedures is not possible. Even after physical and chemical cleaning with manufacturer-recommended procedures, sterile water exited filters with higher turbidity and higher bacteria loading than when it entered. Broken membrane fibers, which may have burst from forceful backwashing, may have caused short-circuiting of unfiltered water. The extent of fouling in PointOne distributions is unknown; however, three concerns are raised: 1) the PointOne's applicability for treating waters of varying quality, 2) appropriate cleaning procedures, and 3) the filter's useful life span. Recommendations: Further research of PointOne performance is recommended, including: investigating the extent of membrane fouling and bacterial growth within deployed filters, characterizing the impact of source water quality on filter performance, establishing a cleaning regimen to better manage fouling, and developing an end-of life indicator and appropriate filter lifespan.

Impact of Gender Relations on Community Led Total Sanitation Processes

Mary Namwebe, Plan International

The importance of involving both women and men in sanitation has been widely recognized at global level specifically in the resolution of establishing the International Decade for Action, 'Water for Life' (2005-2015),

which calls for women's participation in water and sanitation-related development efforts and coincides with the timeframe for meeting the Millennium Development Goals. In Africa, 231 million people still defecate in the open resulting in the widespread death of children under five due to diarrhea, as well as compromising women's safety, privacy and dignity. The Ministry of Water and Environment (2013) estimates that 11 million people in Uganda have no access to sanitation. A World Bank study (2012) estimates that open defecation costs Uganda USD \$41 million annually and results in the death of 19,700 children under 5 each year from diarrhoea. The health risks and economic losses due to the practise of OD indicates the urgency of ensuring adequate sanitation for all. The Community Led Total Sanitation (CLTS) a sanitation approach to end open defecation which empowers communities to build and use latrines without hardware subsidies has gained recognition in Africa. Following five years of implementation in Uganda, CLTS has proven to be a promising solution to the country's sanitation crisis. Recognizing that gender is a critical variable in the CLTS process, Plan International commissioned a study in 2012 to investigate gender relations and other socio cultural factors to determine how they influence the Open Defecation Free (ODF) attainment processes and its sustainability. The study was conducted in Tororo and Luwero districts of Uganda. The study was conducted in 12 villages and the sample was selected using purposive sampling. The study population included heads of household, natural leaders, children, extension staff, village health team members, local leaders, PLWHAs and PWDs. Data was collected through document analysis, 38 key informant interviews and 22 focus group discussions. The study established that both women and men have been fully involved in CLTS implementation. They were involved in triggering, monitoring and mobilization of other community members to attend CLTS activities. They also took up roles as natural leaders and village health teams. The collective action of all people facilitated the participation and inclusion of men, women, boys, girls, PWDs and other vulnerable groups in decision making pertaining to sanitation improvements. They actively participated in all CLTS activities including pre-triggering, triggering and post-triggering. From this study it can be noted that CLTS processes have inspired a shift in the gender division of labour related to sanitation promotion. Men and boys are now engaged in sanitation activities at the household level; they clean latrines, collect anal cleansing materials and water for hand-washing, activities that were traditionally a responsibility for the women in the household. This has provided women more time to engage in other economic activities leading to improved livelihoods and harmony in families. The study also revealed that children made significant contributions to the attainment and sustainability of ODF status. The adolescent girls in the study households were most active, as they often encouraged their parents to install latrines in their households. The interviewees acknowledged the importance of latrine use to protect the dignity of women and girls. CLTS empowered women to take up leadership roles in their communities in the cases observed. They took up roles as natural leaders and VHTs. From the study findings it is acknowledged that there was limited gender awareness at the community level. In light of this, capacity of VHTs, natural leaders and the community needs to be enhanced regarding gender issues. This will enable them to appreciate further gender relations and the relevance of gender equality in CLTS processes. The design of CLTS programs should always be informed by a gender analysis. This will enable community members to identify gender issues, gaps and contribute to finding solutions to address them so as to promote and sustain total sanitation. Based on the active involvement of children in the CLTS process it is recommended that children should be involved in monitoring the CLTS progress within villages and schools. Communities that have not attained ODF status should visit ODF communities with good practices around the involvement of women, men and children.

Mainstreaming Water Safety Plans in Water Supply Systems in Developing countries; Experiences of Amarapuri as best practice from Nepal.

Mahesh Neupane, Government of Nepal

Nepal has made notable progress in last decades by increasing basic water supply and sanitation coverage to 85% and 62% of its population, which is more than respective MDG targets of 73% and 53% till 2015. However, NMIP WATSAN survey shows functionality status of water supply schemes as; well managed - 17.91%, needing

minor repair - 38.85%, needing major repair - 11.82. In this line, Water Safety Plan (WSP) - a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer; could be the best way to upgrade the systems for securing safe water supplies in future. WSP in Nepal is being implemented by Government of Nepal through the sectorial lead agency - the Department of Water Supply and Sewerage (DWSS) under a joint support from WHO/Aus-AID Water Quality Partnership. Since 2006, WSP has been implemented on Water Users' Committee (WUSC)'s ownership in more than 850 schemes facilitating more than 2.5 million water consumers and more than 200 government engineers and each personnel from WUSC have been trained. The water quality has been strictly checked to average 90-93% reducing E. Coli presences to almost zero. Amarapuri Water Supply Scheme (WSS) is one of the inspirational example where WSP has not only secured safe water supplies but also triggered communities towards Total Sanitation (TS). The (5+1) indicators of TS - Use of Toilet, Practice of Hand washing, Use of Safe Water, Use of Safe food, Practice of Cleaning the house and Practice of Cleaning the Communities have increased from 68.88% to 92.33%, 40% to 93.88%, 65.11% to 92.2 %, 75% to 93.22%, 56.11% to 91.88% and 53.33% to 98.44%, respectively after since Open Defecation Free declaration in 2010. The DWSS has now endorsed WSP as mandatory requirement and integrated into the regular government WaSH programs. It has recognized the Amarapuri project as a resource center to scale up WSP efforts at national and international level. DWSS/WHO in 2010, held a national WSP training program where members of Amarapuri WUSC were trained about systematic implementation of WSP. Amarapuri WSS was specially selected due to the high level of commitment of its water service provider and the potential to become a reference project for the region. The Amarapuri WSP included the catchment area near the intake point, intake points, gravity transmission line (2 km), treatment units (sedimentation tank, roughing filter, slow sand filter and chlorination), reservoir tanks (300 m³), distribution networks (18 km), taps (1180 private and 20 public), and a total 8500 beneficiaries of 1331 households. The WSP team of 13 members was formed by the users committee. The team analyzed the water supply system, identified hazards and control measures, and prepared an improvement plan in one month. A total of 17 potential and existing hazards were identified from catchment to consumer and the appropriate risk scores were assigned as high, medium and low based on severity and frequency. The improvement works such as infrastructures repair and provision of public toilet at intake, fencing and wall around grit chamber and pre-sedimentation tank, construction of valve chamber and maintenance of chlorination unit, leakage controls at water mains and networks, and cleaning in tap platforms were done in the following 6 months. The monitoring plan was prepared in February 2011 and regular monitoring was initiated soon thereafter. The users' satisfaction survey was carried out in March and the report was compiled in June. In November 2011, the project was reviewed by an external WSP expert as part of the WHO/Aus-AID project. The assessment confirmed the successful implementation of WSPs in Amarapuri. The WSP implementation has led to multiple improvements in water supply management, operations, and water quality in Amarapuri WSS having remarkably increased consumer satisfaction. Data derived from users' surveys and health reports from local clinics show that prior to WSP implementation, between 30-50% of households reported diarrheal illness; whereas less than 1% of households reported diarrheal illness in post-WSP. Consequently, the local health officials have consistently declared Amarapuri to be "waterborne disease free". The risk assessment step and the resulting risk matrix helped in the addressing priority risks for addition of a chlorination unit and adoption of Standard Operating Procedure (SOP)s for operating the entire water supply system. The WUSC has allocated a regular annual budget of \$1,550 for WSP supporting programs, from monthly tariff raised at (\$0.5)/8 m³. The international WSP groups from Water and Health Division of Timor Leste and Myanmar have frequently visited Amarapuri WSS as a role model of WSP implementation. These experiences prove how mainstreaming WSP in water supply systems could become a reliable tool to sustain our secured water supply systems for safe services in developing countries.

Measuring and reporting the impacts of capacity development projects in water and sanitation

Tommy Ngai, CAWST - The Centre for Affordable Water and Sanitation Technology

Additional Authors: Brittany Coff; Tim Hull-Bailey; Francesca O'Hanlon; Joli Price; Tatiana Viecco

Introduction Within the Water, Sanitation and Hygiene (WASH) sector, a range of organizations offer education and training services. The aim of these activities is to improve access to water and sanitation services through better design and implementation of WASH interventions (Cracknell, 2000). It is important for organizations to measure and report the results of their education and training activities in order to understand the impacts of their work, to implement improved practices, and to be accountable to stakeholders. A key challenge is a lack of clarity on how the results of education and training in WASH should be measured and reported. A global review of 100+ leading capacity builders in the WASH sector found that only 1/3 reports their results (Ngai et al, 2013). Among these, the methods used are often ad-hoc and use prescriptive criteria to assess only whether outputs are achieved (e.g. the number of people trained), neglecting the broader outcomes and longer term impacts. CAWST, the Centre for Affordable Water and Sanitation Technology, is a non-profit organization that provides training and consulting to organizations that work directly with populations in developing countries who lack access to clean water and basic sanitation. CAWST measures its results by what its clients do after receiving training and consulting services. Objective The objective of this study is to explore how CAWST can improve how it reports the results of its education and training activities. The study addresses two research questions: ? What indicators are used by organizations to report the outcomes and impacts of their education and training activities, and what are the best practices? ? What are the strengths and limitations of CAWST's current methods for measuring and reporting results, and how can CAWST improve? Method To complete this study, CAWST collaborated with the Centre for Engineering for Sustainable Development at the University of Cambridge. The research team reviewed the public reporting strategies of 36 education and training organizations, both from WASH and Non-WASH sectors. Results The review revealed weaknesses and best practices in reporting the results of education and training in WASH. A major weakness is that many organizations (33%) do not report the results of their education and training activities at all. Only 19% of the reviewed organizations reported metrics related to program impacts, while the remaining 48% only reported outputs and/or outcomes. Another weakness was a lack of effectiveness in metrics which attempted to report impacts, as many were confusing, difficult to interpret, or did not have clear links showing how the education and training services contributed to the impact. For best practice in organizational reporting, it is necessary to find a balance between the relevance, effectiveness, timeliness, consistency and logic of the metrics. Best practice metrics were identified as metrics which provided a good mixture of moderate to high scores for the criteria listed above. In particular, 'changes to trainee behaviour', 'online involvement', 'participant satisfaction', and 'response to past evaluations' were considered to be examples of best practice metrics. For a set of metrics, best practice is having a combination of metrics which complement each other. For example, the number of people trained was rated poorly for effectiveness, so another metric which is strong in effectiveness (such as trainee satisfaction), should be included. The results of the review were compared with CAWST's reporting processes. CAWST's reporting style was found to be more consistent from year to year than most of the reviewed organizations, however CAWST shared a weakness identified from the review of a lack of reporting on impacts. The comparison provided ideas for new or improved metrics that could add value to CAWST reporting processes. These include a metric related to client satisfaction, the destinations of trainees, number of online clients and their activities and changes in trainee behaviour. Additionally, it would be helpful for CAWST to report how it conducts and responds to evaluations in order to improve. The findings of this study can be utilized by other NGOs to develop effective organizational metrics. This can result in improved organizational reporting and learning, and hence result in the delivery of more effective education and training services. References: Cracknell, B. (2000) Evaluating development aid: issues, problems and solutions. Sage: London. Ngai, T.K.K., Mills, O. et al (2013) A global review of capacity building organizations in water, sanitation and hygiene for developing countries. 36th WEDC International Conference, Nakuru, Kenya. Bailey, T., O'Hanlon, F., Price, J., Viecco, T (2013) How to measure and report the results of education and training in water and sanitation. Unpublished presentation. University of Ca

Observed practices and perceived advantages of different hand cleansing agents in rural Bangladesh: Ash, soil and soap

MD FOSIUL NIZAME, icddr,b

Additional Authors: Sharifa Nasreen; Amal Halder; Shaila Arman; Peter Winch; Leanne Unicomb; Stephen Luby

Background: In Bangladesh, the rate of handwashing with soap is low. Rural communities have historically used ash and soil as handwashing agents. An observational study conducted in 2003 among women in rural Bangladesh found that after defecation 41% used water only, 38% used soil, 19% used soap, and 2% used ash to wash their hands. An earlier study conducted in Bangladesh in the mid 1990s found that soil, ash and soap were similarly effective in removing fecal coliforms from hands. Limited data exists on current practices, and perceptions regarding advantages and disadvantages of different hand cleansing agents, specifically ash, soil and soap. To inform the development of a handwashing promotion intervention we explored current handwashing practices and perceived effectiveness, advantages, disadvantages and barriers to handwashing with different cleansing agents in rural Bangladesh. **Methods:** We used a cluster randomized sampling method to select 1000 households from 68 sub-districts in 19 districts, and conducted five hour structured observations among those households. Field team members recorded the handwashing practices and the cleansing agent used by all household members. In the qualitative component of this investigation anthropologists purposively enrolled 24 households from three villages of Narshindi district in central Bangladesh, where the structured observation found high usage of ash or soil for handwashing. Anthropologists conducted in-depth interviews with adults from those 24 households to explore perceived effectiveness, advantages and barriers of washing hands with these agents and with soap. **Results:** The field team observed that out of 349 opportunities to wash hands after defecation, on 45 (13%) occasions participants used ash or soil, on 67 (19%) occasions they used soap and on 212 (61%) occasions they used water alone to wash their hand(s). Out of 417 opportunities to wash hands after cleaning a child who had defecated, on 39 (10%) occasions participants washed their hand(s) with soil or ash, on 108 (27%) occasions they used soap and on 219 (54%) occasions they used water alone. Using ash, soil or soap to wash hands at other recommended handwashing times (before food preparation, before serving food, before eating and before feeding a child) was rarely (< 1%) observed. Washing hands with water alone was notably higher than using any cleansing agent; before food preparation among 50% (910/1834), before serving food among 74% (1274/1717), before eating among 48% (3385/7035) and before feeding a child among 28% (465/1684) of observed handwashing events. In the qualitative study, most informants reported that in general, community members had the habit of washing their hands with water alone and felt this was sufficient for feeling clean and that they used soap when they saw dirt on their hands. Informants said that they washed their hands after defecation to remove disgusting bad odors. Most informants reported that they used ash or soil for handwashing only after fecal contact, and that ash and soil could clean hands as effectively as soap. Elderly informants believed that after defecation it was necessary to clean the anal area with three pieces of hard soil and then water in order to obey religious rules for attaining purity. Informants perceived soap as a modern product that cleaned visible dirt more effectively than other agents and removed germs and bad odor from hands. Informants stated that ash is freely available from traditional cooking stoves, whereas, soap had to be purchased and is expensive. Moreover, they reported that soap was usually kept inside the living room in a safe place to reduce misuse and not near the handwashing place, where it could be conveniently used for washing hands. **Conclusion:** After decades of promoting handwashing with soap after fecal contact, a similar proportion of rural Bangladeshis were using ash or soil compared with soap. Although communities consider soap an effective cleansing agent, using it for handwashing still remains uncommon, similar to other low income countries. We suggest that interventions should neither recommend nor discourage using ash or soil to wash hands as no studies have evaluated the effectiveness of post-defecation handwashing with ash or soil to reduce disease burden compared to washing hands with water only or not washing hands at all. Rather, we suggest continued promotion of using soap to wash hands, as it remains the handwashing agent with evidence of health

impact. Focusing on achieving religious purity and eliciting disgust feelings may be an effective strategy to encourage hand washing with soap. To address convenience and cost, programs should encourage use of low cost options such as soapy water which may be more successful than promoting bar soap.

Does community ownership help or hinder management of a common good? Experimental evidence from Kenya

Clair Null, Mathematica Policy Research

Additional Authors: Vivian Hoffmann; Renaud Lapeyre; Olga Rostapshova

Background: Examples of poorly maintained and dysfunctional public water infrastructure are all too common in developing countries. Investments provided by governments and donors often quickly fall into disrepair when management is delegated to users because of free-riding and coordination failures. We conducted a randomized evaluation of two approaches to improve the sustainability of donated publicly-available water treatment devices, called chlorine dispensers, in rural Kenya. Methods: The chlorine dispenser is a classic common good in that chlorine is rival in consumption yet it is not practical to restrict access to the device. To maintain the device the chlorine must be regularly re-stocked. 104 communities were randomized into a comparison arm or one of four treatment groups created by cross-cutting two aspects of the terms of the donation: whether or not an upfront contribution to the cost of the dispenser was required prior to installation (a participation requirement common in water projects) and whether or not the dispenser was a portable model that could be removed if the community failed to stock it with chlorine refills (this "use-it-or-lose-it" rental offer was in contrast to a permanent model that could be refilled after a lapse in restocking). Communities in the treatment arms were responsible for purchasing chlorine refills. In the comparison communities, permanent dispensers were installed and chlorine refills were provided at no cost. A baseline survey collected data on demographics, water-related behaviors, risk preferences, and willingness to pay for individual bottles of chlorine (a private good). A follow-up survey administered 3 months after dispenser installation included modules on participation in fundraising, perceptions of the dispenser management committee, self-reported use of the dispenser or other chlorination products, and a test for total chlorine residual in the household's stored drinking water. Maintenance of chlorine dispensers was monitored via phone and in-person inspections for the year following installation, during which time data on purchases of refills was also collected directly from the shops where they were stocked. Results: We find no effect of the participation treatment on maintenance or take-up 3 months after installation during the follow-up survey, or on maintenance 5-11 months after installation based on unannounced visits and refill purchase records. The rental treatment led to a 20 percentage point increase in dispenser maintenance relative to permanent dispensers (which were maintained 41% of the time). Providing refills for free increased chlorine availability by 47 percentage points). We estimate that in communities with free refills enough doses were consumed to consistently treat everyone's drinking water, whereas households in the rental treatment consumed only 20% of the recommended doses and households in communities without the rental treatment consumed 30% of the recommended doses. Discussion: Based on willingness to pay for the equivalent private good, we find that there is substantial consumer surplus to be generated by switching to a community-level delivery system (the chlorine dispenser) - 82% of respondents would be willing to purchase a dose of chlorine at the dispenser whereas fewer than 20% would purchase at the market price for the private good. However, because the chlorine dispenser is non-excludable but the chlorine itself is rival, communities struggle to maintain cooperation. The novel rental contract we tested is not appropriate for all infrastructure - if the infrastructure cannot be moved or disabled (or if disabling infrastructure is not politically feasible) then it will not be possible to enforce the rental terms. Additionally, costs of monitoring may be too high for this to be an efficient approach. Indeed, in the case of the particular infrastructure studied for this evaluation, the cost of implementing the threat of removal is not justified by its impact. Visits to rural water sources by program staff to monitor chlorine availability entail significant costs whereas the marginal cost of providing free chlorine refills

during such visits is relatively minor, and has a large positive impact on chlorine use. Still, there may be other types of water infrastructure which are also common goods for which threat of removal contracts could help promote better maintenance, and as mobile technologies improve monitoring costs could fall steeply. In cases where it is feasible to remove infrastructure from communities that do not use it, doing so could improve the efficiency of allocation through two channels: incentivizing maintenance of infrastructure where it is already installed and redistributing it when it is not well maintained.

Meeting the MDGs in Access to Water: Why do some flourish while others lag behind?

Jami Nunez, University of Colorado Boulder

Why have some countries had more success in extending access to water than others? This research addresses three current research questions of interest. First, what factors generally explain progress? With the question of how to achieve universal access looming, given the post-2015 goals, it is a policy priority to know what factors inhibit and facilitate progress towards more access to drinking water. Second, what are the unique factors that explain progress in access to water in rural areas versus urban areas? Urban access has progressed more rapidly than rural access, where breakdown rates and political incentives have stymied progress. This research suggests that the factors that predict progress in rural areas are quite different than those that predict progress in urban areas. Lastly, does official development aid towards water and sanitation relate to progress in access to these public goods? I draw upon multiple data to test these ideas with a cross-sectional approach in order to test factors that fluctuate over time, such as aid and economic growth, and factors that tend to be relatively stable over time, such as institutional settings and water scarcity. These data include data from the World Bank, the Joint Monitoring Programme, the OECD, World Governance Indicators, the Polity data, and water scarcity data from Gassert et al. 2013. I find that access to water in rural areas is a function of political institutions and political stability. Contrary to recent research by Bain et al. 2013, I also find that official development aid directed to water and sanitation forwards progress in rural areas, although I find no effect in urban areas. Progress toward rural water access also seems to be a tradeoff for countries investing in health services, particularly those directed to urban areas. Progress in access to water in urban areas is affected by more economic factors, such as growth, as well as political stability. These findings, although preliminary, suggest that the factors that predict success in urban areas are dissimilar to those of rural areas and that the effect of development aid is more significant for rural progress than for urban progress.

Predictors of latrine ownership among rural households: do determinants of behavior differ among the poorest households? Findings from a meta-analysis of formative research studies.

Kathryn O'Connell, World Bank

Jacqueline Devine ; on behalf of the World Bank Water and Sanitation Program

Introduction: Sanitation coverage has increased over the years and rates of open defecation have declined globally from 31% to 18% in developing countries (JMP, 2013). However, these levels of growth are observed most frequently in the higher income segments with sanitation coverage lagging in households from the two lowest quintiles and most notably in rural areas where unmet need is highest. This study examined determinants for improved sanitation behaviors across countries and the extent to which these predictors may differ among households from the poorest quintiles. Methods and analysis: Cross sectional formative research data was collected between 2008 and 2012 from households in rural areas of Tanzania (N=983), Indonesia (East Java) (N=2,009), and multiple states of India (Bihar [N=3,971], Meghalaya [N=960], and Rajasthan [N=3,301]). A framework, SaniFOAM, guided examination of opportunity, ability and motivation factors theorized to influence

sanitation behaviors. Data were analyzed using SPSS version 22.0. Likert scales measured perceptions and attitudes towards open defecation and latrine ownership. Scaled constructs were developed using standard psychometric analysis to ensure scale reliability and validity. A household wealth index was estimated from asset variables using principal components analysis, and used as a proxy indicator for household economic status by dividing the wealth into quintiles. Multivariate analysis was used to build country-specific models predicting latrine ownership. Results: Preliminary findings show that a number of factors were found to have a positive and significant relationship with latrine ownership. A consistent predictor of latrine ownership was social norms regarding open defecation in Bihar (odds ratio [OR] 1.2, $p < .001$), Tanzania (OR = 1.7, $p < .01$), Rajasthan (OR=2.2, $p < .001$), East Java (OR=3.7, $p < .001$), and Meghalaya (OR=5.7, $p < .01$). Satisfaction with current defecation place was also found to be a predictor of latrine ownership: in Tanzania and Meghalaya (OR=2.5, $p < .001$), East Java (OR=4.4, $p < .001$), Bihar (OR= 6.1, $p < .001$) and Rajasthan (OR=11.5, $p < .05$). For most countries, there was a significant relationship found for social and emotional and drivers, including improved status, privacy and respite from shame and embarrassment of open defecation: Rajasthan (OR=1.6, $p < .001$), Tanzania and Meghalaya (OR=1.7, $p < .001$), and East Java (OR=2.7; $p < .05$). Consistent with JMP findings, household wealth is significantly associated with latrine ownership across all studies; for example, in Rajasthan, respondents from the richest quintile are more than thirty times more likely to have a latrine than those from the poorest quintile (OR=31.0, $p < .001$). Additional findings will be presented on a sub-sample of the respondents to illustrate whether determinants of open defecation and latrine ownership differ for households in the poorest quintiles. Conclusion: Understanding the specific barriers and drivers to improved sanitation among the rural poorest will help improve programmers' ability to design effective behavior change interventions, particularly as the sector moves toward more equity-focused goals in the post-MDG setting.

Intermittent vs. Continuous Water Supply: What benefits do households receive? Evidence from two cities in India

Kyle Onda, UNC Chapel Hill

Additional Authors: Meenu Tewari

All urban water systems in India currently provide intermittent water supply, as opposed to continuous water supply. Intermittent supply can impair water quality, impair access to sufficient quantities of water, and cause users to waste water and to adopt costly coping mechanisms such as storage, treatment, pumping, and collection of water from alternate sources. Investments in continuous water supply improvements in India are often justified by purported benefits including more efficient water use among large-volume water consumers, better access to piped water among poor consumers, and the elimination of the aforementioned coping costs. The study took advantage of natural experiments occurring with continuous water supply in areas of two neighboring cities in Maharashtra, India. A mixed-methods approach was used to evaluate the effects on water demand and coping behaviors of domestic water customers of introducing continuous water supply to an intermittently operated network. A quantitative component evaluated the impact of continuous water supply on water demand by taking advantage of a natural experiment in which continuous water supply was implemented in pilot neighborhoods of a city in which a billing panel dataset was available. A qualitative component evaluated the extent to which continuous water supply was associated with coping behaviors through interviews with a cross-section of households with and without continuous water supply the two cities. Continuous water supply was on average found to increase water demand by 6-8% relative to intermittent water supply. It did not generally lead to more efficient water consumption among higher income groups, although the poorest households did increase their consumption from very low levels. In terms of coping behaviors, consumers generally continued to incur coping costs under the improved service. A substantial minority of consumers did notice the change in service, while many other consumers did not trust that the service improvement would be permanent. Both external storage tanks and storage of water in vessels in the

home remained common under continuous water supply. Water treatment and pumping also persisted to a lesser extent. There was some evidence for the elimination of the use of alternate sources among the poorest households who got access to continuous water supply. As continuous water supply improvements are implemented in more cities throughout India, the water resource implications of increased water demand under continuous water supply without substantial water demand management measures need to be accounted for. As for coping costs, thorough education and outreach efforts may be necessary for the benefits of continuous water supply to consumers to be fully realized, and evaluation of continuous water supply interventions should consider the probability and timing with which household coping behaviors might change.

Environmental exposure to legacy uranium mine wastes, contaminated water, and immune function among Navajo tribe members--DiNEH study

Jennifer Ong, University of New Mexico

Additional Authors: Esther Erdei; Robert Rubin; Curtis Miller; Bernadette Pacheco; Miranda Cajero; Chris Shuey; Johnnye Lewis

Forty percent of watersheds in the western US are contaminated by mine waste and related metals, which are often located on or contiguous to the watersheds of tribal lands, where ~13% of tribal households lack access to regularly monitored public water supplies. This disparity compares with 0.6% for US homes as a whole. The situation is compounded by the fact that tribal populations are more likely to rely on subsistence lifestyles with land- and water-use patterns leading to greater exposures to local contaminants than predicted by US Environmental Protection Agency (USEPA) default parameters. In addition to the unique exposure patterns, tribal populations are characterized by health disparities associated with lower socioeconomic status, comorbidity, and lack of access to healthcare. On Navajo Nation (NN) in particular, mining has left a legacy of >1100 abandoned uranium mines and waste sites. Navajo communities have long been concerned that increased environmental metal exposures, especially to uranium (U), contribute to poor health outcomes among tribe members. Metal exposures may contribute to disease through various pathways, including dust inhalation, radiation exposure, and contaminated building materials, but the pathway of primary concern is through contaminated water consumption. Sampling and testing of 376 unregulated water sources used for drinking, completed during the course of the Diné Network for Environmental Health (DiNEH) project and related projects, revealed that 27.4% of water sources exceeded the USEPA safe drinking water maximum contaminant level (MCL) for at least one metal. 10.1% of wells exceeded the MCL for U while 17.3% of wells contained arsenic above the MCL. Additionally, ~72% of wells were contaminated with bacteria. The complex exposures to metals and microorganisms on NN, particularly through contaminated water consumption, raise concerns about potentially-altered immune system responses in this population. Based on our past work with another tribe (Cheyenne River Sioux) with chronic environmental exposure to mine wastes, which shows immune response alterations related to metal exposures, our research team began immune function studies on a subset of Navajo participants in the DiNEH study (n=268). We aimed to study potential causes of autoimmune disease (AD) as a follow-up to information generated from self-report in a cohort of 1304 participants. Statistical modeling of exposure-related activities and participants' home proximity to abandoned U wastes indicate an association between exposures and self-reported AD. To investigate immune system responses, we determined lymphocyte subpopulations and measured serum cytokines using flow cytometry. Whole blood samples were used to identify T cells (CD3+), T helpers (CD4+), T cytotoxic (CD8+), B cells (CD19+), natural killer (NK) cells, and HLA-DR+ activated immune cells. Pro- and anti-inflammatory cytokines, as well as antinuclear and specific autoantibodies, were measured in serum using enzyme-linked immunosorbent assays (ELISA). Regression modeling indicates that DiNEH participants who reported increased uranium waste exposures had an increased proportion of activated T cells and decreased proportion of B cells and other antigen-presenting cells. Despite the overall decrease in the B-cell population, the proportion of HLA-DR+, or "active," B cells was increased, indicating a

possible T cell-B cell decoupling. Such cellular changes can lead to lower production of protective antibodies against invading pathogens. Alterations in cytokine production indicated a probable increase in TH2-driven immune responses. These findings indicate altered immune response among the participants related to mine waste exposure.

Poor neighborhood hygiene and low water quality investment

Jennifer Orgill

Additional Authors: Marc Jeuland

Poor neighbor hygiene and low water quality investments Jennifer Orgill, Marc Jeuland Recent research has shown that a range of point-of-use water treatment technologies can significantly lower the prevalence of diarrheal disease in low-income countries. However, many of these technologies face puzzlingly low adoption rates, and even lower long-term usage rates. This paper proposes that perhaps one reason for such low adoption and usage is that consumers face a collective action problem in regions with shared water supply, or may feel that they are unable to effectively maintain the quality of existing water supplies. Utilizing survey data from 900 households in Rajasthan, India, this study examines two main questions: First, is perceived risk of poor water quality associated with willingness to pay (WTP) for water quality improvements? We find that households with higher perceived water quality risk are less likely to invest in water treatment technologies. Second, what mechanisms may explain the fact that higher perceived risk is associated with lower probability of investing in water treatment technologies? We find that neighbor cleanliness may be an important factor driving this result. To address the first question, we use data from a perception elicitation experiment. Each respondent was given ten chits, and was asked to divide these into two groups (safe and unsafe) according to the perceived safety of his or her drinking water. For example, eight candies in the safe pile and two in the unsafe pile would correspond to the perception that the household believed there was a 20% chance that they were at risk from unsafe water. We utilize multiple probit regressions to investigate how perceived risk affects the likelihood of treating water at all (e.g. chlorination, boiling, filtration). We find that an increase in household perception of risk is associated with a statistically significant decrease in the probability of treating water. In other words, households are less likely to invest in water treatment when they perceive their water is less safe To address the second question, we use a basic OLS model to explore how perceptions of neighbor and village cleanliness affect perceived risk. We find that increased perceptions of neighbor uncleanness are associated with increased beliefs that drinking water is unsafe, but that perceived village uncleanness is not. This result provides support to the hypothesis that the hygiene of neighbors directly affects whether households invest time and money into water treatment technologies and behaviors. Households that perceive their water to be unclean may not invest in water treatment because they believe that the poor hygiene habits of their neighbors and immediate environment may render their investment and efforts unsuccessful.

Inventory and Water Quality Assessment of Private Sector Drinking Water Kiosks in Port au Prince, Haiti

Molly Patrick, Centers for Disease Control and Prevention

Additional Authors: Maria Steenland; Amber Dismar; Jennifer Murphy; Amy Kahler; Bonnie Mull; Hugues Bien Aime; Joceline Pierre Louis; Jacques Boncy; Vincent Hill; Thomas Handzel

Background: Demographic and Health Survey (DHS) data from 2005 and 2012 indicate a major growth in use of 'bottled water/water purchased from a private company' for drinking water in Port-au-Prince, Haiti (from 25.4% to 49.0% of households). The largest commercial vendors of water are fixed-point 'private kiosks'. The water is

typically centrally treated by a parent 'provider' using an advanced filtration process using reverse osmosis (RO) membranes and additional processes, such as ultraviolet disinfection, prior to distribution via tanker trucks to refill kiosks. The growth of this sector has proven challenging for governmental organizations responsible for regulation. These organizations lacked both a comprehensive list of the names and addresses of the private kiosks in Port-au-Prince and an updated list of the parent 'providers'. Furthermore, neither the quality of the water at the parent production site nor at the point of sale had ever been systematically evaluated. Between June and August of 2013, the U.S. Centers for Disease Control and Prevention (CDC) and the Haitian Ministry of Public Health/Ministère de la Santé Publique et de la Population (MSPP) conducted an inventory of private kiosks in Metropolitan Port-au-Prince to create a database in order to facilitate regulation. A subset of kiosks was also sampled to evaluate key microbiological, chemical and physical water quality parameters. Finally, a sample of the largest providers' treatment sites were visited to document water treatment methods used at production sites, evaluate water quality, and to better understand how water is transported to kiosk vendors.

Methods: Using Open Street Map's basemap in ArcGIS 10.1, each of the six communes was divided into segments of approximately 2km² using road data as boundaries. Teams were given maps of the segments for which they were responsible. The continuous path of travel method was used to conduct the inventory where the teams systematically surveyed all kiosks on both sides of the roads traversable by tanker trucks. Teams were responsible for locating all private kiosks within the segment, completing a short questionnaire at each kiosk including a brief sanitary inspection, and conducting a test for chlorine residual. A water sample was also collected from five kiosks per team per day and tested at the MSPP National Laboratory for total coliforms, *Escherichia coli*, pH, turbidity, and total dissolved solids.

Results: A total of 1,340 kiosks were identified in the six inventoried communes covered. Eighty-four percent (83.7%) of kiosks were reported to have opened within the past three years, and over half (53.3%) reportedly opened within the 12-months prior to the inventory. Sixty-seven different parent 'providers' were recorded; however, four providers delivered water to 80% of the kiosks. Among all kiosks, the layout and equipment were fairly consistent and 90% sold water for 5 Gourdes (\$0.12USD) per gallon. Free chlorine was not detectable in any kiosk water sample (< 0.1mg/L). A total of 767 kiosks were sampled for water quality parameters. The physical-chemical parameters of kiosk water samples were consistent with treated water samples at the provider level and indicated that the water being sold has indeed undergone an advanced filtration process consistent with RO. The microbiological water quality of 90.9% of the water samples from kiosks met World Health Organization (WHO) microbiological standards (<1E. coli/100mL) at the time of the inventory. The majority (73.9%) of the 69 samples that were positive for *E. coli* were in the low risk level as defined by WHO (≤ 10 MPN/100mL). All *E. coli* positive kiosks were resampled during the inventory period, and most (84.0%) were negative when resampled. Thus, the results indicate that fecal contamination is periodically introduced to a small percentage of kiosks, which poses a potential health risk to consumers. More than half (62.5%) of the water samples from kiosks tested positive for total coliforms (34.7% were > 10MPN/100mL).

Conclusions: Rapid growth of the private kiosk sector in metropolitan Port-au-Prince has occurred in the three years since the January 2010 earthquake and cholera outbreak later that same year. At the time of the assessment, the vast majority of the kiosks sampled were microbiologically safe at the point of sale. While longitudinal and household level study is required, the preliminary results of the sanitary inspections and water quality assessment indicate that this sector can potentially contribute to increasing access to safe drinking water among residents of Port au Prince and elsewhere in Haiti. The implementation of standardized operating procedures to minimize contamination risk, as well as regular surveillance of sanitary condition, procedures and water quality is recommended. A survey is also planned to look at quality of kiosk water after transport and storage at the household level.

Why is water quality testing difficult: A comparative analysis of monitoring performance across sub-Saharan Africa

Rachel Peletz, Aquaya

Additional Authors: Emily Kumpel; Mateyo Bonham; Ranjiv Khush

Introduction A significant fraction of the public health burden faced by developing countries is due to waterborne disease. The transmission of microbial pathogens in drinking water, for example, is a major cause of diarrhea, which is responsible for about 10% of the global mortality among children under the age of five (Liu et al, 2012). Consequently, reducing the risk of contamination and treating drinking water are essential public health improvement measures. Water quality information is vital for guiding these management efforts: - it is necessary for identifying unsafe drinking water supplies; - it is necessary for determining resource allocations for risk mitigation and treatment; - it is necessary for verifying risk mitigation and treatment efforts; and - it is necessary for measuring progress towards national and international safe drinking water goals. Water quality information is also important for building public confidence in public water supplies, which is necessary for promoting bill payments, for raising water tariffs, and for financing service improvements. The World Health Organization (WHO) has emphasized the importance of drinking water quality monitoring, including water quality testing and sanitary inspections, for over three decades (WHO 1976). Furthermore, national policies in many developing countries legally mandate routine water quality testing by both water providers and independent surveillance agencies (Steynberg 2002; WHO 2011; Rahman et al. 2011). Due to the burden of disease associated with microbial contamination of drinking water, these guidelines and policies emphasize the importance of microbial water quality testing. Yet, despite its centrality to public health, consistent regulatory requirements, and the presence of supportive institutional frameworks, microbial water quality testing in the developing world remains limited (Rahman et al. 2011, Bain et al. 2012). Why doesn't microbial water quality testing meet regulatory requirements in developing countries? Monitoring for Safe Water (MfSW) is an applied research effort to answer this question in sub-Saharan Africa. **Methods** In the first phase of MfSW, we collected retrospective microbial water quality data from 72 water suppliers and public health agencies covering over 66 million people across 10 African countries. In the second phase, we have selected 26 of these institutions covering over 42 million people in six countries to participate in an ongoing analysis of water quality monitoring programs. To evaluate the constraints that these institutions face, we are now conducting two program activities: 1. providing financial incentives for meeting regulatory and internal testing targets; and 2. documenting the factors that promote or hinder collection of these incentives. **Results** According to the retrospective data that we collected in the first phase of MfSW, almost all institutions (71/72) reported some type of water quality testing and 87.3% (62/71) reported some microbial testing in the past year. However, only 44.8% (30/67) institutions, [54.1% (20/37) of suppliers and 33.3% (10/30) surveillance agencies] met the WHO guidelines for the frequency of microbial tests conducted annually. The most common microbial testing method was membrane filtration (45.8%; 33/72), followed by presence-absence testing (25.0%; 18/72) and most probable number methods (16.7%; 12/72). We also obtained over 40,000 microbial water quality test results from the 72 institutions that we surveyed in phase 1. The majority of this testing data (78.1%) came from water suppliers managing piped distribution networks. Most of the tests met the WHO guidelines for microbiological quality; 96.8% (31,870/32,912) tests had <1 E.coli CFU/100mL, and 79.4% (4,687/5,901) tests had <1 thermotolerant coliform CFU/100mL. In this presentation we will review our analysis of this retrospective testing data: 1. why do levels of water quality monitoring vary between institutions? 2. what does existing data tell us about microbial water quality in sub-Saharan Africa? We will also discuss the progress of institutions engaged in the second phase of MfSW and their ability to collect financial incentives for improved testing.

Impact of a community-led total sanitation (CLTS) intervention on sanitation access, hygiene behavior, and child health in rural Mali: evidence from a cluster randomized controlled trial

Amy Pickering, Stanford University

Additional Authors: Maria Laura Alzua; Habiba Djebbari

Globally 2.5 billion people lack access to an improved sanitation facility; in Mali, only 15% of rural households use improved sanitation (JMP 2014). Community-led total sanitation (CLTS) uses participatory approaches to mobilize communities to build their own toilets, facilitate sustained behavior change, and eliminate open defecation. Although CLTS has been implemented in over 50 countries, there is a lack of rigorous and objective data on its impacts on sanitation and hygiene behavior, and on health outcomes such as diarrhea and child growth. We conducted a two-year cluster-randomized trial to evaluate a CLTS program implemented by the government of Mali with support from UNICEF. The study population included 121 villages from the Koulikoro district of Mali; 60 villages were randomly assigned to receive the CLTS intervention. Follow up surveys (N=4299 households) collected 1.5 years post intervention delivery revealed that CLTS almost doubled access to private latrines (65% vs. 35%) as well as reduced reported open defecation rates by 71% among adult women and men (prevalence ratio [PR]: 0.29, 95% CI 0.16 - 0.53), by 49% among older children ages 5-10 (PR: 0.51, CI: 0.41-0.63), and by 51% among children under five (PR: 0.49, CI: 0.41-0.57). CLTS households were about half as likely to have human feces observed in the courtyard (PR: 0.48, CI: 0.33-0.70) and 11% less likely to have visible animal feces (PR: 0.89, CI: 0.82-0.95). Latrines in the CLTS households were 3 times more likely to have soap present (PR: 3.3, CI: 2.3-4.8) and 5 times more likely to have water present (PR: 5.4, CI: 3.4-8.7). In addition, latrines at CLTS households were more likely to have a cover over the hole of the pit (PR: 2.8, CI: 2.3-3.5), and less likely to have flies observed inside the latrine (PR: 0.80, CI: 0.68-0.94). Women in CLTS villages felt as though they had more privacy when defecating (PR: 1.15, CI: 1.04-1.29) and felt safer defecating at night (PR: 1.12, CI: 1.03-1.22). Among children under five, CLTS did not reduce the prevalence of the case definition of diarrhea (relative risk [RR]: 0.96, CI: 0.80-1.16); however, the risk of loose or watery stool as measured by an image chart was reduced by 24% for those children not exclusively breastfeeding (RR: 0.76, CI: 0.59-0.98). When accounting for baseline height measurements, children under five years old in CLTS villages were taller (+0.16 height-for-age Z-score, CI: 0.0-0.32) and less likely to be stunted (RR: 0.87, CI: 0.75-1.0). Improvements in child weight (+0.09 weight-for-age Z-score, CI: -0.04 -0.21) and a reduction in the proportion of children underweight (RR: 0.86, CI: 0.71-1.04) were observed but were not statistically significant. This study provides evidence that a pure behavioral intervention with no monetary subsidies substantially increased access to sanitation facilities in rural Mali. Latrines were also cleaner and better stocked with handwashing supplies in treatment villages, indicating improved hygiene behavior. The findings also suggest CLTS may have improved child growth through pathways other than preventing diarrhea, such as reducing the subclinical condition of environmental enteropathy via decreased exposure to environmental fecal contamination.

Evaluating the influence of geology on private drinking water quality in Virginia

Kelsey Pieper, Virginia Tech

Additional Authors: Leigh-Anne Krometis

Background: Approximately 10 to 15 percent of households in the United States are reliant on a private drinking water system (i.e. wells, springs and cisterns; system with <15 service connections and serve on average <25 individuals for at least 60 days per year). These systems, by definition, are not regulated by the Environmental Protection Agency (EPA) under the Safe Drinking Water Act, and therefore homeowners are directly responsible for maintaining and monitoring their drinking water quality. As a result, studies have generally observed that between 20 to 50 percent of private systems exceed at least one of the EPA's health-based drinking water standards and the majority of systems do not utilize any type of treatment. In the absence of treatment to correct groundwater quality, geology is often identified as the most important factor in explaining variation in private drinking water quality. In Virginia, there are five highly diverse physiographic regions: Coastal Plains, Piedmont, Blue Ridge, Valley & Ridge, and Appalachian Plateau. Although the general consensus is that private drinking water quality varies based on physiographic regions, there has been minimal effort to statistically link water quality with the underlying geology. Therefore, this present work aims to investigate the spatial

heterogeneity of drinking water quality in private drinking water systems in Virginia to determine the influence of geology. Methods: Samples were collected via an ongoing collaboration with the Virginia Household Water Quality Program (VAHWQP; www.wellwater.vt.edu), a Virginia Cooperative Extension program based at Virginia Tech. VAHWQP provides educational materials related to private drinking water system construction and maintenance, and offers low-cost water quality testing. Between February 2012 and November 2013, over 2,100 homeowners provided samples for analysis. Preliminary Results: Sixty percent of the samples collected during this effort exceeded at least one of the EPA's health-based drinking water standards for municipal systems. Bacterial contamination was the most common contaminant as 46 percent of homes tested positive for total coliforms and 10 percent also tested positive for *E. coli*. Almost one in five homes had corrosion problems that resulted in elevated lead concentrations ($>15\mu\text{g/L}$). When evaluating spatial relationships, preliminary results suggest that private drinking water quality in Virginia varies based on physiographic regions. There were significant differences (Kruskal-Wallis, $p < 0.05$) in lead concentrations based on sample locations. Concentrations were highest in the Piedmont region and lowest in the Coastal Plains, which may be attributed to the pH of the groundwater observed in these regions. Bacterial contamination also varied significantly by region (Kruskal-Wallis, $p < 0.05$) as contamination rates were highest in the Valley & Ridge and lowest in the Blue Ridge. This research will continue to explore variations in water quality based on location and investigate a multivariate approach to understanding the influence of geology. Overall, this work will provide useful information as geology may be a predictive indicator of water quality issues in private systems.

Measuring intervention fidelity to assess implementation gaps in a sanitation intervention component of a randomized controlled trial

Md.Mahbubur Rahman, icddr,b

Additional Authors: AKM Mainuddin; Sania Ashraf; Faruque Hussain; Abu Mohd. Naser; Leanne Unicomb; Peter Winch; Stephen Luby

Introduction: Rollout of sanitation interventions in time-bound large-scale interventions is difficult because it can include multiple stages, ranging from latrine installation to behaviour change communication encouraging hygienic latrine use. Fidelity assessment rapidly identifies gaps between intended and actual implementation and permits adoption of rapid corrective measures. We conducted monthly fidelity assessments for the WASH Benefits trial in rural Bangladesh to track implementation of sanitation interventions and to assess latrine hygienic status and signs of use. The trial enrolled households with pregnant women who were randomized into eight study arms, three of which included sanitation interventions: a) sanitation only arm, b) sanitation plus water and hygiene interventions (combined WASH) arm, and c) sanitation plus water, hygiene and nutrition interventions (combined WASH plus nutrition) arm. The trial used a pre-determined benchmark of 80% hygienic latrines among intervention households; a benchmark shortfall was intended to trigger investigation of underlying reasons. The objective of this analysis is to describe our fidelity assessment findings and to highlight how they can identify the gaps in a sanitation implementation strategy used to direct corrective measures. Methods: We summarized findings of 16 monthly fidelity assessment rounds from November 2012 to February 2014. For the first four monthly fidelity assessments, we randomly selected 12 clusters (the randomization unit consisted of 8 geographically linked households with pregnant women) during each assessment. We randomly selected 24 clusters during each monthly assessment from the fifth fidelity assessment onwards. Using a structured questionnaire, field staff recorded observational findings on household latrine status and signs of latrine use. We considered a latrine as hygienic if it had a functional water seal and there was no observable fecal contamination in the surrounding environment. We calculated the proportion of hygienic latrines during each fidelity assessment. If during any fidelity assessment round we detected less than the predetermined benchmark of 80% hygienic latrines, we instructed the implementation team to explore the reasons for not achieving the benchmark, by conducting informal discussions with latrine recipients, which informed the

corrective measures required. Results: We did not achieve the benchmark for the presence of hygienic latrines in all three sanitation arms during the first three monthly fidelity assessments but achieved it from the fourth month onwards. The proportions of hygienic latrines detected across three sanitation arms in the first and fourth fidelity assessments were 33% (14/42) and 83% (69/83) for sanitation only; 35% (14/40) and 94% (72/77) for combined water, sanitation and hygiene; and 60% (34/57) and 95% (86/91) for combined water, sanitation, hygiene plus nutrition arms. In the sixteenth fidelity assessment, the proportions of hygienic latrines across three sanitation arms were 95% (95/100) in sanitation only; 99% (118/119) in combined water, sanitation and hygiene; and 96% (110/114) in combined water, sanitation, and hygiene plus nutrition arms. The benchmark was not achieved during the first 3 months primarily because many household members continued to use their existing, previously installed unhygienic latrines in addition to using improved intervention latrines. Based on these early findings, the implementation team closed the existing unhygienic latrines during installation of the improved intervention latrine in subsequent clusters. From the fourth fidelity assessment onwards the benchmark was maintained by ensuring limited access to unhygienic latrines and increasing the number of visits by field staff to households to promote hygienic use of latrines. Conclusion: Detection of problems during fidelity measures and timely exploration of reasons for benchmark shortfalls ensured that the WASH Benefits sanitation intervention adhered to the protocol as intended. Simple observation-based surveys can be used to measure fidelity of large-scale sanitation interventions.

Development and Validation of the SaniPath Rapid Assessment Tool: Characterizing a Complex Problem with a Simple Tool

Suraja Raj, Center for Global Safe Water, Emory University

Additional Authors: Katharine Robb; Katharine Roguski; Habib Yakubu; Steven Russell; Susan Davis; Megan Tulloch; Matthew Scruggs; Linda Andrews; Amir Mokhtari; Stephen Beaulieu; Joseph Ampofo; Amy Kirby; Kelly Baker; Clair Null; Christine Moe

The SaniPath Rapid Assessment Tool is a rapid environmental risk assessment tool for low-resource urban settings; this presentation details the development and validation of this tool. Rapid urbanization has led to a growing sanitation crisis in urban areas of low-resource countries. However, there are little data to inform strategies to mitigate risks of exposure to fecal contamination. The Center for Global Safe Water at Emory University used the lessons learned from an in-depth, 2-year, investigation in Accra, Ghana (Phase 1 of the SaniPath Study) to develop the SaniPath Rapid Assessment Tool. The tool is a simplified, yet informative, means of characterizing the risk of exposure to feces from multiple transmission routes in the public sphere in order to inform advocacy, prioritize investments, and respond to complex urban sanitation needs. The tool provides a standardized methodology with a customizable format that guides the user through a rapid 4-6 week assessment that includes both behavioral and environmental microbiology components. The behavioral survey can be used in households, schools, or community groups and assesses the frequency of behaviors of children and adults that bring them into contact with fecal contamination. Simple environmental microbiology methods, using membrane filtration or the IDEXX Quant-Tray®/2000 method, are employed to quantify the concentration of *E. coli* associated with samples from various exposure pathways. Pathways of exposure include contact with surface waters, contact with public latrine surfaces, ingestion of raw produce, contact with drains, and ingestion of municipal drinking or bathing water. The environmental microbiology data are used along with average intake volumes to determine the dose of fecal contamination (concentration of *E. coli*) ingested during one exposure event. Intake volumes are pre-set in the tool and are derived from literature review and SaniPath Phase 1 data. Relative risk is defined as the product of the dose of fecal contamination per event and the frequency of exposure events. The tool runs off of a flash drive, and data are entered directly into the tool's software. Relative risk plots are automatically generated for each relevant exposure pathway using the data entered by the user. The resulting risk plots allow users to understand what components (frequency of exposure vs.

magnitude of contamination) and pathways contribute the most to the risk of exposure to fecal contamination in different neighborhoods. In order to test the tool's validity, it was piloted in the same four neighborhoods in Accra, Ghana as the in-depth SaniPath Phase 1 study. To test the tool's applicability to diverse urban contexts, it was piloted in two neighborhoods in Vellore, India. In Accra, 432 behavioral surveys were administered and 301 environmental samples were collected. In Vellore, 216 behavioral surveys were administered and 104 environmental samples were collected. All the environmental samples were processed via membrane filtration and incubated on m-ColiBlue24® broth to quantify the concentration of E. coli. Data collected from Phase 1 behavioral surveys and environmental microbiology in the Shiabu neighborhood of Accra were analyzed using the same risk plot methodology that was developed for the rapid assessment tool. There were sufficient comparable data from Phase 1 and the rapid assessment tool to allow for the direct comparison of three pathways: ingestion of raw produce, ingestion of ocean water, and contact with public latrines. Despite differences in sample size, laboratory dilution factors, and exposure frequency categories, the two studies produced the same ranking of the relative risk of the exposure pathways. Ingestion of raw produce posed the highest relative risk when examining the risk plots from both Phase 1 and the rapid assessment tool. This was followed by accidental ingestion of ocean water from swimming or wading and public latrine contact, respectively. The estimated risk of E. coli ingestion from raw produce in adults in Shiabu ranged from 3.5×10^5 CFU/month in Phase 1 to 5.7×10^5 CFU/month in Phase 1.5, and the estimated risk from ocean water ranged from 1.4×10^3 CFU/month in Phase 1 to 1.3×10^2 CFU/month in Phase 1.5. Results from the pilot in Accra were translated to improvements in survey tools and protocols, as well as software usability. An improved version of the tool was piloted in Vellore, India in March 2014. These data will be used to determine how applicable the tool is to different cultural and geographical contexts as well as how the methodology may have influenced data quality. Over the next year, the SaniPath Rapid Assessment Tool will be implemented in new urban settings. Through continued refinement and application of this tool, we aim to enable evidenced-based sanitation investments and policies for low-resource urban settings.

Achieving Increased Sustainability in Rainwater Harvest Projects in Rural Schools in the Southern Rift Valley of Kenya through regular Monitoring and Action Plans

Mark Reimers, Waterlines Santa Fe, NM USA

Additional Authors: Diane Reimers

Sustainability For too long water resource development has focused on the completion of projects without providing enough attention to the long-term sustainability of the work in the developing country. This is changing. The key to change is a commitment to monitor with our partners the activity over a period of years to measure success, identify deficiencies and develop action plans to resolve problems and improve performance. **Background** At many rural schools there is no improved water. Primary school children bring their drinking water from home in a small plastic container. Additional water comes from nearby open ponds, springs and rivers. (The cost is prohibitive for a drilled well in this area in most cases.) **Current Situation** Over the last 14 years, WATERLINES, a small non-profit organization located in Santa Fe, NM, USA, has assisted over 450 schools with a rainwater harvest system. Classrooms at the schools typically have metal roofs for rainwater collection. What is needed is a good gutter system to deliver water to a large storage tank (33,000-50,000 liters). Total cost for the holding tank and gutter system usually runs between \$2,700 and \$3600. The construction is on a cost sharing basis: schools 25% and WATERLINES 75%. **Preliminary Monitoring and Evaluation** For several years, we, at WATERLINES had noticed deficiencies in the established rainwater harvest systems. 1. On the question of the rainwater system as a whole: The schools reported that the basic construction of storage tanks was satisfactory and functioning as intended; however, 2. On the questions related to water collection and use: We found the tanks did not fill as frequently or completely as expected. Most Schools experienced periodic water shortages. We often found a major need to improve the length and quality of gutters. 3. Schools generally have done very

limited maintenance or improvements to the rainwater harvesting since original construction. 4. Very little capital investment by the Kenyan government is occurring at the public primary schools. 5. The question of rainwater quality is a continual source of discussion. The cultural norm is that rainwater is good for drinking without any water purification treatment. It is clearly much improved over most of the traditional pond, spring and river sources. Monitoring and Action Plans In 2012, we at WATERLINES made the decision that our entire program for 2013 would be focused on monitoring (revisiting and evaluating previous projects) and action plans (taking steps to resolve identified problems) at schools with existing rainwater harvest systems. We developed a monitoring questionnaire to be used at the schools by our Kenyan facilitators and the school representatives to evaluate performance and identify problems. In improvement agreements between WATERLINES and the school community, WATERLINES offered to share 50% of the costs up to \$200 US to make necessary improvements. We focused on schools that have had their system in place for five years or longer. WATERLINES completed monitoring reviews and action plans on over 100 schools by the end of 2013. In 2014, WATERLINES plans to complete reviews and action plans on another 48 schools. Observations from Monitoring and Action Plan Implementation 1. Strong support and encouragement by local facilitators is necessary to identify problems, develop budgets, and insure that improvements are carried through to completion. 2 Artisans need training to properly install an effective gutter system which entails--proper materials for gutters, proper placement on the roofs, improved connections and delivery lines to the storage tanks. 3. The quantity of water collected can be significantly increased at a moderate cost. (less than 10% of original project cost.) 4. Schools will do periodic tank cleaning and practice diversion of the first rainfall (first flush) as part of overall improvement of rainwater harvesting program. 5. Water purification treatment is growing in acceptance, but it is till not commonly practices. 6. Schools can be encouraged to improvement maintenance and make improvements in rainwear harvesting by cost sharing. Way Forward The Rainwater Harvesting Community (implementing NGO's, international government AID organizations, Kenyan governmental entities, schools, and parents) should be prepared to do the the following: 1. To provide initial and ongoing capacity building training, 2. To facilitate training for masonry artisans in tank construction and sheet metal and carpentry artisans in installation of good quality rainwater collection gutters 3. To provide adequate budgets for both tank construction and gutter fabrication and installation, 4. To take steps for post implementation monitoring. 5. To advocate in School Districts, Counties, and Kenyan central government for increased provision and funding of safe water in schools.

Current regulations on microbiological performance of Household Water Treatment Systems: Scientific gaps and impact on consumer health

Nirmala Ronnie, Unilever R&D

Additional Authors: Nimish Shah

Household water treatment is increasingly being recognized and practiced as an option in developing countries where water supply through public distribution systems may not be safe or available. Despite this widespread use, many countries currently do not have specific regulations for HWTS, a recent survey of mostly developing countries found that less than half of the responding countries regulate HWTS devices used or sold in their country (WHO 2012). In countries, where standards do exist these may be hazard-based and/or inadequate in preventing disease. Further, many countries have adopted the standards applicable for the drinking water civic supply to HWTS, which mostly address only bacteria as organisms of concern in the treated water. These standards do not consider other classes of pathogens like viruses or protozoa, which are of equal public health concern in drinking water and account for a significant burden of waterborne diseases. Since reductions in indicator bacteria or limiting total bacterial count may have little or no relevance to pathogens of public health significance, extending such an approach to HWTS may not yield the desired public health gains. There are also examples of countries where the microbial log-reduction targets are not based on strong scientific rationale and therefore may not contribute to prevention of disease. The WHO has proposed a robust risk-based approach

employing Quantitative Microbial Risk Assessment (QMRA) to derive standards (WHO 2011), and three- tiered approach and within that the microbiological criteria proposed have limitations in terms of their applicability in a household context and implementation in relation to commercially sold devices. Overall, there appears to be lack of consensus HWTS technology performance requirements and how these are determined. It is critical to develop consensus on approaches to determine microbiological criteria and testing methods internationally and within countries to achieve harmonization and avoid confusion among various stakeholders. This paper presents a review of existing country regulations and guide standards for HWTS. It highlights the scientific limitations of some of these standards and their consequent impact on consumers and public health. It discusses the complexities around implementation of tiered -approach under country regulations, including those related to consumer communication and product labeling. Finally it proposes adoption of a relevant risk-based approach to derive performance standard for commercially sold HWTS based on local evidence to materialize consumer health gains.

Drivers of water insecurity for urban households in Tanzania: water supply, quality, and access to piped water

Olga Rostapshova, Social Impact

Additional Authors: Danae Roumis; Jeff Alwang

In urban Tanzania, piped water networks are limited and water supply is irregular. In response, the US Millennium Challenge Corporation and the Government of Tanzania are implementing a water sector infrastructure project in two urban centers: Dar es Salaam and Morogoro, aimed to improve water supply and quality. Previous literature has documented that household-level water security is affected by access to distribution systems, adequacy and reliability of supply, water quality, and seasonal variability. However, the effects of large-scale infrastructure investments on urban households' water security is not well documented. In this paper, we characterize water use and water insecurity among households in the urban areas prior to the implementation of the planned interventions. Examining pathways through which the program may reduce water insecurity, we analyze the relationship between water supply disruptions and water consumption, expenditures, and time spent hauling water. A rich set of data was assembled as part of an impact evaluation baseline in 2013, using in-depth household surveys and follow-up phone calls, as well as through qualitative interviews, both in Dar es Salaam and Morogoro. Measured household characteristics included connections to the public distribution network, supply disruptions, reports of severe water shocks, perceptions of seasonal rationing and water supply adequacy, as well as water quality; outcome data was collected on water consumption, expenditures, and time spent hauling. Analysis accounted for the two-stage cluster sampling design and results represent population-level estimates. Urban households in Tanzania experience substantial water insecurity, with the poorest households disproportionately affected. Overall, 14% and 54% of Dar es Salaam and Morogoro residents, respectively, have public distribution network connection taps on premises. Access increases monotonically with wealth: in Dar es Salaam only 3% of the bottom socioeconomic quintile is connected to a public network compared to 24% for the top fifth; in Morogoro the bottom and top fifths are connected at rates of 31% and 70%, respectively. Water shortages are common: half of households connected to the distribution system reported a water shortage in the past seven days (49% in Dar, 52% in Morogoro); with 4-5 days of access per week, and highly irregular water supply. As a result, households use multiple water sources, with source varying with household use. 25% of households reported a severe water shock in the past 2 years; a substantial portion of Dar es Salaam (19%) and Morogoro (30%) residents were concerned about the adequacy of water supply in the past 30 days. About one quarter of water samples from household taps tested positive for fecal coliform contamination; the quality of community tap sources was far lower and varied more, with 35% and 52% of sources contaminated in Dar and Morogoro, respectively. In response to increased availability of water through the network, households with access to a tap on premises considerably increase consumption, providing further evidence of insufficient water supply and the benefits of planned intervention.

Water expenditures patterns remained relatively consistent: in both cities, price elasticities are relatively low, as expected given the vital nature of water, with some seasonal effects. Wealthier households spent more on water. Per-capita water consumption was inversely related to household size in both seasons; the presence of children in the household lowered per-capita water consumption by 20%. Urban households in Tanzania also spend substantial time collecting/hauling water. In the dry season, water availability through improved sources is lower and hauling times are significantly longer, while time spent hauling for those who primarily utilize unprotected sources are relatively unaffected by seasonal water shortages. Qualitative data supports the quantitative findings; residential water users reported challenges associated with maintaining water supply, including inconvenient rationing schedules (e.g., water available only at night), the need to obtain water from secondary sources, and price mark-ups by vendors during shortages, despite lower quality of water (from non-piped sources). Faulty infrastructure, seasonality, population growth are oft-cited reasons for the persistent lack of adequate water supply in these urban contexts. Ultimately, water availability for households depends on the distance the household is willing and able to travel, willingness and ability to pay, time of collection, water volume, use, and quality. Households in Dar es Salaam and Morogoro experience marked water insecurity, which affects consumption, expenditures, and time spent collecting water. Investments in water supply infrastructure are expected to ameliorate these circumstances, and effect positive impacts on household wellbeing.

Determinants of water use among urban households in Tanzania: water source access, use, and treatment

Olga Rostapshova, Social Impact

Additional Authors: Danae Roumis; Jeff Alwang

To date, efforts to evaluate safe water interventions in the developing world have emphasized smaller-scale programs in rural settings. Notably missing from the literature are evaluations of large urban-focused water projects, typically reaching many more beneficiaries and greater access disparity; and must take into account the continuity of access to water and the multiplicity of sources used by the households. Access to water is often continuous in urban areas, as numerous sources are available; water availability and access to piped water are constrained by water system capacity and access within a system can vary, affecting the source choice and water quality for each household. This study examines the roles of context and household choice in relationship to water infrastructure access in urban areas of Tanzania. We utilize data from an impact evaluation of Millennium Challenge Corporation's large-scale program to improve water infrastructure in two urban areas in Tanzania: Dar es Salaam and Morogoro. To better understand the impact of improved water supply and quality, we study mechanisms driving households' water consumption decisions. Using baseline household and water source data, we examine household water use choices, focusing on access, source selection and treatment. Half of Morogoro and 13% of Dar es Salaam residents use a tap on premises as the primary water source, yet 22% of those with a tap do not: while piped water from the public network is viewed as the preferred source for drinking water, it is often unreliable due to shortages, network disrepair, and seasonal effects. Non-piped water sources (e.g., boreholes, wells, springs, surface) are lower-quality sources; better-educated households and those from the upper socioeconomic strata are much less likely to rely on non-piped water. Households utilize multiple sources simultaneously, using water from different sources for different purposes: "clean" (non-saline) water is used for consumption, lower quality water (i.e., from boreholes) is used for household activities (washing or cleaning). In Morogoro, tap on premises is most common for all water uses; in Dar es Salaam, other piped sources are the most frequently used for drinking, and non-tap sources are most frequently used for all other activities (>50%). We construct probit and logit models to evaluate the determinants of household access to piped water on premises, choice of main drinking water source, and water treatment decisions. Our results suggest that the use of piped water sources is constrained by supply factors: the probability of piped water use is highly linked to neighborhood characteristics, suggesting large access spillovers. Modeling the household's

selection of main water source (i.e., of drinking water) as a multinomial process, we find the use of own piped water is significantly correlated with household socioeconomic status (those in the upper quintile are almost 18 percent less likely than the lowest quintile to obtain water from a neighbor's tap, a kiosk or another tapped source). Access to electricity, larger dwellings, high education, and female-headed households are more likely to use tap water as the main source. We do not find evidence of substitution of piped water for treatment of non-piped water; instead, households with piped water access are more likely to treat water before drinking than those using non-piped water, although many respondents do not treat their water at all (76% report boiling water from own tap, compared to 30% of those using non-tap sources for drinking water). Higher education, higher socioeconomic status, and female adults are positively associated with treatment probability. We use a two-stage probit model to examine treatment; the first stage specifies household water source as a function of demographics and access to piped water; in second stage, treatment is a function of the endogenous household water source and the other variables. The results show the source of water is significant: even accounting for source endogeneity, households using any piped water (10 pp) or with piped access in household (33pp) are more likely to treat their water, implying a lack of confidence in the sanitary state of piped drinking water, despite better perceptions of quality than other sources. Factors affecting the choice of water source may also contribute to the decision to treat drinking water. We find that while most urban households have some access to the piped network, whether directly or indirectly, system capacity constraints maintain spatial variability in access to water. The intervention is poised to reduce these constraints, and reallocate the households' water consumption portfolio. Impacts on disadvantaged beneficiaries are especially important, who disproportionately bear the burden of lack of piped water on premises and must rely on lower-quality, difficult to access water sources outside the home to meet their water needs.

Impacts of a container-based, household toilet and waste collection service in Cap Haitien, Haiti

Kory Russel, Stanford University

Additional Authors: Sebastien Tilmans; Jennifer Davis

This study evaluates the feasibility and acceptability of providing household-level, container-based sanitation (CBS) services in dense urban settings in Cap Haitien, Haiti. An increasing number of poor residents are living in dense, informal settlements where traditional approaches to excreta management are infeasible due to space limitations, land tenure disputes and price concerns. In recent years several groups have introduced CBS systems that not only reduce the up-front costs to households (HH) but also overcome these feasibility issues. CBS systems show potential as an alternative in poor urban areas. However, a number of questions surrounding CBS systems must be addressed. Considerable stigma is associated with "bucket" systems, which most closely resemble CBS services, and which were prevalent in developing countries during the colonial era. Over time bucket systems were abandoned and prohibited due to a lack of social acceptability and health concerns. Likewise, previous research has shown that pride, prestige and convenience are key drivers of sanitation investment. For CBS services to be seen as a viable option for sanitation planning, public and user acceptance and safety are critical. We attempt to answer two questions: (1) Will users of CBS services change HH sanitation practices, perceptions, satisfaction and demand for CBS services as compared with users of other available options (latrines, public toilets and open defecation)? (2) Will the introduction of container-based toilets increase levels of fecal indicator bacteria (FIB) in a household's stored drinking water as compared with stored drinking water in households using other available options? In collaboration with the Haiti-based NGO SOIL, we designed and tested an in-home, CBS service. The toilet consisted of a specially designed housing that separated urine and feces into two distinctive containers. The user applied a dry cover material (crushed peanut shells) to the feces in the container after every use. Full feces containers were sealed, removed and replaced with a sanitized container two times per week by a collector. The full containers were transported to a government approved and SOIL operated waste processing facility outside the city. Study site, sample frame, and data

collection: The study site consisted of two communities: the informal settlement of Shada and the formal settlement of Avyacion. 125 households in 30 randomly selected clusters within the neighborhood of Shada made up the treatment cohort; 117 households in Shada (control 1) and 132 households in Avyacion (control 2) were randomly selected and enrolled as controls. A baseline survey was conducted in October of 2012, and an endline survey was conducted three months later, in February of 2013. Treatment households were offered a three-month free trial of the CBS service as part of the study, but understood at the end of the study there would be a monthly fee to continue the service. Data Analysis and Results: Use: Prior to the study, approximately 20% of residents in Shada reported using latrines. Approximately 50% of residents reported using public toilets when defecating by day, but only 30% did so at night. After participating in the study however, 80% of residents with the CBS service reported using it both during the day and at night. These reported usage data are corroborated by recorded weights of excreta collected from all CBS service HHs. User satisfaction: At baseline, 29% of treatment HHs reported being "generally" or "very" satisfied with their sanitation situation. During the endline study, this percentage increased to 87%. The share of satisfied HHs in the control cohorts did not change significantly. Attitudes (Pride, Safety): At baseline, 23% of treatment HHs reported being proud of their sanitation situation, which increased to 93% at endline. Similarly, at baseline 30% of participants reported feeling safe from physical or sexual assault when using their primary sanitation option, which increased to 91% at endline. There was no significant change in the control cohorts. Demand: As of the beginning of 2014, SOIL has expanded the service to over 250 paying clients. Water quality: Increased risk of fecal contamination in the home environment is a potential concern with HH excreta collection. We thus tested stored drinking water for the fecal indicator bacteria (FIB) *E. coli* in a subset of homes from all three cohorts during the baseline and endline surveys. Treatment cohort drinking water samples with greater than 10 MPN/100mL decreased by 20% between baseline and endline. Similarly, the control cohort's percentages of samples greater than 10 MPN/100mL fell by 24% and 5%. These results suggest that there was no increase in FIB contamination in treatment HHs relative to control HHs. Overall, our findings suggest that CBS services may be a promising option in settings where traditional choices are considered infeasible.

Results of a 10-Year Sustainability Study using a Mixed Methods Approach

Raquel Sabogal, Centers for Disease Control & Prevention

Additional Authors: Richard Gelting; Kristin Delea; Arlyn Gleaton

The Centers for Disease Control and Prevention (CDC), in collaboration with the American Red Cross (ARC), completed a 10-year sustainability evaluation on a post-disaster water, sanitation and hygiene promotion (WASH) program in Central America. The ARC provided WASH interventions to 110 communities in four Central American countries after Hurricane Mitch in 1998. One objective of the ARC program was to provide sustainable WASH interventions to all of these communities. The ARC completed the project in 2002 after the construction of water and sanitation infrastructure. To evaluate this program, CDC/ARC conducted a mixed-method sustainability evaluation in eight of these communities. The results of this evaluation identify some of the long-term sustainability issues with ARC's WASH program. CDC/ARC completed interim sustainability evaluations in eight communities in February/March of 2002, 2006, 2009 and 2012. Communities are located in El Salvador, Guatemala, Honduras and Nicaragua. We measured sustainability over a 10-year time period by calculating four WASH indicators using household survey data. In 2012, we included seven additional communities to conduct 30 face-to-face key informant interviews in 15 communities, two per community. Key informant interviews provided community residents' thoughts and opinions on the ARC WASH services. We wanted to understand the financial, social, technical, and environmental factors that can influence the sustainability of the program. Fifteen infrastructure surveys and 15 community surveys complimented the household data collected. Indicator results demonstrated that initially the project goals were met; however, there was a gradual decline over time. There were statistically significant reductions in access to water and the percent of population using a hygienic

sanitation facility. We will present detailed results for all indicators. In 2011, the Red Cross National Societies corrected some of the sustainability issues identified by the CDC interim evaluations. Key informant interviews identified seven factors that influenced sustainability: 1] unequal distribution of resources; 2] lack of resident responsibility; 3] insufficient funds from collected water fees; 4] continued vulnerability to natural events; 5] absence of leadership; 6] lack of ownership by residents, and 7] population changes. We group our results from this final evaluation into three sustainability themes: 1) economic viability, 2) social acceptability and 3) technical appropriateness. Improvements in these areas over time could help to ensure a growing community's needs with regard to water service and sanitation solutions that last. A successful sustainability program includes long-term funding and planning. A program should have a plan on how to build local networks to provide technical assistance after a community is re-established post disaster. Such networks can include local government, water utilities, local health clinics, and in-country non-governmental organizations (NGO's). The local government and/or water utility are often good resources for providing technical and potential financial support for a community to maintain water infrastructure. Maintaining water infrastructure can reduce a community's vulnerability to seasonal weather events, a community concern identified in our evaluation. Local health clinics or in-country NGO's can be good resources for promoting continued hygiene programs at the individual and community level. This includes proper management or maintenance of household sanitation facilities and solid waste management for the community. These criteria apply to any community that receives post-disaster interventions. Our results show that even when an organization designs a program to be sustainable and builds a program with community participation, communities will need continuing support once the initial program is completed. It takes several years for communities to rebuild after a major disaster. To ensure better program success, a sustainability program should think about the future at the start of the project and include long-term planning, funding and the building of local networks to meet that objective. The ARC has incorporated this approach into their WASH programming to provide more sustainable disaster response programs.

The Landscape of Sanitation-Related Psychosocial Stress: a grounded theory study of women in urban, rural, and indigenous communities in Odisha, India

Krushna Sahoo, Asian Institute of Public Health

Additional Authors: Kristyna Hulland; Bismita Biswa; Bethany Caruso; Bhabani Das; Matthew Freeman; Nimai Nanda; Panaki Panigrahi; R Satapthy; Rojalin Swain; Robert Dreibelbis

Background: Susceptibility to infection associated with poor sanitation access and compromised personal hygiene behaviors among women is well documented. However, the social and psychological impact of limited sanitation access, particularly among women, and associated health risks are not well understood. The state of Odisha lags far behind much of India in terms of access to sanitation, over 88% of the rural population lacks access to water and sanitation facilities, and open defecation and urination is commonly practiced in low-resource settings. Our study aims to develop a conceptual model of sanitation and sanitation-related psychosocial stress (SRPS) among women of reproductive age in three specific infrastructure-restricted settings: rural, urban slum, and rural indigenous (tribal) communities in Odisha, India. Methods: We used a grounded theory approach to examine sanitation related psychosocial stress in women. In total, 12 focus group discussions (FGDs) and 56 in-depth interviews (IDIs) were conducted in four life-stage groups (unmarried adolescent girls, women married within the past two years, women who were currently pregnant, and adult women age 35-45) in each of our three study sites. We selected two different urban settlement types: one informal, densely populated slum with access to a privately-operated communal latrine and two planned settlements with constrained access to government-supplied water and electricity. Rural and tribal communities included in our studies were primarily agricultural. FGDs and IDIs were equally distributed among sites and life stage groups. Data collection explored topics such as general sources of stress in the household, sanitation practices, and

challenges associated with sanitation related activities (i.e. defecation, urination, menstruation, post-defecation cleaning, and bathing), and associated psychological and social impacts. Interview guides were iteratively adapted in light of emerging findings during the data collection process. Interviews were transcribed in the local language (Odiya) and translated into English for coding and analysis. Translated interviews were coded in MAXQDA. A subset of interviews were double coded by the researchers and inter-coder reliability was assessed to ensure consistent coding. During data collection, coding and analysis, researchers wrote detailed memos to discuss emergent themes and interrelationships of SRPS factors. Findings: Women in Odisha encounter a range of challenges related to sanitation behaviors including social, sexual, environmental, supernatural and health-related stresses. Across all sites, women discussed shame at being seen by others, physical discomfort during the rainy season, and fears associated with night and darkness. There was considerable variability in psychosocial stressors among the three geo-social settings of our study. Data from urban slum communities revealed that stress and fears about sexual violence (i.e: peeping, revealing, and sexual assault) encountered during sanitation-related activities was higher than in other settings. Stress related to sexual violence circumscribed other key determinants of SRPS that were unique to urban settings such as lack of privacy, crowding, and limited space for open defecation. Respondents in rural areas primarily identified social and normative stressors associated with sanitation activities, including: shame at being seen by others - particularly males - during defecation-related behaviors and the considerations of family and individual reputation. Restrictions on the social role and social visibility of women in rural areas determined when women are allowed to leave the home, how they are supposed to bathe, and with whom they can be seen. Women in tribal areas identified similar challenges as our rural sample, but were markedly more comfortable with existing defecation-related behaviors and were less likely to position these challenges as acute stressors. Indigenous respondents described fewer social restrictions on women and had fewer concerns about privacy than any of our other respondent groups, despite the fact that indigenous communities are widely viewed as the most resource-constrained population within our sample. In response to the range of factors influencing SRPS, many women engaged in maladaptive behaviors such as withholding food or liquid, defecation and urination and in some cases limiting their use of water for personal hygiene. Conclusion: Beyond the walls of a latrine, sanitation practices are embedded within social, environmental, and resource landscapes that have specific consequences on the psychosocial impacts of sanitation-related practices. Understanding sanitation-related psychosocial stress and the unique determinants and consequences of this stress for population groups within India is essential. Our ongoing research activities are focusing on quantifying the severity and frequency of SRPS factors.

Attributes exhibited in business models for scaling-up water and sanitation services

Caroline Saul, eawag

Additional Authors: Heiko Gebauer

The paradox that "pilots never fail, but also never scale" unfortunately expresses the reality of water and sanitation services in most low-income countries. Organizations successfully implement individual water and sanitation pilot projects; however, they do not earn the expected social and economic returns that are expected from further investment. To explore the challenges in the scaling-up process, we rely on management theories and apply business model thinking. A business model is an organization's underlying logic and strategy for creating and capturing value, be it economic or social. Our research explores how water and sanitation business models can become financially sustainable in a way that it is possible to finance the scale-up the services they provide. We applied a purposeful sampling approach to gain access to water and sanitation providers in low-income countries. We identified 89 case leads of organizations and evaluated them according to the availability, reliability and validity of primary and secondary data. Altogether, we collected and analyzed data on 19 organizations, all of which have successful pilot projects that provide water and sanitation services. The organizations were successful, because as they grew, they created an alignment among the business model

dimensions of Value Capture, Value Creation, Customer Identification, and Customer Engagement. Value Capture begins to resemble that of traditional business investments, which replace the initial philanthropic and governmental grants. The importance of financial goals grows in prominence relative to social goals in the business models. Organizations approach Value Creation in a way that internalizes value chain activities such as setting-up their own design, manufacturing, and assembly centers. For example, organizations invest in setting-up own manufacturing capacities for toilets or water filters, instead of relying on partners. For the Value Creation, it also became evident that organizations externalize marketing, distribution, and sales activities. Some organizations use franchising models for selling water and sanitation services, instead of employing their own sales staff. To expand Customer Engagement, organizations depart from standardized and often cost-efficient designs for water and sanitation services. They broaden their offerings to reach middle-income customers. Products and services become more aspirational and quality-driven. With regard to Customer Identification, organizations deliberately move beyond the single revenue stream from the pilot phase to multiple revenue streams. Sanitation business not only rely on financial support from donors, but also revenues from selling or renting toilets and/or revenues from selling end-products from the treatment processes such as compost, biogas and so on. Water businesses create revenues from carbon credits, selling water or water filters, as well as donors for covering investment costs. Balancing these multiple revenue streams is a key challenge in financing the scaling-up process. Essentially, business models must evolve from the pilot phase of a water or sanitation venture as they expand their service or customer base. This research represents an initial effort to identify themes that characterize successful water and sanitation projects. These themes can inform decision making a business model design for organizations that are leaving the pilot phase. *can be modified to focus more heavily on either water or sanitation examples

Impact of ""The Great WASH Yatra"" campaign on behavioral determinants and on the intention to wash hands with soap: Findings from the visitors' survey

Elisabeth Seimetz, Eawag

Additional Authors: Sonia Karuthedath; Hans-Joachim Mosler

Despite being both preventable and treatable, diarrhea remains the second leading cause of child mortality in the world. Washing hands with soap at critical moments, especially after contact with feces and before handling food, can effectively prevent the transmission of diarrheal pathogens. Key goals of "The Great WASH Yatra" campaign were to promote life-saving handwashing behavior in rural India, harnessing the positive power of fun, games, and super stars. To assess the immediate impact of the campaign, visitors to "The Great WASH Yatra" carnival were interviewed before and after their visit. The surveys were based on the Risk, Attitudes, Norms, Abilities and Self-regulation (RANAS) model of behavior change in order to explore possible impacts of a campaign visit on behavioral determinants and their influence on the intention to always wash hands with soap after using the toilet. A total sample of 693 matching pre- and post-interviews were conducted. When comparing scores from pre- and post-interviews, a significant increase was observed in the indicated intention to always wash hands with soap after using the toilet. Likewise, the majority of the behavioral determinants were significantly higher after the respondents' visit to the campaign. However, all effect sizes were small, except for the increase in health knowledge with a medium effect size. When entering the differences in the behavioral determinants into a multiple regression analysis, they accounted for approximately 59% of the total variance in changes in the intention. Significant predictors that emerged were perceived vulnerability to diarrhea, thinking that washing hands with soap is worthwhile, important people's thinking one should wash hands with soap, the ability to always wash hands with soap, and personal commitment to the behavior. About half of the interviewed adult visitors indicated having played campaign games themselves. When comparing players to non-players, no differences were found as to changes in the intention to wash hands with soap. However, respondents who had actively played a game gave significantly more correct answers regarding the

causes of diarrhea and how the disease can be prevented. No differences were found as to changes in other behavioral determinants. Even when controlling for the duration of the respondents' visit, no differences could be found. Only for visitors who participated in the soap lab, an activity where participants could try out the effectiveness of handwashing with soap to remove germs, indirect associations between participation in the lab, changes in behavioral determinants and changes in the intention to always wash hands were found. The results show a limited impact of "The Great WASH Yatra" campaign on visitors' indicated intention to always wash hands with soap as well as on the RANAS behavioral determinants. Considering that there were almost no differences between players and non-players as to changes in the intention and in the behavioral determinants, no additional impact of an active participation in campaign games was found.

Addressing the paradox through small doable actions to improve domestic water management: high water and sanitation access and high diarrheal death in Southwest Bangladesh

Abu Hena Mustafa Kamal Sikder, FHI360

Additional Authors: Julia Rosenbaum; Jonathan Annis ; Orlando Hernandez

Addressing the paradox through small doable actions to improve domestic water management: high water and sanitation access and high diarrheal death in Southwest Bangladesh Globally, diarrhea is the second major causes of child mortality. In Bangladesh, it is also a major cause of child death and DALYs (Disability Adjusted Life Year) . Unsafe drinking water, inadequate availability of water for hygiene, and lack of access to sanitation together contribute to about 88% of deaths from diarrheal diseases . WHO estimates about 24,000 deaths of under 14 years olds (approximately 1 in every 2,000 children) in Bangladesh is due to diarrheal disease, attributable to 11% of the total mortality of this age cohort. In contrast to this alarming situation, the country achieved commendable success in ensuring safe water and sanitation. JMP data from 2012 shows 85% access to improved water sources and 85% to improved or shared sanitation facilities. Given high levels of access, the apparent contradiction in diarrheal death and sanitation statistics suggests shortcomings in household level WASH practices that perpetuate fecal oral contamination. To explore, the USAID WASHplus Project conducted quantitative and qualitative research to understand household water management practices and subsequently identify associated behavioral improvements that can be integrated to ensure the safety of water at all stages from collection to consumption. Random selection of 1445 households (HH) with children <5 were interviewed using a structured questionnaire in four sub-districts of the country. Microbial testing of water using the Aquagenx Compartment Bag Test (CBT) at source, transport container, HH storage container, glass after consumption, household pond and tippy tap/handwashing station was also conducted in a parallel subsample of 100 HH to test progressive water quality from source to consumption/ use. Additionally, qualitative interviews with key informants to further probe and triangulate were conducted as needed at several phases. The study found that 98.9% of HHs fetch drinking water from a tube well (borehole) and 73% of HHs have access to sanitation facilities. The survey also identified 19% cases of diarrheal episodes in the two weeks before to the survey (much higher than the 5% reported in 2011 national DHS data.) Further investigation particularly focusing on behavioral aspects unveiled some potential risky practices that are likely to cause recontamination of water and ultimately have caused this high prevalence of diarrhea. For instance, despite universal access to tube well, 81% reported using surface water for cooking and cleaning utensils due to cultural/culinary preferences, 14% do not consistently cover the container while fetching water and among those who cover, 20% uses coconut shell which proves even more risky than covering if not cleaned regularly. Similarly, in terms of storage, 23.2% reported storing the containers in the floor/ground, 7.4% and 5.9% were observed to dip a finger while serving and pouring water from the container. Taking into account current practice and considering the social and cultural milieu, researchers next developed a list of 'small doable actions ' (SDAs), a behavior change approach based on behavioral theories and best practice that people are less likely to move directly from current "bad" to ideal practice; rather they will try smaller actions considered feasible and based on positive outcomes, and will

stage themselves towards ideal practice. Therefore, a continuum of practices at source, transport and household were developed and tested such as: safety of the source (keeping clean the spout and platform of tubewell, minimizing children playing with tubewell, use of lid for the tube well head); water collection technique (properly cleaning the container before collection, avoiding use of the hand to spill out extra water from the container); safe transportation (cover with clean lid while transporting, avoid finger dipping in the water, not to use sari to cover the container); hygienic storage (storing in a narrow neck container and not in the floor, using a lid larger than the mouth of the container) and safe consumption (ceasing to dip fingers in the container, using tube well water for preparing foods that are not boiled). The study then applied the BEHAVE framework to identify audience-specific behavioral determinants and related activities to improve domestic water management practices. These were incorporated into a theory- and community-based WASH program in Southwest Bangladesh. Improving domestic water quality management practices hold great in reducing prevalence of diarrhea, particularly in settings with universal access to safe drinking water. Subsequent endline and DHS data will quantify changes in household practice, diarrhea prevalence and child growth attributable to improved access and practice.

Service Levels of Household Rainwater Harvesting Systems and Multiple Water Sources in Northeastern Nicaragua

Daniel Smith, University of Leeds

Additional Authors: Barbara Evans; Joshua Briemberg

This paper reports on research which contributes to a global understanding of how households select from amongst multiple water sources when carrying out a range of domestic water-related tasks. The focus of this part of the research is the use of household rainwater harvesting (RWH) facilities in a community in Nicaragua. The research is the first of a series of case studies which aim to develop methodologies for assessing use of multiple water sources, and to test the hypothesis that domestic water budgets are strongly informed by perceptions about the water produced. An understanding of this is considered critical to effective monitoring, particularly of the cost-effectiveness of interventions. The first case study is based in an indigenous Miskito community in northeastern Nicaragua where household RWH systems are being installed as part of the "Lazos de Agua" WASH program. Multiple alternative sources of water are also in use in the community. WaterAid and Millennium Water Alliance are implementing the program with FEMSA Foundation, Coca-Cola Latin America, and Fons Catalá. The program baseline data, and other recent research, confirm that where available, households tend to use multiple sources of water in rural Latin America and worldwide. The research uses a conceptual framework based on two stakeholder groups - "implementers" and "users". "Implementers" are responsible for technical design of the water supply intervention (in this case RWH). "Users" are responsible for decisions about use and operation. Taken together, the perceptions of implementer and user groups define water service levels and ultimately the cost-effectiveness and impacts of the water supply intervention. Seasonality is also taken into account. The research uses mixed methods. The technical methods include high-frequency data logging of rainfall and water levels in RWH tanks; installation of water meters on RWH tank taps; water source mapping; and water quality sampling. Structured interviews with water users are used to explore usage of multiple water sources and perceptions in both the dry and rainy seasons. A special tool known as the perceptions interview asks respondents to rank different water sources according to ten characteristics including quality, security, and ease of use. Finally, water use will be quantified using a combination of simplified water diaries and twice daily observation over a period of four days in each season. Preliminary results from the first round of data collection in the dry season are now available. The population of approximately 500 is distributed in 72 households. 57 households have RWH systems with 4,000 L of storage. At least 21 hand-dug wells without pumps, one drilled well with a hand-pump, and six surface water sources are also available. Of 12 households studied, nine used three or more water sources. In 10 households where water use was quantified,

25% of the total volume used across all households came from sources other than the primary source as determined by volume. If the primary source is defined as that most used for drinking, 45% of water used across all households came from alternate sources. Results from the first week of data logging in seven household RWH tanks showed that between 1 and 16 liters per person per day of rainwater water were used. These households relied on RWH systems for 0 to 40% of water consumed. Water quality sampling indicated that RWH tanks had a lower probability of testing positive for E. Coli than hand-dug wells. RWH tanks generally had much lower turbidity and more neutral pH than wells. Concrete-lined hand-dug wells had lower E. Coli counts than unlined wells, which may be due to higher frequency of use of the former, confirmed in interviews. Perceptions about water sources are strong and significantly affect usage. The quality of water from RWH generally received high rankings compared with other sources, but perceptions of "dirtiness" and animals in RWH tanks were cited by five of ten responding households as reasons to prefer drinking from other sources even when these were unimproved. Perceptions of quality were also cited as reasons both to drink and not to drink water from one other available improved source. The interviews also revealed what may be cultural attitudes towards water supplies. Multiple respondents said that RWH is not a "source" of water, is not "natural", or does not "produce" water compared to, say, a well; some related this to perceptions of health and reliability. By the time of the conference, full datasets from the dry and rainy seasons will be analyzed to build on these early results. Actionable research outputs are expected to include recommendations for RWH system design, an estimate of cost-per-volume of water provided by RWH, and a comparison of methodologies for assessing service levels when more than one water source is used. The program plans to expand this research to Mexico.

Evaluation of the performance of a silver-ceramic tablet and silver-impregnated ceramic water filters alone and in combination in 80 rural households in Limpopo Province, South Africa

James Smith, University of Virginia

Additional Authors: Beeta Ehdaie; Rebecca Dillingham; Amidou Samie

We recently invented a porous ceramic tablet impregnated with metallic silver "nanopatches" that can be used for household-level water purification in the developing world. When placed into a 10- or 20-L household water-storage container, the metallic silver in the tablet is gradually oxidized to ionic silver and diffuses through the porous ceramic medium into the bulk solution. The ionic silver effectively disinfects waterborne pathogens. The tablet has been designed so that ionic silver levels in water are sufficient for significant disinfection within 8 hr of contact time while not exceeding the silver drinking water standard of 100 µg/L. We have previously reported on the effectiveness of this technology in a laboratory setting. In this study, we evaluate the field performance of the technology in 80 rural households in Limpopo Province, South Africa, and compare its effectiveness to silver impregnated ceramic filters manufactured at a local filter factory established by the University of Venda, the University of Virginia, Rotary International, and PureMadi. In addition, we evaluate the effectiveness of combining the two technologies (e.g. placing a ceramic tablet in the lower reservoir of the filter assemblage to provide residual disinfection to the stored water). This study was conducted following approval of the Institutional Review Boards of both the University of Virginia and the University of Venda and with coordination from Dr. Vhonani Netshandama, Director of Community Engagement at the University of Venda. Ceramic tablets were manufactured in a prototype manufacturing facility at the Observatory Mountain Engineering Research Facility at the University of Virginia by combining clay, 20-mesh sawdust, water, and silver nitrate in appropriate proportions, pressing the mixture at 1000 psi into a tablet-shaped mold to a final diameter of 6.5 cm and height of 3.5 cm, and firing the tablets in a kiln at a 900 °C. Thirty households were selected to study the ceramic-tablet performance. Each household received two 20-L plastic water-storage containers with a cover and spigot. One container per household held a silver-ceramic tablet, and the other container in each household held a ceramic tablet without any silver. This latter container and tablet served as a control. Both tablets appeared to be identical, and the residents could not distinguish between the silver-ceramic tablet and the control tablet.

Residents were instructed to fill both containers at night before going to bed and using water from both containers equally throughout the following day. They refilled the containers each evening. Each household was visited weekly over the ensuing 5-week period and water samples were collected from both containers for analysis of total silver, coliform bacteria, and *E. coli*. An additional 25 households were given ceramic water filters with lower plastic receptacles and spigots manufactured by women potters at the Mukondeni Pottery Cooperative and Filter Factory in Mashamba, South Africa. Samples were collected weekly from the spigots and from the source water used to fill the filters. Finally, 25 households were given ceramic water filters with receptacles and a silver-ceramic tablet for the lower receptacle reservoir. For both of these two cases, collected water samples were analyzed for total silver, coliform bacteria, and *E. coli*. Results of the study demonstrated that all three approaches significantly reduced total coliform bacteria and *E. coli* relative to the controls (for silver-ceramic-tablet households) or the source water (for filter and filter-plus-tablet households). Percent removals between the three treatments were not statistically different. Median percent removals were 95% (ceramic tablets), 97% (ceramic filters), and 99% (ceramic filter plus tablet). Silver levels in all treated water samples were less than 20 µg/L, significantly below the drinking water standard of 100 µg/L. These results indicate that silver-ceramic tablets are an effective point-of-use water-treatment technology with respect to disinfection of coliform bacteria and *E. coli*. User surveys indicated that all the technologies were simple to use and culturally appropriate. In addition, silver-ceramic tablets are simpler to use and less-expensive to manufacture than ceramic water filters. They are also more durable and easier to transport. They can be used with existing household water-storage containers. Data collection for these households will continue through August 2014, and these long-term performance data will be available during the conference presentation.

Factors Influencing Laboratory Evaluation of Point-of-Use Water Treatment Technologies: Effects of Testing Conditions on Performance

Mark Sobsey, University of North Carolina at Chapel Hill

Additional Authors: Nirmala Ronnie; Nimish Shah; Tucker Witsil; John Gilles; Emily Bailey

Treatment of water at point-of-use is now widely recognized as an effective intervention to immediately improve the microbiological quality of water where it is consumed. Determining the microbiological performance efficacy of POU water treatment technologies has been limited by two widely different constraints: (i) the strict but artificial and potentially unrealistic test specifications of the several existing protocols that have been in existence and become widely used for decades, such as those of the US Environmental Protection Agency and NSF, and (ii) international, flexible and adaptable but non-specific performance evaluation suggestions of a recent World Health Organization publication that encourages the selection of performance evaluation test conditions that are representative of and appropriate for local conditions, contexts and technical capacities. Given these two extremes, there is a need to consider the extent to which differences in test conditions and materials may influence the microbiological performance of a POU treatment technology and its ability to meet log₁₀ microbial reduction performance targets. Here, we identify a number of critical factors that will influence the performance of POU treatment technologies especially for log₁₀ bacteria reductions and advocate for greater attention to the development of performance evaluation test conditions that are realistic, representative and reproducible. We present evidence showing that the choice of test waters can dramatically change the log₁₀ reductions of microbes by POU treatment technologies and that performance can be much lower when using real-world waters instead of standard test waters. The type of POU technology can also influence performance when using test waters of different quality, with some water quality constituents increasing and others decreasing log₁₀ reductions. Of considerable importance for microbiological performance evaluation of POU technologies are the choice of test organisms, their sources, their properties and the conditions of their use. Microorganisms naturally present in water sources may be very different in physiological and morphological states in comparison to the same species of test microorganisms propagated and prepared in

the laboratory. State of aggregation, association with solids, extent of injury, being in the viable but non-culturable (VBNC) state antecedent growth conditions will influence the extent of log₁₀ reduction by water treatment processes. Other factors that may influence log₁₀ reduction performance of POU treatment technologies are the choice of specific test strains employed and the choice of diluent, assay methods and culture media. For example, plating the same test bacterium such as a lab strain of *Escherichia coli* prepared on a non-selective culture medium versus a differential selective medium has been shown to give as much as a 10-fold difference in plating efficiency and estimated bacteria concentration based on colony forming units, even without exposure to a POU treatment technology. This presentation proposes specific approaches to address some of these complicating factors within performance evaluation test protocols and testing schemes and also encourages further research in this area to identify appropriate and representative test conditions, test methods and materials that can provide reproducible POU technology performance evaluation results. While there is a need for a harmonized and specific protocol for technology performance evaluation of microbial reductions on a global basis, there is also a need for flexibility and adaptation of such protocols and test conditions to local conditions, contexts and resources. In settings with limited resources, the use of alternative but robust and realistic test protocols should be encouraged and efforts to harmonize such alternative protocols are needed to address the issues that could cause potential microbial reduction performance differences highlighted here.

Spot-checks to measure general hygiene attitude

Ina Sonogo, EAWAG

Additional Authors: Hans-Joachim Mosler; Elisabeth Seimetz

Background. Hygiene behaviors are fundamental for the prevention of diarrheal and other diseases. A variety of behaviors from cleaning water vessels over handwashing to keeping a household free of animal feces can be counted as hygiene behaviors. However, it remains unclear if and how those different behaviors interrelate and if a general attitude towards hygiene can explain them all. **Method.** In 2012, we conducted a survey about water, sanitation and hygiene with 762 households in rural Burundi using quantitative structured interviews, observations and spot-checks. Spot-checks are rapid observations which have the advantage that they are easy and fast to measure and that biases due to social desirability can be avoided. The main research question of this study was whether a general hygiene attitude is responsible for more specific behaviors (e.g. personal hygiene of the primary caregiver), which explain the hygienic conditions of the household measured by a comprehensive list of spot checks. Further, we wanted to test whether general hygiene attitude relates to other important measures of hygiene, health and psychological constructs. **Results.** Using structural equation modeling we were able to calculate a model well-fitting our data (CFI = .941; RMSEA = .058). On the first level of the model, "personal hygiene of the primary caregiver", "hygiene of the child", "hygiene of the household", "hygiene related to animals", "hygiene of water vessels" and "hygiene of the latrine" explained the hygienic conditions measured by spot-checks well. On the second level of the model, general hygiene attitude was able to explain the just mentioned more specific hygiene behaviors. Using structural equation modeling, we calculated the relationships of this general hygiene attitude with several other variables. We revealed significant relationships of general hygiene attitude of medium effect sizes to self-reported handwashing ($r = .31$) and observed handwashing ($r = .35$), to self-reported latrine cleaning ($r = .41$) and to a measure of child health indicated by the occurrence of eyes and nose discharge ($r = .42$). The relationship to the psychological variable "commitment to hygiene" was significant with a large effect ($r = .62$). **Conclusion.** There is a common ground for different hygiene behaviors as they are meaningfully interrelated. General hygiene attitude can be measured with a comprehensive list of spot-checks and is related to other important variables like self-reported or observed handwashing or child health. The correlation to "commitment to hygiene" shows the strong interlink of psychology and behavior.

Improving handwashing and toilet use in Philippines Schools through behaviour change interventions

Regina Souter, International WaterCentre

Additional Authors: Declan Hearne; Diane Cousineau; Adam Biran

Improving the hygiene practices of children while at school can positively impact the health and wellbeing of those children; improved hygiene practices as a result of increased WASH access coupled with appropriate promotional strategies can reduce the incidence of disease, resulting in reduced absenteeism, and potentially leading to increased educational performance, and subsequently, to economic growth at a household, community and national level. The International WaterCentre and London School of Hygiene and Tropical Medicine worked with UNICEF and its development partners in the Philippines to understand current handwashing and toilet use behaviours of school children, and develop and test interventions to improve these practices. In particular, the project intended to develop and test interventions to further encourage independent handwashing with soap (iHWWS) before eating and after toileting, and toilet use. The framework for the research combined the Theory of change approach to articulating the steps required from interventions to desired impacts, with the FOAM approach to understanding hygiene behaviours and identifying opportunities for improvement. Research was conducted in both urban and rural schools, in some schools that had existing hygiene-related interventions (that sought to improve handwashing through habitual group handwashing activities and improved access to group hand washing facilities) and some with no additional interventions. The research indicated that although the group handwashing interventions were variably implemented, they did correlate with increased iHWWS in some cases, and iHWWS was consistently lower in schools without these interventions. The research also indicated remained significant scope to further improve iHWWS practices. In schools with the group handwashing interventions, formative research was conducted to explore existing opportunities, ability/knowledge and attitudes to iHWWS and toilet use. This research indicated that while knowledge was not a barrier to improved hygiene practice, there was scope for further improvement to iHWWS through targeted behaviour change interventions. Findings suggested that the group handwashing activities had increased the self-efficacy of students to handwash and had also improved social norms for conduct of iHWWS in schools. A projective technique was employed to further explore student perceptions and motivations associated with handwashing. The approach did not uncover any gross negatives in terms of the potential for motivating improved handwashing. Overall the evidence leaned towards disgust and affiliation as the drivers with the greatest potential for promoting iHWWS, possibly supported by appropriate reward and punishment for younger children and messages around attraction for older children. We also determined that the most significant barrier to children's use of toilets was not behavioural, but rather, the availability and accessibility of functional toilets. Utilising the formative research results, the 'HiFive for HySan' package was developed; this was set of activities aimed at motivating iHWWS of children and triggering in-school dialogue and actions on how to better maintain clean and maintain the function of toilets and iHWWS facilities. The activities targeted behaviours of both school staff and children. The activities included a song, game, story book and associated wall murals that used hygiene messages drawing on the motivations of peer affiliation and disgust, and a wall chart and worksheet targeting facilities provision, maintenance and use. The potential impacts of the HiFive interventions on iHWWS, toilet use and facilities were evaluated after a pilot implementation of HiFive, and will be reported in this presentation, along with recommendations for scale-up of the interventions. Lessons learned about developing and evaluating hygiene behaviour change programs will also be shared.

Integrating Water Resources and Demand to Improve Drought Resilience and Build Water Strategies: A Pilot Approach to Kenya's Arid and Semi-Arid Lands

Sarah Sparker, Millennium Water Alliance

Additional Authors: Doris Kaberia

Building long-term resilience against recurrent drought in arid lands is one of the challenges addressed by the Kenya Arid Lands Disaster Risk Reduction - Water, Sanitation, and Hygiene (KALDRR-WASH) program, a two-year program supported by USAID and The Netherlands. This presentation focuses on an innovative approach developed and tested in the program, using local, participatory water planning to match water resources with water demand and using hydrogeological data at the catchment level to build natural and artificial storage to improve groundwater water recharge, retention and reuse. The Challenge: In Kenya's arid and semi-arid lands (ASALs), the total demand for water often exceeds the water available to people and livestock. This problem is compounded by weak support from government and competition for resources amongst water users, which creates the potential for conflict. Most water-related interventions are short term and target a single problem, rather than the whole complex of problems that communities face. Although Kenyans experience periods of severe water scarcity, annual rainfall is actually sufficient to support their livelihoods. The gap arises because a large portion of the water disappears unused through surface runoff, flooding and evaporation. Integrated approach to matching water supply and demand: In collaboration with Dutch technical partners Acacia Water, IRC, and Aqua for All, MWA members executed an innovative approach that integrates the management of local water resources and services. Using the RIDA framework (for resources, infrastructure, demand and access), it evaluates on one hand the potential of water resources and existing supply infrastructure, and on the other hand total water demand and water access challenges. This integrated, area-based approach encompasses all local water uses (domestic, livestock, agriculture), all local water resources and all local water stakeholders (operators, users, government). Based on field assessments and research, an estimate is made of the actual water gap for the coming ten years. Next, strategies are developed to meet these gaps through water infrastructure, water governance, water service management, and capacity development. Stakeholders divide responsibilities for coordinating the different strategies of the water master plan. Cost estimates for the strategies are based on the life-cycle costs approach analysis of water services. Stakeholders then select recharge, retention and reuse strategies to complement traditional water sources, to increase the amount of useful water. 3R interventions extend the chain of uses and store water in shallow aquifers, the soil profile, open water and tanks. The ultimate goal is to create secure water buffers that can meet the local water demand. This translates into increased resilience during droughts, higher productivity and better access to drinking water. Promising findings and initial successes from the pilots: ? Only a relatively small amount of rainfall needs to be stored to meet demand in rural areas, even in the driest years. ? Local, participatory water master planning is a strong tool for guiding interventions and building resilience to drought. ? In Wajir, the participatory planning meeting addressed and defused conflicts over water and land. The mapping of the water gaps informed discussions on options for grazing land strategy in both wet and dry seasons. Participants agreed to create new water sources near homesteads to avoid conflicts with neighboring clans with migrating herds. ? In Moyale, stakeholders said that the tools provided an excellent opportunity to integrate traditional water management practices, which are neglected in most other planning processes. ? In Marsabit, Wajir and Turkana, government representatives recognized the link with Kenyan planning mechanisms, and said the new tools would help them translate county plans into actions. Future Directions: The pilot was based on proven approaches developed in different contexts but tailored to ASALs in Kenya. The next task is to refine the methodology so that it will be replicable and can be scaled up. Steps include the following: ? Linking the methodology to the government's existing water management planning approach and institutions. ? Improving interpretation and applicability of the maps (e.g., for irrigation or specific conservation techniques). ? Streamlining participatory processes for small sub-catchments, catchments and/ or county administrative levels. ? Improving planning with information on the financial sustainability of water interventions. Specific examples of the use and results of the methodology will be given as part of the presentation.

What doesn't kill you makes you richer: Adult wages and the early-life disease environment in India

Dean Spears, Delhi School of Economics & r.i.c.e.

Additional Authors: Nicholas Lawson

A wide economic literature documents links between early life health and human capital, and between human capital and adult wages. In this paper, we ask the following question: does the early life disease environment in developing countries influence adult economic wages? We investigate this question using survey data on adult men in India, matched with census data on two measures of their early life disease environment: infant mortality rates and open defecation. Using a district-level differences-in-differences strategy, we show that men born in district-years with lower infant mortality and better sanitation earned plausibly higher wages in their 20s and 30s. We apply our effect estimates to calculate the social and welfare consequences of the disease environment, which are considerable. In particular, eliminating open defecation would increase tax revenue by enough to completely offset a cost up to \$462 per household that stops defecating in the open. A socially neutral elimination of open defecation in India would increase the net present value of lifetime wages by more than \$1800 for an average male worker born today. These large economic benefits ignore any other non-wage benefits of improved health or reduced mortality.

Household water insecurity in Ethiopia: Insights from mixed-methods studies in three regions

Edward Stevenson, University College London

Additional Authors: Matthew Freeman; Argaw Ambelu; Yihenew Tesfaye; Craig Hadley

INTRODUCTION Household Food Insecurity scales have proven a useful alternative to more costly and intrusive methods of household nutritional assessment, e.g. measures of physical growth or dietary recall. In the case of the USDA Household Food Insecurity Access Scale, answers to 9 yes/no questions about households' consumption and coping strategies are highly correlated with growth, diets, and broader health measures such as psychological distress. WASH practitioners might benefit from a similar approach to Water Insecurity (WI) monitoring, which could save time and energy in M&E, and provide more timely feedback on project effectiveness. **METHODS** Through research in 3 hydrologically diverse regions of Ethiopia (South Gondar, South Wello, and Lower Omo), we investigated the predictive potential of a prototype WI questionnaire. Developed from qualitative work in S Gondar, the questionnaire reflects such dimensions of household WI as "worry over water supply", "drinking water that is unsafe for health", and "quarreling with spouse or neighbors over water" (a total of 32 items, each coded as yes/no). Covariates included household SES, water consumption in liters, distance to main source of drinking water, household food insecurity, and women's psychological distress (the WHO Self-Reporting Questionnaire, a 29-item inventory of symptoms such as "trouble sleeping", "headache", and irritability). In all sites the primary respondents were women, who were in most cases the household members with greatest responsibility for water collection. FGDs were also carried out to attain qualitative data on WASH conditions and other sources of stress. **RESULTS** Responses to the household WI questionnaire significantly predicted women's psychological distress in all three sites; and the relationship was robust to controls for covariates including women's age and household food security. In the Lower Omo, communities with access to improved sources reported lower household WI, although this difference was only marginally significant. FGD data suggested that many other factors in addition to the distance and type of water source affected women's levels of psychological distress, including social obstacles to accessing water, and fears of crop failure or the illness or death of loved ones. **DISCUSSION** This study demonstrates that a prototype household WI questionnaire developed in Ethiopia predicts women's psychological distress under diverse ecological conditions. Qualitative data suggest that improvements in community management of water resources (e.g. the performance of WASH Committees) might be as important for household WI as improvements in physical

infrastructure (such as availability of protected sources), and also that water is only one of many sources of stress for rural Ethiopians. In future work we will use principal components analysis to identify dispensable items in the questionnaire, and assess the sensitivity of the WI instrument to differentials in water access within and between communities (e.g. recent water infrastructure improvements in some communities in the Lower Omo and South Wello study sites).

Contextual and socio-psychological factors predicting habitual cleaning of water storage containers

Andrea Stocker, Eawag

Additional Authors: Hans-Joachim Mosler

Recontamination of drinking water between water collection at the source and point of consumption is a current problem in developing countries. The household drinking water storage container is one source of contamination and therefore should be cleaned regularly. First, the present study investigated contextual factors which stimulate or inhibit the development of habitual cleaning of drinking water storage containers with soap and water. Second, based on the Risk, Attitudes, Norms, Abilities and Self-regulation (RANAS) Model of behavior, the study examined which socio-psychological factors should be influenced by an intervention in order to promote habitual cleaning. In a cross-sectional study, a total of 905 households in rural Benin were interviewed by structured face-to-face interviews. A forced entry regression analysis was used to determine potential contextual factors related to habitual cleaning. Subsequently, a hierarchical regression was conducted with the only relevant contextual factor entered in the first step ($R^2 = 6.7\%$) and the socio-psychological factors added in the second step ($R^2 = 62.5\%$). Results showed that the type of storage container significantly predicted habitual cleaning, although its β -value was low ($\beta = -.10$, $p = .000$). The most important socio-psychological predictors were commitment ($\beta = .35$, $p = .000$), forgetting ($\beta = -.22$, $p = .000$) and self-efficacy ($\beta = .14$, $p = .000$). The combined investigation of contextual and socio-psychological factors proved to be beneficial in terms of developing intervention strategies. Possible interventions based on these findings are recommended.

Acceptability of using and paying for shared water points and for a passive water chlorination device among low-income urban communities of Dhaka

Farhana Sultana, The University of Melbourne

Additional Authors: Amy Pickering; Jennifer Davis; Yoshika Crider; Nazrin Akter; Afsana Sharmin; Leanne Unicomb; Stephen Luby

Background The lack of access to adequate and safe drinking water supplies leads to repeated episodes of waterborne diseases and deaths in low-income countries. Bangladesh bears a large burden of diarrheal diseases, especially among children aged <5 years. Breaks in water pipes allow for contact with human feces, undermining the effectiveness of chlorination at water treatment plants. Barriers to water treatment at the household level include cost, time and maintenance. We have been exploring an alternative technology that automatically adds an appropriate dose of chlorine at the last stage of water collection to treat water while it is being drawn. We aimed to leverage the system where water points are currently shared and maintained by low-income urban communities by adding a low cost approach to improve the microbiological quality of drinking water. We explored community interest in and willingness to pay for a passive water chlorination device by conducting a qualitative study to explore communal perceptions about the benefits, barriers and successful and unsuccessful payment schemes for accessing safe water among those currently using shared water points. **Methods** We conducted the study from January to May 2013 in the Kallyanpur community in northern Dhaka, Bangladesh. To

select study respondents we used a free listing of shared water point users in the compound, local elites and landlords. We then verified their monthly bills to cross check successful (payment occurs) and unsuccessful (payment does not occur) bill collection schemes. Based on the availability and willingness to participate in the study, we then purposively selected 44 respondents. Field staff conducted four group discussions with a total of 20 community elites and landlords, and 10 in-depth interviews with the users who pay, 10 with the users who do not pay, and four with community-based organization members. We also conducted two in-depth interviews with representatives from the NGO, named Dustho Sasthyo Kendra (DSK), who were involved in facilitating the legal shared water connections in low-income communities in 2005 and the municipal water utility, Dhaka Water Supply and Sewerage Authority (WASA). Findings Community members commonly reported that shared water points were a government-authorized piped water system that created communal ownership among residents. After installation of the water points, they found it less expensive to obtain water compared to purchasing drinking water from the markets, they now had unlimited access to water and they saved time and physical effort compared to collecting water from distant sources. Community members also reported payment schemes were undermined by communal discord and failures in the system from sharing common water points during peak hours including theft or no provision of electronic meters, theft of pump handles, an inaccurately high billing system by Dhaka WASA, and illegal connections to the shared water points by politically powerful community members in order to avoid payments. Community members, Dhaka WASA and DSK representatives reported that water from shared points was poor quality, it smelled bad and had visible dirt and feces that they perceived caused diarrheal diseases. Most of the households did not treat water by boiling water or using chlorine and filters as these options were too expensive. The small number of households that treated drinking water used chlorine tablets and alum potash, or purchased mineral water for drinking. Those using chlorine tablets intentionally under dosed their water to avoid smell, to save money and to extend their supply of chlorine tablets. They considered the idea of passive water chlorination as a method that could provide accessibility to safe water which would have health and financial benefits thereby saving money on medication and hospitalization. However, they added that the introduction of a passive chlorination device needs communal agreement and low costs (per household 0.07 to 0.125 USD monthly) considering community affordability, so that everyone will accept and pay for it willingly. Conclusion Our findings suggest that the introduction of shared water points was an improvement over prior arrangements by providing accessible and legal piped water to low-income urban communities of Dhaka. However, this has not increased access to safe drinking water. The community continues to experience diarrheal diseases and does not regularly treat drinking water due to high cost. A technology that treats water at the point of collection would be acceptable if it was low enough cost, but it would have to be integrated into the current contentious system of managing water points.

Effectiveness of Mass Media campaigns in changing Water, Sanitation and Hygiene related health behavior in rural Bangladesh

Sonia Sultana, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr, b)

Additional Authors: Jade Benjamin-Chung; Amal Halder; Leanne Unicomb; Abul Shoab; Probir Ghosh; Stephen Luby

Background: Water, sanitation and hygiene (WASH) interventions can reduce diarrheal disease by promoting behavior change at key times. In low income countries, most WASH-related interventions are delivered through interpersonal communication (e.g. household visits, community events), the most effective are implemented intensively but these are too costly to scale with limited resources. Mass media can be a powerful and cost effective method to deliver messages that encourage people to adopt target behaviors by reaching a wide

population, repeatedly. Very few WASH mass media interventions have been evaluated for effectiveness in reaching the target audience including in Bangladesh. The Sanitation, Hygiene Education and Water Supply in Bangladesh Program (SHEWA-B) was a large five-year project implemented by the Government of Bangladesh and UNICEF. The program delivered targeted water, sanitation and hygiene interventions to 58 sub districts in 16 districts of Bangladesh from 2007 to 2012. The program was initially implemented by community hygiene promoters, who were recruited and trained within the local communities to provide WASH health messages and motivate household members to adopt target WASH behaviors. An evaluation conducted in 2009, detected only modest changes among a handful of the outcome indicators. In 2011 a mass media campaign was launched to address the lower-than-expected impact. The current study aimed to assess whether the SHEWA-B mass media campaign was effective in changing intervention-related health behavior knowledge and practices. Method: The SHEWA-B mass media messages were aired on radio and TV from November 2011 to February 2012 and again between October and December 2012. We collected data from randomly selected households from 355 and 300 clusters selected by probability proportion to size sampling from 15 intervention sub districts at two time points (July to September, 2011 and July to October, 2012). We used structured questionnaires including interview responses, behavior demonstrations and environmental spot checks to collect data on knowledge (recalling health messages) and health outcome (target behavior practice) indicators. During the behavior demonstrations, participants were requested to show how they usually wash and dry their hand after using toilet for defecation. To compare the proportions of health knowledge and behaviors between 2011 and 2012 we estimated adjusted proportion ratio (APR) and used a generalized estimating equation regression model, controlling for wealth, age, education and village level clustering. Results: A total of 8,947 and 8,400 respondents, caregivers of children under 5 years old, were interviewed during the 2011 and 2012 household surveys. Among the respondents, 3,777(45%) reported learning health behavior messages from mass media (TV and radio) in 2012 compared to 3,318(37%) in 2011 [APR=1.21; 95% CI: 1.09, 1.35, $p<0.001$]. The proportion of respondents who could recall SHEWA-B messages also increased from 2011 to 2012, this included handwashing messages [2,666(30%) vs. 3,804 (45%), APR=1.56; 95% CI: 1.30, 1.87], sanitary latrine use and feces disposal messages [2,741 (31%) vs. 3,824 (46%), APR=1.57; 95% CI: 1.31, 1.88] and safe water messages [2,370 (26%) vs. 3,318(40%), APR=1.62; 95% CI: 1.32, 1.98] ($p<0.001$). Moreover, several target handwashing behaviors improved significantly between 2011 and 2012 among the respondent households. These include improvement among children (3-5 years old) demonstrating handwashing with soap after defecation (48% vs. 66%, APR= 1.38; 95% CI:1.26, 1.50), caregivers demonstrating handwashing with soap after defecation (56% vs. 70%, APR=1.17; 95% CI:1.12, 1.22), child hand cleanliness (25% vs. 28%, APR=1.15; 95% CI:1.07, 1.24), caregiver hand cleanliness (41% vs. 47%, APR=1.19; 95% CI:1.12, 1.27) and handwashing location with water and soap present (52% vs. 63%, APR=1.12; 95% CI:1.05, 1.20) ($p<0.000$). Conclusion: Our findings suggest that mass media likely contributed to increased recall of health messages and in turn an increase in observed target behaviors in SHEWA-B intervention areas, enhancing health promotion delivered by promoters over the preceding four year. However, while mass media was cited as the most common source of message recall in 2012, we could not accurately determine whether the messages recalled were from the SHEWA-B media campaign due to limitation of our surveys. Questions to better determine message sources should be developed to attribute changes to mass media campaigns. Determining factors underlying the translation of knowledge to practice in response to a mass media campaigns is worthy of investigation.

Carbapenem Resistant Bacteria in Drinking Water: Method Development and Field Testing in New Delhi, India

Windy Tanner, University of Utah

Additional Authors: James VanDerslice; Devinder Toor; Ramesh Goel; Scott Benson; Christina Porucznik; Robyn Atkinson-Dunn

Antibiotic-resistant infections are a significant public health concern with serious implications, including prolonged and more expensive hospital stays and increased risk of death from infections that would otherwise be treatable. Of particular concern is the rapid increase in the number of carbapenem-resistant infections as carbapenem antibiotics are considered the drug of last resort. While the majority of documented carbapenem-resistant infections have been linked to hospitalization, there is significant concern, and much uncertainty, about community acquisition and transmission of carbapenemase-producing bacteria. Fecal waste may play a role as the intestinal flora is a major reservoir of carbapenemase-producing bacteria in the body. This has raised concerns that fecal wastes may be a reservoir for carbapenem-resistant bacteria, and that these bacteria may be spread through fecal-oral transmission routes. Several factors suggest that fecal-oral transmission of carbapenem resistance could become a major cause of new infections in areas lacking adequate water supplies and sanitation systems. Like other fecal-oral diseases, asymptomatic colonizations are common and there are reports of asymptomatic individuals shedding carbapenem-resistant *E. coli* for extended periods. A small number of studies have found carbapenem-resistant bacteria in environmental samples, including treated drinking water. Many of the carbapenem-resistant organisms isolated were not Enterobacteriaceae. Consequently, these bacteria would not be detected by the coliform enzyme-substrate tests typically used in routine drinking water quality testing. As a result, it is possible that common waterborne bacteria (HPC bacteria) that are currently thought to be of little public health significance and not regulated by health-based standards, may in fact be vehicles for exposure to carbapenem-resistance. Methods used to test water for antibiotic-resistant bacteria are much more complex and costly than standard P/A methods, such as antibiotic selection on centrifuged or filtered water samples or direct testing for particular resistance genes using molecular methods. As such there is a clear need for methods to detect a wide array of antibiotic-resistant organisms in drinking water. The objective of this work was to develop, validate and pilot test a practical, low-cost method to screen for the presence of carbapenem-resistant coliform and other heterotrophic bacteria in drinking water. The method modifies an established presence/absence fluorogenic heterotrophic plate count method by incorporating meropenem and vancomycin to select for carbapenem resistance. Four strains of *Klebsiella pneumoniae* and one *Pseudomonas* strain with varying susceptibilities to meropenem were used to create spiking suspensions. Recovery rates were estimated using IDEXX Quanti-Tray® most probable number (MPN) method (IDEXX Laboratories, Westbrook, Maine). Single cell detection was assessed by comparing spike recoveries of bacteria in deionized water containing HPC reagent alone and deionized water containing HPC reagent and various levels of meropenem. The evaluation was also conducted for a 100 ml presence-absence format using a target spike of 1-10 organisms. We used this P/A method to screen 19 drinking water samples from households connected to the piped water supply in New Delhi, India, for the presence of carbapenem-resistant bacteria. Samples containing meropenem-resistant organisms were sub-cultured onto selective media to identify those with Gram-negative bacteria. Species identification, meropenem minimum inhibitory concentration, and multiple antibiotic disk zones of inhibition were determined for the recovered Gram-negative isolates. The use of 0.125 µg/mL meropenem resulted in MPN counts similar to the MPN counts of the spikes without antibiotic for all spiked organisms including the less-resistant *Klebsiella*. In tap water, the addition of 5 µg/mL vancomycin to this meropenem concentration optimized the test by successfully inhibiting growth of non-resistant tap water organisms without compromising the recovery of the target carbapenem-resistant organisms. In the 100 mL P/A format, this combination of antibiotics inhibited any growth of non-target organisms while allowing detection of the carbapenem-resistant organisms.. Fluorescence in all positive spiked sample bottles was observed by 24 hours of incubation. Of the 19 water samples collected for the pilot study, 68% (n=13) of the samples gave a positive fluorescent result with the fluorogenic heterotrophic plate count reagent in the presence of 0.125 µg/mL meropenem and 5 µg/mL vancomycin. Ten of the 13 positive samples grew isolates on MacConkey agar with 0.5 µg/mL meropenem.

WASH & Nutrition: Successes, Challenges, and Implications for Integration

Jordan Teague, WASH Advocates

Additional Authors: Jay Graham; Elizabeth Johnston

It is increasingly recognized that there is a strong inter-relationship between nutrition and WASH and that both are critical for child health and development. Based on this growing body of evidence, efforts are now underway to integrate WASH and nutrition programs. There is limited evidence, however, on how WASH and nutrition activities are integrated in the field, what barriers integrated programs face, and what implementers believe to be necessary for successful integration. The aim of this study was to explore the integration of WASH and nutrition programming in order to identify barriers to and necessary steps for successful integration of WASH and nutrition programs. Sixteen semi-structured in-depth interviews were conducted with key stakeholders from both the WASH and nutrition sectors, exploring integration of WASH and nutrition programs, including barriers to integration and potential steps to more effectively integrate programs. Interviewees were purposively recruited based on their positions in organizations that had been identified as having both WASH and nutrition programming. Key individuals in these organizations were contacted with an invitation to participate, or to recommend other individuals who may be more appropriate. Nineteen invitations were sent to individuals at ten organizations, from which 16 individuals were interviewed (84 percent response rate). Each interview was transcribed and was analyzed using NVivo 10 via the grounded theory method, allowing relevant themes to emerge from the interviews. The interviews revealed emerging themes in barriers to effective integration of WASH and nutrition programs, and highlighted the needs of each sector to achieve more effective integration. In total, 14 factors were found to negatively influence integration, while 11 were identified as critical actions, strategies, and changes needed for more effectively integrated programs. Key barriers included insufficient and siloed funding, staff capacity and interest, knowledge of the two sectors, coordination, and limited evidence on the impact of integrated programs. To achieve more effective integration, respondents highlighted the need for more holistic strategies that consider both sectors, improved coordination, donor support and funding, a stronger evidence base for integration, and leadership at all levels. The results suggest that to integrate WASH and nutrition effectively, donors should support integration and fund operational research to determine whether there are additive or multiplicative effects that can be gained from integrated programs. Improved knowledge sharing among sector professionals is needed, and incentives should be designed for the two sectors to more effectively work together toward common goals. Implementers and donors desiring to integrate their WASH and nutrition programs can use the results of this study for program planning to prepare for challenges they may encounter, and to know what conditions are necessary for successfully integrated programs.

Laboratory development and field testing of sentinel toys to assess environmental fecal exposure of young children.

Belen Torondel, LSHTM

Additional Authors: Yaw Gyekye-Aboagye; Parimita Routray; Sophie Boisson; Wolf Schimdt; Thomas Clasen

Introduction: Different methods have been used to measure the impact of WASH interventions on environmental exposure to faecal pathogens thought to be typical transmission pathways. These include testing the presence of faecal indicator bacteria in hands, drinking water, flies and surfaces. The aim of this study was first to develop, standardize and validate a tool for investigating environmental fecal contamination through the use of a sentinel object in laboratory conditions and later to test the method in an Indian rural setting where a sanitation intervention has been delivered and evaluated. **Methods:** Different type of balls were investigated in laboratory settings to explore which material could be more suitable to uptake more bacteria (non-pathogenic

Escherichia coli (ACTC 25922) on their surface. We also performed bacteria survival analysis under different environmental conditions and tested different method for bacteria removing and recovering. Once the best type of ball material and method of bacterial recovery was selected, the ball was used to measure the impact of an Indian rural sanitation intervention in faecal environmental contamination. Foamy sterile sentinel toys were distributed to children <5 from a subsample of 360 households (approximately 6 households from 30 intervention and 30 control villages). We encouraged children to play with the toys in their household settings for 1 day, rinsed them in 300ml of sterile water and assayed the water the following day for thermotolerant coliforms (TTC). Results: Foamy balls were the best candidates for the study as they could take up more bacteria, followed by plastic balls; rubber balls were least effective. There were no significant differences in the recovery of the bacteria using a mechanic agitation versus no agitation method. Temperature and moisture content of the environment influenced bacteria uptake and survival (higher temperatures and moisture levels favoring more bacteria uptake). When the foamy balls were tested in the sanitation trial setting, we observed that there was a trend for less contamination of the sentinel toys in the intervention arm (17% reduction of odds of being in a higher category of contamination) compared with the control arm, but the confidence intervals of the odds ratios were wide and included one. Conclusion: Sentinel toys could be a good method to evaluate the impact of WASH interventions on environmental exposure to faecal pathogen. In rural India, we found suggestive evidence that households with sanitation facilities had lower levels of fecal contamination in the environment, but the difference was not significant. The variation found in this study was typical for measures of environmental contamination, and could require large sample sizes to ascertain differences between groups with statistical significance.

Hydration, water supply, and cognition among school children: results from a randomized control trial in Zambia

Victoria Trinies, Emory University Rollins School of Public Health

Additional Authors: Matthew Freeman

Background: Access to drinking water during the school day may improve children's ability to learn through the positive effect of hydration on attention, concentration, and short-term memory. The link between dehydration and lower cognitive performance has been well-established among adult populations and among school children in high-income settings. However, until recently this relationship has not been evaluated among children in low-resource settings. We conducted a pilot study in Mali where we assessed pupils' cognitive function on days they were and were not provided with supplemental drinking water. Data from this pilot showed a trend linking the provision of water with improved cognitive performance, but the results were not significant. We believed that a "practice effect" had masked the results of the pilot; scores were compared across two testing sessions and pupils performed better on the second session regardless of intervention group. The aim of the current trial was to build on the pilot with an improved methodology to investigate the relationship between cognition, hydration, and water consumption among children residing in a water-scarce setting. **Methods:** This study was a randomized control trial. We visited five schools in Chipata province, Zambia, for one day each. The schools had no water points within 0.5km of the school grounds and were all within two hours of Chipata town. All pupils in grades 3-6 whose parents provided consent were invited to participate in the study. Pupils were randomly assigned to receive either a bottle of drinking water in the morning that they could refill throughout the day (water group, n=149) or were not provided with supplemental water and could only access drinking water that was normally available at the school (control group, n=143). Pupils in the control group were provided with a bottle of water after the completion of study activities. We assessed hydration in the morning and afternoon using urine specific gravity (USG) measured with a portable refractometer. Children were considered dehydrated if their USG exceeded 1.015. Immediately following the afternoon hydration assessment, we administered six cognitive tests to assess short-term memory, concentration, visual attention, and visual motor

skills. All tests had been validated for use with children in previous cognition studies. Independent samples t-tests were used to compare cognitive test scores between the water and control groups, and linear regression was used to compare afternoon hydration level and cognitive test score. Results: Mean morning USG was 1.018 for both the water group (SD 0.0062, range 1.002-1.032) and the control group (SD 0.0061, range 1.000-1.031). Afternoon USG increased among the control group (1.022, SD 0.008, $p < 0.001$) and decreased among the water group (1.006, SD 0.009, $p < 0.001$). Mean scores for one of the cognitive tests, which assessed visual attention, were significantly higher among the water group ($p = 0.049$). There was no significant difference in mean scores between the water and control groups for any other test, and there was no trend of improved scores among either group. There was no significant correlation between afternoon USG and any test scores, although one test did show a borderline association linking increased hydration to increased performance on a visual attention test ($p = 0.079$). Conclusions: Results show that moderate dehydration among school children is prevalent and increased throughout the day in the absence of supplemental water, and that improved access to water decreases dehydration prevalence. There is some evidence suggesting that hydration improves visual attention among school children, but we did not find a clear association between hydration, drinking water, and cognitive performance. For most tests, there was a high degree of variation within each testing group, which limited our ability to detect significant differences between the two groups. We chose to use mean scores within each intervention group rather than using pupils as their own controls across two testing sessions in order to limit the improvement in scores that came from taking the test repeatedly. Future studies may benefit from an alternative methodology.

Effects of interventions aimed at improving cleaning behaviour of privately shared toilet users in Kampala slums, Uganda

Innocent Tumwebaze, University of Zurich and Eawag

Additional Authors: Hans-Joachim Mosler

Introduction: Cleanliness of shared toilets in urban slums is more fundamental to health and psycho-social wellbeing than the other limitations associated with shared toilets. In this study, we conducted an intervention research among users of privately shared toilets in the slums of Kampala to establish determinants influencing their collective cleaning behaviour and piloted interventions to increase participation in cleaning. We used the RANAS (risks, attitudes, norms, ability and self-regulation) model, with items from the social dilemma theory. The RANAS model integrates constructs from the Theory of Planned Behaviour (TPB) and the Health Action Process Approach (HAPA). **Methods:** A longitudinal study was conducted in three slums of Kampala between December 2012 to September 2013 to assess and improve the cleaning behaviour of shared toilet users. Only households using privately shared toilets (excluding public, communal or toilets used by only one family) were included in this study. We started with a pre-intervention study to establish the existing shared toilet users' cleaning behaviour and determining factors. Consequently, cleaning interventions (group discussions) were designed and implemented to improve families participation in cleaning shared toilets. Respondents with dirty toilets were randomised into discussion or non-discussion blocks, supplemented by toilet monitoring at different time intervals. In the post-intervention follow-up, we evaluated the effect of the interventions on respondents' cleaning behaviour and determinant factors. Linear regression analysis was done for the pre-intervention data analysis and general linear models (GLM) for repeated measures used for post-intervention data analysis. **Results:** Out of 424 respondents interviewed in the first study, 44.3% of the respondents reported cleaning their toilets on a daily basis. Respondents whose toilets were dirty ($n = 149$), mainly attributed it to the big number of users (40.9%) and the lack of cooperation from other user families (30.2%). The main factors significantly associated with respondents' cleaning behaviour were ability and self-regulation factors. To improve cleaning cooperation, obligation and commitment factors perceived important among shared toilet users, group discussions were hypothesized to be effective in improving cleaning behaviour. Only 305 of the initially 424

interviewed respondents were available at the post-intervention follow-up. A total of 119 respondents belonged to the randomised groups (non-discussion groups = 40, discussion groups = 79). Overall, the mean change in behavioural factors was greater in discussion than non-discussion groups. For example, cleaning behaviour was about three times more in the discussion than non-discussion groups, perceived cleaning cooperation was about four times more in the discussion than non-discussion groups and self-regulation factors of cleaning obligation and commitment was three times more in the discussion than non-discussion groups respectively. Conclusion: With the discussions, we were able to improve shared toilet users' cleaning behaviour as well as targeted psychological determinants. Initiating discussions or encouraging users of shared toilets to talk to each other is a viable way of improving toilet cleanliness.

Water, Sanitation, and Hygiene-Related Risk Factors for Soil-Transmitted Helminth Infection in a High-Density Urban Setting, the Kibera slum, Nairobi

Caitlin Worrell, Centers For Disease Control and Prevention

Additional Authors: Stephanie Davis; Ryan Wiegand; Gerard Lopez; Kennedy Odero; Leonard Cosmas; Sammy Njenga; Joel Montgomery; LeAnne Fox; Sharon Roy

Individuals living in urban slums have limited access to municipal services, including water and sanitation. Evidence suggests that water, sanitation, and hygiene (WASH) factors influence risk for soil-transmitted helminth (STH) infections, which disproportionately affect school-aged (SAC) and preschool-aged children (PSAC). However, further characterization of WASH factors and their impact in high-density urban settings is needed to identify intervention points. To examine these issues, households containing a PSAC (6-59 months) or SAC (5-14 years) were randomly selected from those enrolled in a population-based surveillance system in the urban slum of Kibera which is administered by CDC's International Emerging Infections Program. Data collection included a comprehensive household-level questionnaire and environmental assessment for risk factors related to WASH measures. Households were evaluated by construction material and elevation. Household WASH factors were classified by the WHO/UNICEF water and sanitation ladders and hypothesized WASH-related risk factors were tested for associations with STH infection. STH infection was determined by collecting up to three stool specimens from one child per enrolled household, and testing the stool for STH ova (*Ascaris*, *Trichuris*, and hookworm) by the Kato-Katz method. Analyses employed univariable and multivariable Poisson regression modeling to produce prevalence ratios. A total of 676 households containing either a selected PSAC (n=201) or SAC (n=475) met the inclusion criteria for analysis. The majority of the surveyed population was of Luo ethnicity (69.4%) and 53.3% of the children were female. Household elevation ranged from 1,709 to 1,764 meters, and was categorized in 10 meter intervals. STH prevalence was 40.8% among PSAC and 40.0% among SAC. Infection with *Ascaris* (23.2%) and *Trichuris* (26.5%) species were common, while hookworm infection was rare (<0.2%). Among included households, 1.5% reported piped water on premises and 98.5% another improved drinking water source, mainly public taps (97.6%); however 67.7% of these sources were unauthorized connections into adjacent municipal pipes. An inconsistent water supply was reported by 85.6% of households and 71.0% reported ever having difficulty meeting daily household water needs, most often due to financial barriers (73.8%), lack of storage space (25.6%), and long queues to collect water (17.5%). In this setting, where water is often purchased by households, average household water expenditures per person were \$0.33 USD per week. Overall, 1.3% of household sanitation facilities were improved, 81.7% shared, and 13.9% unimproved; 3.1% of households practiced open defecation. In univariable analysis, STH infection was significantly associated with Luo ethnicity (PR=1.95; 95% confidence interval (CI) 1.08-3.51) and location of household's toilet off premises (PR=1.33; 95%CI 1.00-1.77). Always treating water (PR=0.81; 95%CI 0.66-0.99), clean towel use during hand drying (PR=0.58; 95%CI 0.38-0.87), deworming in the last year (PR=0.80; 95%CI 0.66-0.96), finished flooring material in the household (PR=0.76; 95%CI 0.62-0.94), and the presence of electricity in the household (PR=0.70; 95%CI 0.55-0.87) were protective against STH infection. Every 10 meter increase in elevation was associated

with a 10% reduction in prevalence of STH infection (PR=0.89; 95%CI 0.83-0.96). On multivariable analysis, STH infection was significantly associated with treating water usually versus always (aPR=1.5; 95%CI 1.15-1.97), while finished household floor material (PR=0.76; 95%CI 0.60-0.95), deworming in the last year (PR=0.75; 95%CI 0.63-0.90), and 10 meter elevation increases (aPR=0.90; 95%CI 0.84-0.97) were protective against STH infection. STH infection in Kibera is related to WASH-associated factors. This population faces gaps in water availability and sanitation quality, putting the population at risk for STH infection. While urban slums represent a complex epidemiologic setting, the results presented here may assist policy makers in identifying points of intervention, likely to include behavior change, such as household water treatment and hand hygiene, and infrastructure improvements, such as sanitation provision and water runoff management. Overall, long-term STH control here and in similar settings likely requires an integrated approach involving multiple stakeholders such as tenants, landlords, the private sector, and government officials.

Piloting a point of use water treatment intervention among elementary school children in Bangladesh

Farzana Yeasmin, International Centre for Diarrhoeal Disease Research, Bangladesh

Additional Authors: Farhana Sultana; Leanne Unicomb; Fosiul Nizame; Dalia Yeasmin; Shahjahan Ali; Rouha Sarkar; Peter Winch; Stephen Luby

Introduction Treating drinking water in schools could reduce absenteeism in low income countries where water is microbiologically contaminated. School-based interventions are a promising method for motivating behavior change among students, but there is little evidence to guide consistent water treatment. Our study explored the feasibility and acceptability of low-cost (53,400L of water treated/\$1.00) water treatment in elementary school communities in Bangladesh. **Methods** We conducted a baseline assessment in schools and a Trials of Improved Practices study to aid development of a water treatment intervention. We collected information from 2 urban and 2 rural schools on current drinking water practices, storage facilities, understanding of our proposed hardware options, and point of use (POU) water treatment methods to design the intervention. The field team implemented an intervention in 4 additional schools (2 urban, 2 rural) that included drinking water hardware installation. Hardware included a 100L tank with handles, tank stand, liquid sodium hypochlorite with a dispenser and lock. The team recommended that students drink chlorinated water from their own bottles to avoid disease transmission and helped form a hygiene committee with students, teachers, school management committee and parent teacher association members, janitors and education officials. The team trained teachers to deliver behavior change communication sessions using flipcharts and cue cards as part of regular hygiene classes. During the intervention, the team conducted six, 4-hour structured observations in each school. One month after the intervention began, the field team conducted 2 focus group discussions with students, and one with school hygiene committee members of each school. Fourteen months after the intervention commenced in each school, field workers conducted three 4-hour structured observations of students, a focus group discussion with students classified as chlorinated-water adopters and non-adopters, and one with teachers, school management committee and parent teacher association members. **Findings** One month after the intervention began, fieldworkers observed that among 141 events of drinking treated water, 93 (66%) students used their own bottles and 43 (31%) used common cups or hands. One month after the intervention, all the teachers and students who participated in the focus groups said that they were drinking chlorinated water. Most of the students stated that they considered it safe, it had health benefits and treatment reduced germs which decreased absenteeism so that their study habits and grades improved. Teachers suggested that the availability of liquid chlorine in local markets would be useful for long term continuation of safe drinking water provision at schools. Most of the students reported that chlorinated water smelt bad but they continued drinking it and within a few days became used to the smell. Most of them said that teachers and students of the hygiene committees regularly motivated and monitored chlorinated water consumption. Student hygiene committee members at three schools and the cleaning staff at one urban school cleaned tanks, filled them with water and

added chlorine each school day. The school community paid the recurrent cost of chlorine throughout the intervention by monthly installments. Students and janitors maintained the hardware. During the 14 month follow-up we observed 732 drinking water events, 653 (89%) when chlorinated water was consumed and 78 (11%) when tube-well (untreated) water was obtained for drinking. During 131 of 653 (20%) events students used their own bottles, in 469 of 653 (72%) events used common cups and in 55 of 653 (8%) used both hands to drink water. The majority of students who participated in focus group discussions reported that they perceived chlorine as a medicine that treats water, kills germs and makes water safe to drink. Conclusion This intervention promoting low-cost liquid chlorine POU treatment of drinking water was feasible and acceptable with high level consumption of treated water 14 months after implementation. This contrasts with low level liquid chlorine POU treatment attained during an urban household intervention. The reasons for high uptake are not known and could include teachers' motivation and monitoring. Formation of hygiene committees institutionalized the intervention promotion in schools, and covered costs of liquid chlorine. Weekly hygiene sessions and education materials encouraged students to practice the promoted water treatment behaviors after the introduction of enabling hardware. Continued promotion and availability of liquid chlorine in local shops could support and improve safe drinking water at schools and could decrease student absenteeism. To scale up this intervention, chlorine dispensers will need to be available for schools, supplied by the government or subsidized for purchase by school hygiene committees.

POSTER PRESENTATIONS

Public Health in Pakistan: A Decade of Past Experiences and Future Challenges

Waseem Ahmed, Health And Nutrition Development Society-HANDS

OBJECTIVES: Project is aimed to provide the students sustainable access to Water And Sanitation Hygiene services in order to meet their rights to water and sanitation and improve education environment. The purpose of the baseline study was to get a bench mark for implementation of the pilot Project DATA SOURCE: This study was undertaken in all government and non-government schools in Gadap Town in September to December 2012 and data was collected on the availability of basic infrastructural facilities in the schools with respect to access to water & sanitation services. The universe of the study was Gadap Town Karachi, Sindh, Pakistan. The selected Town has 509 schools including public and private sectors. In these schools total number of students enrolled is 50000. The data was collected through different set of questionnaires that included both qualitative and quantitative format. Water samples were collected from 509 schools and tested by Pakistan Council of Research in Water Resources (PCRWR). **M ETHODOLOGY:** Water Aid and HANDS launch WASH program in 500 schools of urban slums in Gadap town and innovative approaches were introduced to engage local communities, school management, students and government officials. The basic purpose of the intervention is to sensitize all stakeholders about the importance of school WASH program and introduce the low cost models to provide water, sanitation, hand washing facilities at school level along with the integration of hygiene promotion **POLICY RELEVANCE:** Water is an essential element for our survival. Pakistan is blessed with adequate surface and groundwater resources, but unfortunately rapid population growth, urbanization and unsustainable water consumption practices have placed immense stress on the quality as well as the quantity of water resources in the country. Deterioration in water quality and contamination of lakes, rivers and groundwater aquifers has resulted in increased waterborne diseases and other health impacts. The current study has shown that nearly 50% of government schools and 24% of Non Government schools were operating in unhygienic environments and Piles of garbage/trash were present outside these schools. Practice of open defecation was much more in students of Government schools than in the students of Non Government schools. Only 46 Schools (less than 10%) were identified that they had Health & Hygiene teachers. Similarly, only in 53 (nearly 10%) schools the Health Education materials was available. The toilet facilities were available in 222 (62.4%) government schools and in 130 (85%) private school. (Over all 352 schools - 69 % have some sort of toilet facilities but only 48 % were functional). Most of these were dirty and filthy. These toilets had different systems for flushing and sewage disposal. Flush system toilets in 272 schools (53.5%), pour latrines system in 75 (15.2%) and flush attached to open drainage lines in 5 (2.3%) schools. Only in 90 (17%) schools had water supply for wash rooms including tap water supply, few schools used tankers and water in large drum/ container and small cans. In 191 (37%) schools one person had been assigned for cleanliness of the wash rooms. The data revealed gross negligence with respect to hand washing practice and availability of water & soap and its usage. The availability of hand washing facility in schools was very low: only in 96 (18%) schools. The availability of soap for washing hands was even lower only in 77 (15.2%) schools. The cost of soap falls in the ambit of recurring financial expenditures of the school budget. But it is identified that cost of soap is not budgeted and the School Managements do not pay for soap. There were different sources of water including the Tap (piped) water was present in 148 (29.5%) schools, Hand pump was used in only 9 (0.02%) schools; water in some form was purchased in 23 (0.04%) schools. Most of the supply pipes were old, rusty, leaking and needed repair. In most of the schools (86%) supply was on daily basis while in 14% schools on weekly basis. The schools were using combination of three types of water storage methods by using (i) Underground water tank (ii) Overhead water tank and, (iii) On ground fiber water tank. Most of the schools stored water in ground-based Fiber Water Tank was used. In 39 (52.7%) schools the water storage facility was cleaned on bi monthly basis and in 10 (13.5%) school on monthly basis, in 23 (31.1%). A significantly large number of Government and Non Government Schools were not using any water purification method or filter to make the water safe for drinking. **CONCLUSION** The study baseline findings supported to develop the priority setting and need identification for the intervention. The findings are also supporting to develop the advocacy and awareness

Menstrual hygiene management knowledge, facilities, and practices associated with school absence among Bangladeshi adolescent school girls

Mahbub-Ul Alam, icddr,b

Additional Authors: Amal Halder; Stephen Luby; Khairul Islam; Aftab Opel; Abul Shoab; Probir Ghosh; Supta Sarkar; Therese Mahon; Leanne Unicomb

Many adolescent girls in low-income countries struggle to find appropriate places and facilities in their school that support management of menstrual hygiene, and they miss class during menstruation. However, there is little evidence that school menstrual hygiene management facilities impacts attendance at school. This study aims to examine the association of menstrual hygiene management knowledge, facilities, and practice with absence from school during menstruation among adolescent girls in Bangladesh. We conducted a nationally representative, cross-sectional study in rural and urban schools in Bangladesh from March to June 2013 among menstruating adolescent (11 to 17 years old) school girls from grade II to grade X. We sampled 700 schools from 50 urban and 50 rural clusters within Bangladesh using a probability proportional to size sampling technique. We interviewed 2,332 adolescent school girls and conducted environmental spot checks in each school for menstrual hygiene facilities, particularly the presence of a separate improved toilet for girls with soap, water, and disposal bin. Respondents were asked to report whether they usually miss class during menstruation and to estimate the average duration (days) of absence each cycle. To assess the association between absence from school and menstrual hygiene management facilities at school, student practice and knowledge, we estimated adjusted prevalence difference (APD) using generalized estimating equations to account for school-level clustering and control for education level and age. A minority (36%) of the 2,332 adolescent school girls knew about menstruation before menarche. The most common reported practices included the use of old cloth among 86% (1,904), and use of one-time pads as absorbent during menstruation among 10% (355). School facilities were limited; only 12% (291) of adolescent school girls had access to gender-specific latrines with water and soap available and only 3% (70) of school girls had a sanitary pad disposal bin inside latrines. Among school girls, 82% (1,906) thought that school facilities were not appropriate for managing menstrual hygiene; 40% (931) reported missing school during menstruation, for an average of three school days each menstrual cycle. Absence from school during menstruation was more common in schools where girls did not have a place to change their pad/cloths than where there was a place in the school (APD=0.41; CI: 0.29, 0.53; $p \leq 0.001$); among girls who reported that they didn't feel comfortable at school during menstruation compared to those who did (APD=0.51; CI: 0.44, 0.57; $p \leq 0.001$); among girls who thought the problem of menstrual hygiene management interferes school performance compared to those who did not (APD=0.15; CI: 0.09, 0.20; $p \leq 0.001$) and among girls who thought that menstruation was a female illness compared to those who did not (APD=0.14; CI: 0.07, 0.21; $p \leq 0.024$). School absence was related to knowledge about menstruation, discomfort during menstruation and lack of school menstrual hygiene management facilities. Efforts to improve the ability of school girls to manage menstrual hygiene at school by providing a supportive environment and increased awareness can benefit students into adulthood in addition to more immediate health and educational benefits by reducing absence. Further exploratory studies to better understand reasons for school absences can inform development of effective interventions for improved menstrual hygiene management at schools.

Mooncups, pads and rags: WASH needs and access for menstruating girls in rural Kenyan schools

Kelly Alexander, Liverpool School of Tropical Medicine

Additional Authors: Clifford Oduor; Elizabeth Nyothach; Kayla Laserson; Frank Odhiambo; Linda Mason; Alie Eleveld; Penelope Phillips-Howard

Background: Water, sanitation and hygiene (WASH) programmes in African schools have received increased attention on the potential impact of poor menstrual hygiene on equity for girls' education. School water access and good latrine conditions are important aspects of the school environment for pre-pubescent and menstruating girls in Tanzania, (Sommer 2012) Kenya (McMahon, Winch et al. 2011, Mason, Nyothach et al. 2013) and South Asia (Mahon and Fernandes 2009); however a study in Malawi found no impact of school WASH on girls' absenteeism (Grant, Lloyd et al. 2013). Qualitative studies report the negative impact poor WASH conditions on girls' privacy and comfort at school (Redhouse 2004, Bolt, Shordt et al. 2006, Njuguna, Karanga et al. 2009, Jasper, Le et al. 2012, WaterAid 2012) and lack of menstrual hygiene management (MHM) may affect girls' engagement at school due to fear of leakage (Crichton, Okal et al. 2012, Mason, Nyothach et al. 2013). While insufficient MHM resources are available for schoolgirls in low-income countries (LIC), further research is required to clarify the impact of improved MHM on school and health parameters (Sommer, Kjellén et al. 2013, Sumpter and Torondel 2013). We conducted a Menstrual Solutions Study (Ms Study) in rural western Kenya enrolling menstruating primary schoolgirls (14-16 years) in classes 5-8 to receive a menstrual intervention and puberty education. The Ms Study aimed to understand the acceptability, use and safety of various menstrual solutions, within the context of the school environment, and evaluate their impact on adolescent girls' schooling, health and well-being. The purpose of this WASH sub-study was to document the needs of menstruating girls using different MS, and chart the changing patterns of WASH facilities available longitudinally over ~18 months, and its effect of on girls' needs. Methods: 30 government primary schools in rural western Kenya reached inclusion criteria of 70:1 pupil:latrine ratio and water on the day of an unannounced visit. Schools were block randomised into 3 equal arms for target girls' to receive disposable sanitary pads, menstrual cups, or maintain 'usual' (traditional, i.e., cloths) practices. Between June 2012 and December 2013 enrolled consented girls were individually screened by study nurses twice-termly. Focus group discussions were conducted among girls, parents and teachers, on girls' menstrual needs and experiences before, during, and after the study. Structured repeat facility surveys recorded WASH use, conditions and water, sanitation and hygiene services in study schools. School attendance has been documented. Results: Preliminary analyses demonstrate that girls need private places to wash or change, and water for washing hands, rags or other materials in order to feel more comfortable at school when they are menstruating. Across six follow-up visits to schools we observed that depending on the round 76-96% of schools were observed with water for handwashing. Between 16-53% of schools were observed to have soap by the handwashing stations. In terms of water being placed in or near girls' latrines, this was seen at 17-30% of schools during the follow-up rounds. Over the study the number of schools with a "private, lockable place for girls to wash or change" varied, with 30-56% of schools having these facilities at any point in time. Girls from the sanitary pad schools reported disposing pads inside latrines; however on a number of occasions used pads or wrappers were observed on the floor of the latrine or in the bushes outside. Girls in the pad schools reported no difficulty maintaining good hygiene and MHM was generally easy; particularly compared to what they "used to use." As with pads, hygiene was not a challenge for cup users; girls emptied the cup in the latrine and reinserted it, stating that they were usually able to wash their hands before and afterwards. Issues affected by all girls in all groups were a shortage of latrines and minimal break time to cue and utilise the facilities. Additional analyses will be performed by October, with more specific findings on longitudinal WASH changes in schools. Conclusions: Overall, despite the sometimes poor, less than ideal, WASH conditions at the schools, there were no health safety issues identified by the girls, nor by the nurses monitoring the girls. In order for girls in rural primary schools in Kenya to feel more comfortable and engaged in school, it is necessary for there to be better access to latrines, private latrines, and daily water and soap provision for handwashing, and washing of useable menstrual materials.

Water and rice: irrigation and water concerns in Punjab, India

Katherine Alfredo, Columbia University

Additional Authors: Tess Russo

Punjab is often considered the epicenter of the Green Revolution in India, however the sustainability of agriculture is now at risk. Grain yields doubled or in some cases tripled, while crop costs decreased due to improved varieties and seeds, irrigation, and agrochemical application. The policy and management practices that led to food security for India have ignored the rapid rate at which groundwater resources and water quality have diminished in Punjab since the 1970s. To sustain the food production, water quality, water availability, and farmer livelihoods, major shifts in behavior are required. We have been working to engage farmers, agricultural corporations, and regional policy makers with innovative research to adapt crop selection, and irrigation and agrochemical application practices. Our objective is to develop options to reduce the impacts of current practices and climate change on water and energy use, while maintaining or enhancing productivity and rural income. Agriculture in Punjab is driven by economics and government policy, but remains subject to environmental resources. The government procurement of high-water-demand rice and wheat, and subsidized energy for pumping and fertilizers remain steady despite the groundwater level and quality both declining at unprecedented rates. Given these conditions, we are conducting research in four areas: (1) development and testing of low-cost sensors to improve irrigation efficiency, (2) monitoring the quality of water over the course of the growing season, (3) modeling to quantify the relationships between crop choice, climate, and groundwater depletion, and (4) economic and crop optimization modeling to improve the government procurement program. This research explores several of these pathways through modeling and experimental field work to consider methods of optimizing irrigation, crop planting, and fertilizer application in the constraints of the policy structure surrounding rice farming in India. For the UNC Water and Health Conference, we focus on areas (1) and (3). Over the past 3 growing seasons, soil moisture tensiometers were distributed to local farmers in order to help optimize water application; however, this farmer adoption was low (~30%). The original tensiometer was designed as a low-tech instrument to keep costs around \$0.50 (Rs 300), yet this has not increased adoption or willingness to pay. Many farmers requested a tensiometer that would be easier to use and read, so a higher-tech version was developed which will cost about 5-times more. The upcoming rice growing season, summer 2014, the new electronic tensiometer will be tested in the field. This research will review the work conducted over the past four years working with Punjabi farmers to optimize water use. We will present the results from tests using the new tensiometer and project the potential impact that widespread adoption of the technology would have on groundwater level decline. To accomplish modeling the relationships between crop choice, climate, and groundwater depletion, a significant amount of data is required, but is not readily available for the region; therefore, we use Bayesian methods to estimate hydrologic properties and irrigation requirements for an under-constrained mass balance model. Using the known values of precipitation, total canal water delivery, crop yield, and water table elevation, we present a method using a Markov chain Monte Carlo (MCMC) algorithm to solve for a distribution of values for each unknown parameter in a conceptual mass balance model. Model results were used to test three water management strategies: (1) continue current practices, (2) reduce irrigation using tensiometers, and (3) replace high water consuming rice with low water consuming crops. Results of this study can be used to inform and motivate the management changes both on-farm and in government required to ensure sustainable agricultural production in Punjab.

Have you updated the PUMP? Experiences in monitoring and improving rural safe water services with an online management platform

Andrew Armstrong, Water Missions International

Water Missions International has developed a web-based platform that enables in-depth and ongoing monitoring of rural water supply services as well as targeting of post-construction support. The program update and management platform, or "PUMP", serves as a link between multiple information systems used at Water Missions International and it has become the central location for managing water supplies throughout their respective life cycles. The reporting structures required to update the PUMP are uncomplicated, accurate and reliable when introduced with adequate training. The platform has significantly improved availability,

consistency, retention, speed of retrieval and analysis of information on water supply systems supported by Water Missions International. Key capabilities of the PUMP and examples where information gathering has led to improved programming will be presented through case studies. These functionalities include the platform's ability to: accept data from multiple sources in various formats (e.g. keyed entry copied from hand-written reports, fillable forms and SMS); track activities, schedules and budgets while ensuring critical milestones are reached (e.g. confirming community investment); track and compare performance indicators related to water quality, management capacity, financial stability and safe water utilization at a single site or across different sites within a single program; and generate customized report cards for various stakeholders (e.g. community, government, implementation partner, etc.) and alerts for a variety of situations (e.g. when scheduled follow-up visits are missed or when water quality parameters are found to be outside of acceptable range).

Embedding a capability approach within sanitation marketing

Dani Barrington, Monash University and International WaterCentre

Additional Authors: Stephen Saunders; Srinivas Sridharan; Regina Souter; Jamie Bartram; Kate Shields; Urooj Amjad; William Aalbersberg; Semisi Meo

Sanitation marketing aims to improve community well-being through its core practices of innovating sanitation products and services (e.g., toilets and waste management services), stimulating demand for 'improved' sanitation, and strengthening sanitation markets. Sanitation marketing practices appear to implicitly consider human rights principles, as they aim to ensure that communities enact their rights to privacy and dignity when using sanitation products and services, while at the same time upholding community rights to life by reducing sanitation-related illnesses, deaths, and violence (UN Water, 2008). However, there is the question of whether sanitation marketing fully incorporates a Human Rights Based Approach (HRBA) to Development that particularly recognises the right to self-determination (UN Development Group, 2003). That is, the fundamental human right that enables people to develop and progress socially, economically, and culturally in a manner that they themselves determine. Self-determination is a unique human right in that it is recognised in both the International Covenant on Civil and Political Rights and the International Covenant on Economic, Social and Cultural Rights; and is the only human right that is applicable to both collectives and individuals. The extent to which sanitation marketing practices explicitly recognise the right to self-determination is unclear, as most sanitation marketing initiatives attempt to achieve well-being by changing 'bad behaviours' to pre-determined 'good behaviours'. By predetermining what are 'good behaviours', even with active community involvement, sanitation marketing runs the risk of denying people their rights of self-determination. Hence, to adopt a true HRBA, sanitation marketing must explicitly aim to enable rights-bearers to realise and enact their rights to self-determination. To achieve these aims, we propose that sanitation marketing practices should incorporate some of the main components of the Capability Approach (Sen, 1999, Nussbaum, 2011). The Capability Approach is well aligned to the HRBA as it considers the right to self-determination as a substantive 'freedom' (i.e., the opportunity to choose and to act), and ascribes an urgent task to sanitation marketers to improve well-being, as defined by their community capabilities. We present the main components of the Capability Approach, and relate it to sanitation marketing practices. We then explore some implications of embedding and putting into practice a Capability Approach within sanitation marketing. Nussbaum, M. (2011), *Creating Capabilities: The Human Development Approach*, Harvard University Press, Cambridge, U.S. Sen, A. (1999), *Development as Freedom*, Anchor Books, New York, U.S.A. UN Development Group. 2003. *The Human Rights Based Approach to Development Cooperation: Towards a Common Understanding Among UN Agencies* [Online]. UN Development Group. Available: <http://hrbaportal.org/the-human-rights-based-approach-to-development-cooperation-towards-a-common-understanding-among-un-agencies>. UN Water (2008) Factsheet: Sanitation contributes to dignity and social development. New York, USA.

Factors influencing community health promoter performance in a large-scale handwashing and home water treatment intervention in urban Bangladesh

Farzana Begum, icddr,b

Additional Authors: Peter Winch; Leanne Unicomb; Elli Leontsini; Pavani Ram; Probir Ghosh; Mst Mobashara; Bijoya Sarker; Tania Jahir; Stephen Luby

Background Community health promoters (CHPs) are frequently used change agents for large-scale health interventions, predominantly delivering messages through interpersonal communication. WASH interventions commonly include both hardware and software components. However CHP training often focuses on delivering educational messages rather than addressing hardware problems related to use and maintenance. Despite the reported impact of CHP performance on intervention effectiveness, little is known about the barriers they face when implementing large-scale WASH programs that include hardware. This study was undertaken at the end of an intervention that was provided to 5,000 randomly selected low-income household compounds, implemented from March 2011 to August 2013. We describe CHP knowledge of roles, responsibilities, intervention messages; barriers to promoting handwashing with soap and home water treatment with liquid chlorine, and difficulties addressing enabling hardware issues. We also explore factors that motivate CHPs to perform their duties.

Methods Fifty-five female CHPs ages 18 to 45, with a minimum of 10 years of education were recruited from the local community. Each CHP was expected to reach 400 households or 100 compounds on average through monthly home visits. They received a monthly remuneration for approximately 48 hours of work per week. They received basic and refresher training at the beginning and during the second year of implementation. They were trained on their roles and responsibilities, target intervention behaviors, and communication and facilitation skills. They delivered behavior change messages, distributed hardware, filled chlorine dispensers, solved problems and monitored hardware functionality. CHPs promoted handwashing with soap at three key times: after defecation, after cleaning child's anus, and during food preparation. To encourage home water chlorination they demonstrated the chlorination procedure and educated target household members on five benefits of using chlorine to treat water. We interviewed all 55 CHPs using a semi-structured questionnaire and asked about their job responsibilities, benefits of the intervention, barriers faced and factors that motivated them to do their work. We calculated the proportions of hardware and non-hardware promotional barriers and determined the difference of these proportions. We constructed economic and social motivation factors from six motivation related variables and performed factor analysis. An economic factor was constructed from the variables; employment opportunities, and competitiveness of salary and benefits offered. A social factor was constructed from the variables; recognition by the community, connection with a reputable organization and family support to be a CHP. To determine the association of these motivation factors with CHP age we determined the mean difference of factor score between two age groups.

Results Of 55 CHPs, only 23 [42%] could recall at least 7 of their 8 responsibilities. 19 [34%] recalled 5 hardware related responsibilities (hardware distribution, functionality check, replacement, storage vessel marking, and chlorine refills). 51 [93%] CHPs recalled all three key times for handwashing, and all (n=55) mentioned the correct dose of chlorine for treating 10L of water. Only 15 [27%] CHPs recalled all five benefits of drinking chlorine-treated water. Among training subjects, CHPs predominantly recalled non-hardware topics that included their role and responsibilities (62%), intervention messages (51%), communication skills (62%) and facilitation skills (58%). Barriers faced during home visits included hardware related problems (breakages, leakage) more commonly than non hardware problems (e.g. access restricted by compound owners, increased detergent price and chlorine smell; 45% vs 5%, $P \leq 0.001$). When comparing the barriers to promoting handwashing and chlorination, 46 [60%] CHPs mentioned that promoting chlorination was more difficult than handwashing. We detected that younger (< 35 years) CHPs were more motivated by economic factors (Mean difference = 0.04, $p = 0.022$), whereas the social factor (Mean difference = 0.056, $p = 0.011$) was detected as a stronger motivator for those >35 years.

Conclusion Although CHPs had good knowledge of handwashing and the dose of chlorine for water treatment, they had poor knowledge of

their roles and responsibilities, particularly those related to hardware. They had limited recall of the benefits of home water chlorination. CHP motivation differed by age. To implement large scale WASH interventions that include enabling hardware, the CHP training and supervision plan should include measures to ensure that they clearly understand their roles and responsibilities, understand the benefits of the intervention and are capable of responding to technical hardware problems. Social motivation can be highlighted when recruiting, training and mentoring CHPs for similar program

Assessment of Pathogenic Bacteria in Greywater and Irrigated Soils

Maya Benami, Ben Gurion University of the Negev

Additional Authors: Osnat Gillor; Amit Gross

Reuse of greywater (GW) for irrigation is recognized as a sustainable solution for water conservation. One impediment for reuse of GW is the possible presence of pathogens. Sustainable on-site GW application requires that systems be efficient, cost effective, and safe in terms of public health and the environment. To understand possible GW health risks the abundance of six pathogens and indicators were investigated in three recirculating vertical flow constructed wetlands (RVFCW) treating GW. Our objectives were to: 1) examine pathogen loads in biologically treated versus disinfected GW and to 2) test for the pathogens in the soil irrigated by GW. The study was conducted in a unique field setup of three on-site GW treatment systems i.e., RVFCW's equipped with chlorinators and low pressure 50W UV lamp disinfection systems. We tested the same sourced raw, treated and disinfected GW for pathogens and indicators. In addition, we tested the GW irrigated soil in household yards and as a control sampled four soils irrigated with freshwater. The different matrices were sampled for *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella enterica*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, and *Shigella* spp. over the course of one year using culture -dependent and -independent methods. Similar bacterial pathogens and indicators were found in treated GW and the respective irrigated soils. Interestingly, a similar array of pathogens was also found when freshwater was used to irrigate the soil although none were found in the water. Moreover, the abundance of these bacteria in treated GW- and freshwater- irrigated soils was of the same order of magnitude, putting to question the source of the pathogens. To further eliminate the putative health hazard posed by treated GW we tested the efficiency of simple UV and chlorine applications on the treated GW. Pathogen and indicator concentrations were markedly reduced in both methods. Our results suggest that GW irrigation has no effect on the diversity and abundance of the tested pathogens and indicators in yard soils. We further show that disinfection is effective in treating the pathogens present in GW to lower than infectious dosage levels. We therefore postulate that it is possible to use GW for yard irrigation: (a) because it is possible to treat GW using low tech systems and disinfection for safe reuse and (b) because treated GW may not be a major contributor to pathogens in yard soils.

Effect of encouraging low-income households to create their own handwashing station on handwashing with soap before food preparation and before feeding a child

Debashish Biswas, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)

Additional Authors: Fosiul Nizame; Sumitro Roy; Tina Sangvi; Stephen Luby; Leanne Unicomb

Introduction: Diarrhea, an important cause of child death, increases from around the time that complementary foods are introduced. Consumption of contaminated food may contribute to diarrhea and growth faltering. Caregiver's hand hygiene during food preparation can prevent food contamination and reduce diarrhea transmission. Washing hands with soap is more common when water and soap are together at a convenient

location. However, in Bangladesh, especially in rural locations and among low income communities, soap, water sources and handwashing places are often distant from food preparation and child feeding areas. Alive & Thrive through a local NGO conducted a three month pilot nutrition and hygiene intervention in two rural districts in Bangladesh. The trial aimed to determine the acceptability and feasibility of the intervention and comprised two groups; one where 40 households received a free of cost handwashing station consisting of a 40 litre plastic bucket with tap and lid, stool and a 1.5 liter plastic bottle with free detergent powder to make and store soapy water (a mixture of water and detergent powder) as an alternative to bar soap. A further group comprised 40 households that were motivated to place their own soap/soapy water and a water vessel near the food preparation and child feeding area. Methods: Community health workers promoted intervention recommendations through home visits, mothers' group meetings and community meetings with a video show. They assisted study participants to install the study-provided handwashing station at the recommended place or encouraged mothers to develop their own handwashing station from available household resources and demonstrated soapy water making. They encouraged mothers and other family members to wash their hands with soap/soapy water after defecation/cleaning a child's anus, before food preparation and feeding a child. A qualitative team assessed the effectiveness of promoting provision of households' own handwashing station compared to providing one for free in facilitating handwashing behavior. Qualitative assessments included semi-structured interview and unstructured observation during three follow-up visits over a period of 80 days to determine the frequency of handwashing with soap among caregivers and regular use and location of handwashing stations in a convenient place. Results: By the end of the trial, reported handwashing practice rates among caregivers increased from 71% (24/34) at the first assessment to 89% (31/35) in the final assessment in the study-provided handwashing station group and from 53% (21/40) to 71% (29/41) in the own handwashing station group. Observed handwashing with soap was detected among 80% (8/10) from study-provided handwashing station group and 50% (5/10) among the own handwashing station group at the final assessment. Although the proportion of caregivers who reported use of handwashing stations (both water vessel and soap/soapy water) was higher in the study-provided handwashing station group, by the end of the trial, among the group that developed their own handwashing station 63% (26/41) of caregivers reported and 40% (4/10) were observed using a handwashing station regularly. This mostly comprised an existing household bucket for water storage, a jug or mug to pour water over hands and a plastic bottle for making and storing soapy water. Study participants explained that the main motivator for regular use of a handwashing station was having water and soap in one place near the food preparation and child feeding area, so that they did not need to go elsewhere to wash hands with soap. Community members in both intervention groups reported preference for soapy water over bar soap because they found soapy water easier to use, dispense from the bottle with a hole in the cap; pour into the palm of their hand shortening the duration of handwashing. They described that there was minimal waste of soapy water by children. Conclusion: A handwashing station with soap and water placed at a convenient location can increase handwashing behavior and in the absence of large scale provision of handwashing stations, caregivers can be encouraged to create and use their own handwashing station.

How did E. Asian Tigers Provide Sanitation Access So Quickly?

Timothy Brewer, WaterAid

Additional Authors: Henry Northover; Shin Kyu Rue

How Did East Asia's 'Tigers' Provide Sanitation and Hygiene So Quickly? This paper will discuss how high levels of sanitation service at scale can be achieved, even in poor countries over short time horizons. This will be a timely contribution to the debate over what is possible within the 2015-2030 timescale and how best to improve sanitation and hygiene at scale. It will argue that ? Sanitation transformation is commonly government-led and integrated with a plan of economic development that incorporates housing and planned urbanisation ?

Programmes which omit to support the structural issues of weakly staffed, unclearly led and uncoordinated sector institutions are unlikely to achieve sustainable transformation at scale ? Narratives of national transformation, economic and human development may be more powerful than health statistics or education benefits to advocates for sanitation We will present new research into the political economy of achieving universal access to sanitation, discussing the East Asian developmental states. Several countries in East Asia have achieved universal access to sanitation in a rapid timeframe, from a baseline economy and global context similar to that faced by many developing countries now. While recognising the highly contextual and complex nature of sanitation improvements and development, WaterAid has commissioned this research into recent history, to identify key lessons that may apply in other country contexts. This presentation will synthesise new research into how countries achieved the transformation of universal access to sanitation within 15 years, and what the WASH community can learn from their experience particularly in post-2015 framework of universal access to WASH. The presentation will interrogate the roles of government policy, state subsidy, state owned enterprises, housing policy and city planning, international aid, the role of education departments, and public health messaging, as well as private supply and behaviour change. Key questions include: - To what extent were local level behaviour change efforts influential? - Was sanitation coverage an outcome or a driver of economic growth? - What level of coverage was achieved while the countries were still LIC equivalent? An early draft of this paper will be presented as a discussion paper at Stockholm world water week, and the final paper will be further shaped by the responses and discussion that this generates. The research will target a diverse audience including representatives of developing country government, multilateral and bilateral donors and civil society, with the aim of encouraging constructive debate around the drivers of sanitation in development. We hope to foster a multi-disciplinary discussion drawing together WASH sector professionals and those with expertise in governance and aid management. The UNC Water and Health conference will be the ideal venue to disseminate the conclusions of this research to policy-makers, practitioners and researchers. We want to encourage discussion of the drivers of sanitation transformation at nationwide scale, examine examples of 'positive deviance' in developmental states and discuss the lessons for others. UNC will allow us to open this research to challenges and questions from experts, in order to identify weaknesses or areas for further study Additionally we are keen to share the political messaging and concepts around water and sanitation that have proven sufficiently persuasive in one setting, and to ask whether advocates are exploiting parallel opportunities sufficiently in countries where progress is slow. In the context of the global conversation around development after 2015, and the goal of universal access by 2030, this evidence will: ? Build support for the principle of sector-strengthening as a necessary condition for nationwide the transformation of national approaches to sanitation ? Promote innovative and powerful new advocacy messages in different contexts ? Provide inspiration for government and sector professionals ? Challenge some elements of the established 'INGO' programme and community based approaches to sanitation at scale

The WASHplus Approach for Discovering, Collecting, Curating and Disseminating WASH Sector Knowledge and Information

Dan Campbell, USAID WASHplus

Introduction - One of the conference themes is Monitoring and Evaluation: Impact and Efficiencies for Projects and Programs. This poster will provide information on developing knowledge management programs for WASH organizations and discuss methods to monitor and evaluate the effectiveness of a knowledge management program. In the WASH sector, information and resources are scattered among a wide range and number of publications, organizations, information networks, experts etc. Social media channels have helped to contribute to this flood of information. Sorting through this growing and often overwhelming amount of information requires a careful process of identifying, selecting and validating to ensure that you are finding and in turn sharing the best sector information available. Globally, according to online research firm eMarketer, total social media users are forecast to grow everywhere, but the most explosive growth over the next few years is

expected to occur in the Asia-Pacific region (including China, India, and Indonesia), Latin America, the Middle East, and Africa. As users in these regions join in these technologies, even more WASH practitioners will utilize these methods to access, identify and share information and make social and professional connections.

WASHplus Approach - This poster will explore the sources, methods and dissemination channels used by the WASHplus project to find, manage and share WASH sector knowledge and information. This approach can be adapted by other WASH organizations that may also be overwhelmed by the process of finding and sharing information, and at the same time seek cost effective ways to do this. Steps that are part of the WASHplus approach include: - Identification/Collection of Information -- Follow key journals and websites and subscribe to key listservs -- Monitor social media channels such as Twitter, Yahoo, Facebook and LinkedIn -- Build your social network to develop regular sources of information and to use as channels of dissemination -Analysis --Select relevant information that is high quality and timely -Content Curation - Curation is the process of collecting, filtering, organizing and editorializing your own organization's information as well as content from other organizations and individuals. Content can be visual, textual or aural content. The steps in this phase includes: -- Define goals and approach (specific or very targeted) -- Understand you audience needs and gaps in knowledge and information -- Develop Content: Focus on the interests of the audience/users. Examples of content types include: blogs, articles, announcements, presentations, newsletters, websites, infographics, webinars, podcasts, videos - Dissemination - -Target/segment specific audiences --Select appropriate social media and other channels such as: Social networking sites (e.g. Facebook, LinkedIn,); Video and photo sharing websites (e.g. Flickr, YouTube); Blogs (Wordpress, Blogger); Microblogs (e.g. Twitter, Tumblr); Forums, discussion boards, and groups (e.g. Google Groups, Yahoo Groups); Video on demand and podcasts. - Monitoring and Evaluation - Monitoring and evaluating the effectiveness of information dissemination activities and evaluating the usefulness of products or channels is more than just counting likes and followers.

Life-Cycle Cost Analysis and Affordability of Fluoride Mitigation Alternatives in Ethiopia

Jim Chamberlain, University of Oklahoma

Additional Authors: Anisha Nijhawan

Consumption of excessive geogenic fluoride in drinking water can lead to dental and/or skeletal fluorosis. Appropriate technologies for fluoride removal from groundwater sources in east Africa fall into two main categories - coagulation/precipitation and adsorption. Two feasible coagulation/precipitation techniques are the Nalgonda system and electrodefluoridation (EDF), the latter being a newer innovation from India. Adsorption systems have used two types of media: activated alumina (AA) and bone char made from locally available cattle bones. All systems are being used to treat groundwater with fluoride concentrations that are as much as an order of magnitude higher than the WHO recommended limit of 1.5 mg/l. Sustainability of the selected approach depends upon a pricing structure that is both affordable (and, thus, adoptable) and profit-generating so that private enterprises may recoup costs and increase market share. This research compares the four systems on a life cycle costing basis of all costs for delivering fluoride-safe water, from catchment to consumer. Costs at both household- and community-level scales are evaluated on several bases - by volume of water delivered and by household. Recurring costs include capital maintenance and replacements, as well as ongoing operation costs. Finally, the affordability of each alternatives is assessed using demographic data, the ability to pay, and requirements for long-term sustainability.

Future of Sanitation lies at its Origin of Development

Vijaya Kumar

Additional Authors: Chilukuri Chilukuri

With the advent of fast urbanization and population explosion, our attention to address the sanitation issue is more focused towards Technological development and Financial needs. In the whole of the scenario, the missing functionary is the 'beneficiary' for whom we have been very well concerned. Today, we have technologies that can construct an individual household toilet at a cost equivalent or less than the cost of a cell phone. However, People's demand has been more towards owning Cell phone rather than to own toilet. Unfortunately, most people do not aware of these aspects. The poor and the women and children are the most suffered. Hence it is indeed very important and essential to bring "Social Transformation" among the people, communities, the authorities that implement for the welfare of the society and the environment. The Social transformation develops Trust, sense of belonging by their involvement, willingness to contribute and leadership for the actions needed. The main thrust in promoting Social Transformation in cities, towns and villages lies in emphasizing awareness creation among people about benefits of safe sanitation, healthy living and benefits of open-defecation-free habitats as well as pollution-free environments. People of the habitat should be involved from the design stage till the completion of their sanitation project. The process is illustrated as below: The whole of the habitat project population should consider as one unit of operation. Initially prepare the list of beneficiaries and personally have interactions through Door-to-Door meetings. Community sittings, Village meetings with concerned stakeholders further strengthen the plan of action. Identify the professional abilities of the individual beneficiaries, like masons, helpers, carpenters, electricians, etc. In the two pit toilet technique, except the pan and p-trap the rest of requirements including pit digging, super structure are service oriented which the mason and the labour can handle. Organize a plan of action with the beneficiaries sharing their services. An integrated approach of beneficiaries formulating as a single family for a targeted time frame has been a noble effort on the part of people's dedicated contribution. The message from this model is the transformation of people's mind set as 'Movement' and the possibility of constructing toilet at a minimal cost of the pan and trap; the rest is all labour. The capacity building programmes for masons and other functionaries should be Training of Trainers (TOT) programmes which would indeed help in fostering the construction of toilets at individual household level and at the same time disseminating to other areas in the same manner. The cost items being only the PAN and the P-trap, one can approach for international assistance like UNICEF or local government or private sector can promote production of these equipment at a reasonable cost or government can provide subsidy to these items. Or, one can approach for financial assistance from corporate sector under the Corporate Social Responsibility. In India efforts are in practice to transform the sanitation culture from a socially oriented system into a "Peoples Movement" by exploring and demonstrating on-site innovative alternatives. Thus the near future of sanitation in the developing countries lays at its origin of development, namely, "the people". Its direction can now be defined towards promotion of developing open-defecation-free societies with pollution-free environments. In general, around 80% of population belong to rural and small and medium towns. We can target this approach covering those people's sanitation needs. This approach is cheaper and the implementation is faster. The solution to address the problem of sanitation for the developing world, which also implies the near future of sanitation, lies in adoption of "Technological development with Social Transformation". This approach also combats the problem of manual scavenging in countries of India. It is essential to turn the sanitation development process into a people's movement with the people themselves becoming agents of change. This innovative approach provides sustainable environmental sanitation development to bring about lasting change in the habits and attitudes of the community. This approach has assisted in building the capacities of the communities with the objective of helping them to learn and believe in their own ability to help themselves, their communities and others. The above were implemented on ground reality successfully. Around 4,500 slums of Hyderabad have been benefited under this process. The whole village of Hirmitla in Mewat district of Haryana has become open-defecation-free village and recognized under Nirmal Gram Puraskar of Government of India.

Examining the influence of urban definition when assessing relative safety of drinking-water in Nigeria

Elizabeth Christenson, UNC Chapel Hill

Additional Authors: Robert Bain; Jim Wright; Stephen Aondoakaa; Rifat Hossain; Jamie Bartram

Reducing inequalities is a priority from a human rights perspective and in water and public health initiatives. There are periodic calls for differential national and global standards for rural and urban areas, often justified by the suggestion that, for a given water source type, safety is worse in urban areas. For instance, initially proposed post-2015 water targets include classifying urban but not rural protected dug wells as unimproved. The objectives of this study were to: (i) examine the influence of urban extent definition on water safety in Nigeria, (ii) compare the frequency of thermotolerant coliform (TTC) contamination and prevalence of sanitary risks between rural and urban water sources of a given type and (iii) investigate differences in exposure to contaminated drinking-water in rural and urban areas. We use spatially referenced data from a Nigerian national randomized sample survey of five improved water source types to assess the extent of any disparities in urban-rural safety. We combined the survey data on TTC and sanitary risk with map layers depicting urban versus rural areas according to eight urban definitions. When examining water safety separately for each improved source type, we found no significant urban-rural differences in TTC contamination and sanitary risk for groundwater sources (boreholes and protected dug wells) and inconclusive findings for piped water and stored water. However, when improved and unimproved source types were combined, TTC contamination was 1.6 to 2.3 times more likely in rural compared to urban water sources depending on the urban definition. Our results suggest that different targets for urban and rural water safety are not justified and that rural dwellers are more exposed to unsafe water than urban dwellers. Additionally, urban-rural analyses should assess multiple definitions or indicators of urban to assess robustness of findings and to characterize a gradient that disaggregates the urban-rural dichotomy.

New latrines, old latrines: drivers of demand for urine-diverting toilets and local sanitation innovation in peri-urban Malawi

Richard Chunga, London School of Hygiene & Tropical Medicine

Additional Authors: Richard Chunga; Joe Brown

Pit latrines are a common form of sanitation in peri-urban areas but they have several limitations. Alternative on-site sanitation technologies have been introduced and promoted in many settings in Southern Africa to overcome some of these limitations. One of the most popular of these is a urine diverting toilet (UDT), a dry composting latrine. Although recycling of human excreta into valuable compost is a key feature of this technology, proponents also believe that the technology could also be ideal where adequate space for sanitation is unavailable, since UDT represents a more permanent solution over pit latrines, which are often replaced once full, which requires additional space that may be valuable in urban and peri-urban settings. Despite widespread efforts to promote and implement UDTs, adoption has been very slow in Malawi and there is limited information about factors affecting uptake in target populations. From January to September 2013, we carried out a mixed methods study in Blantyre and Lilongwe City in Malawi to explore key factors affecting the adoption of this technology and to explore other strategies that users adopt to cope with the limitations of pit latrines, with a specific focus on sanitation option decision-makers (in this context: landlords). We interviewed 11 landlords with UDTs, 45 landlords without UDTs and 10 tenants using UDTs. After in-depth interviews, we selected 27 peri-urban areas that have been targeted in UDT promotion efforts using a multi-stage sampling approach and recruited 1300 landlords at random who have not adopted UDTs to participate in a study of sanitation uptake. Results of qualitative interviews carried out as part of the mixed methods research identified five key drivers and three barriers associated with the adoption of UDTs. Landlords adopt or desire to adopt UDTs because they want to: avoid running out of space for sanitation, own a sanitation facility that will not

collapse, avoid installing sanitation facilities frequently, own a sanitation facility that is compatible with limited space, and to access compost (cheap fertiliser). However, accessing compost was not the most important driver for most landlords, despite this being a focal point of local messaging in promotion. Results from the household survey show that only 5% (61) of the landlords interviewed had intention to adopt a UDT. Fewer landlords had intention to adopt UDTs because they are not perceived as affordable, they are not compatible with multiple tenants (important in this rapidly urbanizing area) and they introduce an unacceptably high burden to users for operation, especially when shared among multiple households. We found, however, that local innovation of pit latrines provided a more compelling alternative to UDTs. Landlords generally cope with the limitations of pit latrines by pouring water to pit latrines to extend the lifespan of their pit latrines, installing new pit latrines on old pit latrine sites or old refuse spots, and improving the build quality of their pit latrines. After landlords make these improvements, the pit emptying process presents advantages over UDTs. Adaptive strategies undertaken by landlords to cope with the limitations of pit latrines are easier and cheaper to implement than investment in a UDT or other alternative sanitation technologies such as pour flush toilets or fossa alterna toilets. This study underscores the importance of user innovation as a key factor in making sanitation work for the urban poor. Expanding access to sanitation must be based on a clear understanding of the needs, desires, means, and behaviours of the target population and a recognition of their adaptive strategies for overcoming the limitations of existing technologies.

Improving Health in Rio de Janeiro's Favelas through Water Education

Morgan Close, Project WET

Rio de Janeiro is in the international spotlight with the 2014 World Cup and the 2016 Olympics. The government of Rio de Janeiro and Brazil have promised infrastructure upgrades to the residents of favelas, however to date residents have seen little improvement. However, the Project WET Foundation believes residents can improve their living conditions through simple behavior changes around water, sanitation, hygiene and trash management. Project WET implemented a customized education program in favelas in the North Zone of Rio de Janeiro with the goal to create a healthier environment through lasting behavior change. This program allows communities to focus on solutions that they can control in the short-term--behavior change that results in decreased contamination of water, water loss, parasites and disease. Data was collected from control neighborhoods not using the Project WET program and neighborhoods using the Project WET program to determine any effects of the education program on health behaviors. (Note: next data collection will be in July with results ready before October)

Sanitation externalities, disease, and children's anemia

Diane Coffey, Princeton University

Anemia is a disorder of the blood marked by lack of hemoglobin, the protein responsible for carrying oxygen throughout the body. Hemoglobin deficiency has serious health and economic consequences. In adults, it reduces work capacity and thus productivity, and is a major cause of maternal mortality in developing countries. Children who are hemoglobin deficient have impaired cognitive ability and physical development, and are more susceptible to disease. Considering the high global prevalence of anemia, and the relationships between child cognitive ability, schooling, and adult productivity, anemia is a health problem with enormous human and economic consequences. International variation in anemia rates is not well explained by differences in income. Indeed, Alderman & Linnemayr (2009) suggest that economic growth alone is unlikely to reduce the high rates of anemia in developing countries. In sub-Saharan Africa, malaria is known to be a major cause of anemia. In South

Asia, however, where malaria is far less prevalent, explanations for high anemia rates have tended to focus on diets. Without denying the importance of food intake, this paper focuses on the disease environment, and particularly intestinal diseases that inhibit nutrient absorption, as a cause of anemia. Although prior research has linked intestinal disease to nutritional outcomes (Checkley et al., 2008), this is the first paper to link poor sanitation environments with average hemoglobin levels in populations. As in Spears (2013), this paper measures sanitation by estimating rates of open defecation. Open defecation is the practice of defecating outside without a toilet or latrine. Over a billion people worldwide defecate in the open, and it is especially common in South Asia. Nearly 60 percent of the people in the world who defecate in the open live in India. Open defecation is of public interest because it has significant negative externalities; even people who use toilets or latrines can be made sick by open defecation in their environments. Further, those who use toilets or latrines do not capture the full social benefit of the behavior. This project hypothesizes two main mechanisms through which poor sanitation causes anemia. This first is intestinal parasites; intestinal parasites cause blood loss in the stool, lack of appetite, competition for nutrients, and damage to the intestinal wall that leads to decreased absorption of nutrients. The second is environmental enteropathy, a disease which alters the lining of the intestine and inhibits absorption of calories and nutrients. The approach of this paper is novel in that it applies econometric techniques to nationally representative and cross country data in order to show relationships at a population level. Prior studies about the causes of anemia tend to use smaller data sets than the ones used here, and randomized trials of interventions to improve hemoglobin tend to focus on independent variables measured at the individual level, such whether a child received an iron supplement, fortified food, or a deworming pill. However, because of the externalities associated with open defecation, its effects are most appropriately studied at the community level. This paper presents several empirical analyses of children's hemoglobin levels that indicate that open defecation contributes to a disease environment that causes anemia. It uses three complementary methodological approaches, including cross country variation, cross-sectional variation within South Asian countries, and over time variation within regions of Nepal to establish the robustness of the relationship between children's hemoglobin and the practice of open defecation. All of these analyses show a statistically significant and quantitatively important association between open defecation and children's hemoglobin levels. This paper also provides direct evidence for one of the proposed mechanisms leading from open defecation to anemia: it finds that in India, the association between taking parasite medicine and children's hemoglobin is lower for children who live in places with higher rates of open defecation, and thus have higher exposure to reinfection. These results, combined with traditional economic justifications for investment in public goods, suggest that policy makers and program implementers should consider sanitation provision an important part of the public response to anemia, especially where open defecation is widely practiced.

Over-reporting in handwashing self-reports: potential explanatory factors and alternative measurements

Nadja Contzen, Eawag

Additional Authors: Sandra De Pasquale; Hans-Joachim Mosler

Background The most effective prevention against diarrheal disease is handwashing with soap at key times. Handwashing interventions are thus a program priority in development and emergency-relief organizations. Interventions' evaluations are essential to identify effective programs leading to improvements in behavior and health. However, measuring handwashing behavior is quite difficult. Household observations are thought to be valid but they are time-consuming and thus very inefficient; self-reports are thought to be very efficient but invalid (i.e. biased) with desirable practices being over-reported. While social desirable answering is claimed to be the main cause of the inflated self-reports, the underlying factors and mechanism are understudied. First, the present research aimed to study in-depth the processes involved in over-reporting with the purpose to gain new indications how to improve interview questions and situations and how to adjust self-reported data to mitigate

over-reporting. The factors to be tested included (1) social desirable answering as a personal tendency or as a social phenomenon depending on prevalent social norms and the presence of third parties; and (2) factors affecting the encoding, retrieval and integration of behavior information. Factors considered in this second group were i) dissonance reduction through over-reporting, ii) a regular daily household routine as it might help to remember the intention to wash hands and thus lead to more accurate encoding, iii) frequent task interruptions as dealing at once with many things impairs remembering, so that people might forget regular handwashing more often when being frequently interrupted and thus encode less accurately, and iv) a person's general tendency to over-estimate. Further, the project aimed at testing alternative interview questions that potentially alleviate the response bias. Method Data were collected cross-sectionally as part of a larger handwashing project in rural villages of the Borena zone, Ethiopia, by means of two- to three-hours-long observations and one-hour-long interviews with the primary caregiver in a household. A total sample of $N = 554$ was surveyed. Data were analyzed by means of correlation analyses, hierarchical multiple regression analyses, independent and dependent t-tests and analysis of variance. Results Factors explaining over-reporting. In terms of social desirable responding, participants with a personal tendency to respond socially desirable and with high injunctive and descriptive handwashing norms tended to over-reporting in stool- and food-related handwashing. In addition, dissonance processes were also correlated with over-reporting; that means that respondents with low handwashing frequency and high handwashing health knowledge (what supposedly causes dissonance) as well as low cognitive rationalization showed more over-reporting than respondents with (1) high handwashing frequency and high handwashing health knowledge, (2) low handwashing frequency, high handwashing health knowledge but high cognitive rationalization, and 3) low handwashing frequency and low handwashing health knowledge. Additionally, over-reporting of food-related handwashing was higher for respondents with a general tendency to over-estimate. Alternative interview questions. While the tested approaches suggested in the literature to mitigate social desirable responding (i.e. loaded questions wording, forgiving wording and permissive or restrictive contexts) did not affect over-reporting, the present project also tested a new approach to measure handwashing, namely script-based covert recall. At this, instead of asking directly about handwashing, respondents were asked to retell typical behavior sequences of key activities relevant for handwashing (e.g. food preparation). The retelling should activate the according behavioral memory scripts which are thought to include handwashing if handwashing is habitually performed as part of the relevant key activities. With this measurement, over-reporting was significantly lower with regard to stool- and food-related handwashing when compared to conventional self-reports directly asking about handwashing. Conclusions Although the difficulties involved in measuring handwashing by self-reports and observations are widely known, the present study is the first one investigating factors explaining over-reporting in handwashing; it also tested measures to mitigate over-reporting. While it delivers only initial results on a complex phenomenon, it contributes to a limited evidence-base on a highly important subject, that is how to evaluate handwashing interventions efficiently and accurately. We hope that the present study stimulates further research looking on over-reporting in handwashing.

Improving monitoring of sustainability in WaSH: evaluating existing frameworks and a systematic review of the evidence

Ryan Cronk, The Water Institute at UNC

Theoretical work on sustainability in water, sanitation, and hygiene (WaSH) has led to improvements in the sector, but less attention has been paid to identifying the empirical determinants of sustainability. Theoretical models establish technical, social, financial, policy, and environmental determinants of sustainability. Such models are useful for highlighting the types of factors that are expected to determine sustainability over time, and can predict with some accuracy that interventions lacking certain provisions will fail at high rates. However, few of these ab-initio tools can accurately predict the sustainability of apparently adequately-designed WaSH interventions (i.e. the probability that measurable benefits will continue to flow to beneficiaries over time), or

identify the highest-impact opportunities for improving the sustainability of such programs. Ongoing operations of WaSH interventions depend on complex processes that can fail at many different points in countless ways. Each of these ways represents a potential "sustainability factor," but not all factors are equally important in a given program or setting. Numerous studies have demonstrated that in a given setting, a small number of "critical sustainability factors" may explain the majority of the variability in outcomes. This systematic review compares theoretical sustainability monitoring tools to empirical studies that have examined factors that significantly affect sustainability in WaSH. This review produces the first list of core indicators that can be used to measure sustainability in WASH projects and programs. This core list of indicators provides a set that can be cost-effectively included within existing monitoring tools and initiatives and can be brought to scale. Gaps in the literature and future WASH sustainability research needs will also be examined.

Dewatering and Drying of Sanitary Wastes by Novel Use of a Breathable Membrane Process

Steven Dentel, University of Delaware

Additional Authors: Shray Saxena; Solmaz Marzooghi; Babak Ebrazzi; Paul Imhoff

The simplest form of management of sanitary wastes is to separate the water from waste and dispose of the latter in a hygienic manner. This is easier to do in treatment facilities with very high flow capacities and advanced technological capabilities. However, in developing nations with high population densities and shortage of free land, open defecation and primitive pit latrines fail to do this. Both allow waste-contaminated water to escape, leading to unsanitary conditions. Here, we describe a new process that dewater and dries fecal sludge using a hydrophobic or "breathable" membrane. This type of membrane does not allow passage of liquid water, or of any contaminants within the water, but does allow transport of water vapor, driven by a difference in vapor pressure or temperature. The evaporated moisture condenses on the other side of the membrane to produce contaminant-free water. Unlike common mechanical dewatering processes, no mechanical pressure is required, because the temperature gradient is what induces water migration. We show how this method derives from the membrane distillation process used in desalination and, perhaps most surprisingly, how the membrane resists fouling or clogging through repeated use. The result is a process capable of producing completely dried solids and clean water using a modest temperature gradient. Hence, it offers a potential solution to the sanitation problems of developing world. Our research required evaluation of numerous variables, including membrane types and the properties of the inner and outer fabric layers into which the membrane is laminated. We report on two evaluation methods we developed: for both, one side of the membrane is placed directly in contact with the sludge and, while water vapor is released through the membrane, the sludge solids content is monitored while it increases. One method is for processes with air on the opposite side of the membrane, and the other applies when the opposite side is soil/water. Using these methods, we determined the rate of water vapor release per area of membrane under a variety of conditions. Our first observation was simply that the drying occurs quite completely, even with modest temperature differences. An important point is that the sludge separates from the membrane as it dries, leaving a clean membrane for re-use (Figure 1). These observations are consistent with the results from electron micrograph images of hydrophobic membranes, before and after sludge drying. The drying rate provides additional evidence that the membrane is not clogging, because it stays almost constant over reuse of the membrane (Figure 2). However, the drying rate is strongly dependent on the membrane properties, so prediction of performance can be predicted by measuring the thermal and evaporative resistances of the membrane. These parameters, which also take into account the membrane tortuosity, porosity and thickness, can be measured using a "Sweating guarded hot plate." We show the results of these tests and relate them to breathability and other characteristics of process performance. Theory predicts that drying rates should decrease if water or soil on the membrane's exterior limit mass transfer due to low void volume or to any degree of water saturation. We confirm this experimentally. We conclude with the planned means of implementing this process. With the collaboration of WaterAid in India, this process is to

be installed in slums of Kanpur, India, in two specific types of locations. The first is for very poor areas with flimsy shelters and widely practiced open defecation; used drums, vertically placed and partially buried, will be lined with an air-permeable spacer and, interior to this, the breathable membrane. The second is for areas with no sanitation but crowded masonry structures, using elevated toilets with sludge drying and contaminant capture at ground level with a vertical or horizontal membrane fabric-lined drum (Figure 3). The low cost, low maintenance and simple design of these toilets (with details provided in our presentation) will provide affordable sanitation for a typical family, allowing waste drying while preventing contaminant release. Drying in situ increases the use time before the container is emptied, with the waste being further composted after removal.

Development of low-cost and effective sorbents for drinking-water fluoride mitigation in developing regions the Rift Valley of Ethiopia

Junyi Du, The University of Oklahoma

Additional Authors: Teshome Yami; David Sabatini; Elizabeth Butler

Fluoride in drinking water can cause severe health problems at levels above the World Health Organization drinking water standard of 1.5 mg/L. Therefore it is imperative to remove fluoride from drinking water. Among current available technologies for fluoride removal, adsorption is efficient, economical, and suitable for household use. While many materials, such as activated alumina, activated carbon, bone char, and clay, are widely used as fluoride adsorbents, their high manufacturing costs and low fluoride adsorption capacity limit their applications in less developed regions. Therefore, the objective of this study was to develop low-cost but high-efficiency fluoride removal adsorbents specifically for use in remote areas settings. Specifically, this study focused on two aspects, i.e., development of cost-effective synthesis methods for aluminum-based adsorbents using low-cost raw materials and technologies that are available even in rural areas of developing regions, and improvement of fluoride adsorption capacity of low-cost indigenous adsorbents through aluminum amendment or acid treatment. Aluminum (hydr)oxides were prepared in buckets by adding ligands (sulfate and citrate) and varying temperature (25 °C and 200 °C) in order to influence the degree of crystallinity. X-ray diffraction analysis and scanning electron microscopy showed that the samples aged at 25 °C had lower crystallinity and a smoother surface than those aged at 200 °C. Aluminum (hydr)oxides prepared with sulfate were more amorphous compared to those prepared with citrate and with no excess ligands. Regarding the maximum fluoride adsorption capacity, the addition of excess sulfate during aluminum (hydr)oxide precipitation led to the highest value of 40.0 ± 2.4 mg/g. Formation of basaluminite on the surface might account for the good performance of the aluminum (hydr)oxide prepared with excess sulfate. Another group of aluminum-based adsorbents, Mg-Al layered double hydroxides, were also synthesized for comparison to the aluminum hydr(oxides). While the Langmuir model predicted a higher adsorption capacity for the Mg-Al layered double hydroxide at equilibrium dissolved fluoride concentrations much higher than those tested in this study, the aluminum hydr(oxides) performed better at dissolved equilibrium fluoride concentrations in the range of the WHO standard of 1.5 mg/L. In addition, some indigenous materials including fibrous materials, wood char, zeolites (or molecular sieves), crumbled ceramic (> 1 mm), and cow bones were modified with AlCl_3 or acid. Then, the fluoride adsorption capacity of different modified materials was tested for a range of initial fluoride concentrations. Results show that amendment with AlCl_3 resulted in a pronounced improvement in fluoride adsorption capacity for crumbled ceramic and zeolites, suggesting the possibility of applying these materials in fluoride removal. Cow bones treated with 50% H_2SO_4 also displayed impressive fluoride adsorption capacity compared to untreated bones and bone char; and this finding would initiate a new approach of bone-utilization in fluoride removal for developing regions besides charring. This paper will thus present a number of approaches to improving fluoride adsorption using low-cost and locally available materials and technologies in country, and will

discuss benefits of these materials in fluoride mitigation in the Rift Valley of Ethiopia.

Service monitoring in Ghana: Do the benefits outweigh the costs?

Vida Duti, IRC Ghana

Additional Authors: Marieke Adank; Tyhra Kumasi; Stef Smits

In Ghana, the Community Water and Sanitation Agency, in collaboration with IRC, is in the process of developing a system for water service monitoring. Under this initiative, water service monitoring has been undertaken in three pilot districts over the course of three years. Comprehensive data was collected by district staff on all improved communal water systems in these three districts, the service providers managing these systems and the service authority supervising and supporting these service providers. This has improved insight in the actual, rather dire state of rural and small town water services, with only about 20% of water supply facilities providing services in line with national norms and standards, and none of the service providers meeting the benchmarks set on all service provider indicators. The monitoring data also showed clear correlations between the performance of service authorities and service providers and between service provider performance and water services. The monitoring findings have sparked sector debate at national level on what is needed to improve the current situation, but also on whether the current norms and standards have been set at a realistic level. In the pilot districts, access to up-to-date information on the status of water services has prompted local government to take direct action related to improving functionality rates and performance of service providers, like the rehabilitation of broken down facilities and the (re-) establishment and training of community-based water service providers. Furthermore, the development of service monitoring in Ghana has enabled the CWSA to define the future frame of monitoring and realignment of development partnership to coalesce activities to support a government-led agenda for rural and small town water sector monitoring. However, water service monitoring is not cheap. Expenditure on service monitoring in three pilot districts in Ghana was found to be in the same order of magnitude as the entire annual district budget for recurrent costs related to water, sanitation and hygiene activities. Nationwide ongoing service monitoring thus implies the need for a substantial increase in (public) funding for water service monitoring. The question can be raised whether the increase in effectiveness and efficiency in water service resulting from improved accessibility of water service information, is sufficient justification for the extra costs that service monitoring brings along. It could be argued that the impact of service monitoring does not only depend on the availability of up-to-date and accessible monitoring data, but also on factors like availability of local capacity to analyze, interpret and use the monitoring data, and the mandate, motivation and availability of resources to respond accordingly. Improved access to information of water services is thus a critical piece of the puzzle for ensuring sustainable water service provision, but needs to be considered within the wider political economic context in order to have the desired impact.

A multilevel longitudinal study of the determinants of household drinking water quality in four districts of Northern Ghana

Michael Fisher, UNC Chapel Hill

Additional Authors: Kate Shields; Kaida Liang; Jamie Bartram

Drinking water coverage is increasing in low and middle-income countries (LMICs), but many rural communities lack access to improved sources, and many improved sources do not provide water of acceptable quality. Furthermore, even when source water is safe, significant secondary contamination may occur at the point of use, particularly if water is stored in the home. In Northern Ghana, most rural communities lack access to piped

water in the home, and fetch drinking water from communal sources, storing this water in the household until it is used. Many previous studies have examined stored and source water in rural LMIC settings. However, few have analyzed paired source and stored water quality data over time, or included important source, household, and community characteristics that may affect the chemical and microbiological quality of drinking water in these settings. We conducted a multilevel longitudinal study of drinking water quality from sources and households in over 100 communities across 4 districts of Northern Ghana. Water quality data were collected at the source and household level, using field-based chemical and microbiological testing methods, including the use of a compartment bag test with ambient temperature incubation to measure *E. coli* concentrations of samples. Sanitary inspections were conducted at each water point on every visit. Household-level sanitation coverage was assessed, and household water storage conditions were observed. Water quality at the household was analyzed as a function of source type, sanitary inspection score, household sanitation facilities and practices, household drinking water storage practices, and other household and community-level and environmental factors, including seasonality, community-level sanitation coverage and ODF status. Household microbiological water quality was further analyzed as a function of source water microbiological quality and turbidity. Implications for rural water quality monitoring, as well as rural drinking water service delivery, are explored. This work represents the first in a series of multilevel longitudinal studies of source and household water quality using simple field-based methods. Field-based methods represent a valuable opportunity for reducing the cost and expanding the scope of water quality monitoring in rural LMIC settings. The use of paired source and stored water samples permits more nuanced investigations of the factors affecting stored water quality. Finally, the use of longitudinal data provides insights into the role of seasonality in determining both the water quality of an individual source and the variation in source utilization by households throughout the year.

Understanding why boiled water users adopted solar water disinfection (SODIS) in rural Vietnam

Max Friedrich, EAWAG

Additional Authors: Hans-Joachim Mosler

Background: Acute respiratory diseases and diarrhea are the main causes of infant death in developing countries. Indoor air pollution increases the risk of young children to contract respiratory infections. Contaminated drinking water is one of the main reasons for diarrhea. Solar water disinfection (SODIS) is an easy, low-cost and environmental friendly water treatment technique. Other than boiling, SODIS does not require burning biomass, so SODIS can reduce the indoor air pollution with smoke and the burden of respiratory diseases, particularly for women and children. This study quantifies the behavioral determinants of SODIS uptake by boiled water users following a behavior-change campaign in the Mekong Delta, Vietnam. In addition to the behavioral factors related to SODIS, the study quantifies the impact of behavioral factors related to boiling water. As a theoretical framework, the Risk, Attitudes, Norms, Abilities and Self-Regulation (RANAS) model is employed. **Method:** 649 randomly selected rural households in Long An and An Giang province were surveyed through quantitative structured interviews. For the present analysis, a subsample of 210 households was statistically analyzed. Households that either consumed boiled water at present and knew SODIS or households that had adopted SODIS instead of boiling water were included in the analysis. **Results:** Few surveyed households used SODIS and boiling was the most common way of water treatment. Point-biserial correlations of SODIS use with behavioral factors of SODIS use and factors of boiled water use identified 10 factors that had a medium to strong effect ($r > .3$) on SODIS use. The relation of SODIS use and the factors referring to SODIS was further quantified using multiple logistic regression (Nagelkerke $R^2=0.712$). Affective beliefs regarding SODIS, planning of SODIS, injunctive and descriptive norms in favor of SODIS and commitment to SODIS were significantly associated with SODIS use. Unlike hypothesized, additionally including the behavioral factors referring to boiling water only slightly improved the fit of the model (Nagelkerke $R^2=0.742$). **Conclusions:** Despite the advantages and intensive promotion of SODIS, boiled water is still the preferred water treatment

option by most surveyed households. The present study identifies the determinants of SODIS use and non-use. Possible key messages for future SODIS promotion are discussed. This study shows that behavioral factors of the competing behavior, boiling water, do not have a considerable impact on SODIS use. Thereby, the study does not only extend the current state of research but gives evidence-based suggestions how SODIS can be further promoted.

Adoption and Sustained Use of the Arborloo in Rural Ethiopia: A Cross-Sectional Study

Dionna Fry, Rollins School of Public Health, Emory University

Additional Authors: Matt Freeman; Katherine Cunliffe; Bekele Abaire; Yeshewahareg Feyisa; Dejene Mideksa; Argaw Ambelu; Maureen Cunningham; Susan Dundon; Sarah Sparker

Introduction: Within rural areas of Ethiopia, 19% of people use improved sanitation, 28% used unimproved or shared sanitation, and 53% practice open defecation. This lack of sanitation has no doubt contributed to high levels of diarrhea, trachoma and helminth infection. In 2004, poor access to water, sanitation and hygiene contributed to 16.2% of the total burden of disease (in DALYs) and 14.9% of all deaths in Ethiopia. Due to the dire sanitation situation in Ethiopia and Government policy, low-cost and zero subsidy options are needed; however, few studies have assessed the effectiveness, equity and sustainability of these approaches and how they might facilitate movement up the sanitation ladder for the poorest of the poor. This is the first study to rigorously assess the arborloo, a low-cost ecological sanitation approach developed in 1999 by Peter Morgan. The arborloo design allows for movement of the latrine slab and tree planting in the used pit, increasing food availability. Catholic Relief Services (CRS) began promoting the arborloo in 2004 within Ethiopia and has since provided 80,000 arborloo slabs. This study assessed the arborloo's sustained use and equity of access to initial program benefits within CRS program areas in rural Oromia Region, Ethiopia. In partnership with Emory University and the Millennium Water Alliance, researchers identified behavioral, attitudinal and resource-related factors that may contribute to the arborloo's adoption and sustainability. **Methods:** We used a two-stage stratified cluster random sampling approach to select 690 households in 20 villages in the Oromia Region. Sampled households received arborloo promotion between 2004 and 2012. GIS data of household locations were analyzed for spatial clustering of sustainability using Kulldorff binomial spatial tests. We used principal component analysis to assess socio-economic status (SES), an indicator of adoption and sustainability. We examined arborloo adoption and sustainability using survey weights and procedures in SAS and modeled sustainability with logistic regression. We conducted 24 key informant interviews and 33 in-depth interviews to ascertain additional detail on why households chose to adopt and sustain arborloo use. Qualitative data was themed and triangulated with the survey data. **Results:** The arborloo had high rates of adoption in study areas. Of all respondents, 462 (67.0%) households started using an arborloo. Adoption was associated with household size, religious practice, SES, and female household head's age. We found strong evidence of sustained use of arborloos. Of households who ever had the arborloo, 352 (76.2%) had sustained their arborloo use. Sustainability was most strongly associated with use of the arborloo pit for tree planting, male household head's level of education, receipt of a cement slab, and SES. **Conclusions:** This research provided evidence for the effectiveness of CRS Ethiopia's arborloo intervention, which can help improve current and future programming. Our findings point to areas for improvement including proper arborloo maintenance and planning, pit usage, sanitation marketing, and access to initial program benefits for the poorest of the poor. Improved low-cost arborloo programming has the potential to increase rural sanitation coverage, which would, in turn, decrease the burden of WASH-related disease in Ethiopia.

Personal history of water carriage is associated with self-reported pain location and ratings of general health: a cross sectional survey in South Africa, Ghana and Vietnam

Jo-Anne Geere, University of East Anglia

Additional Authors: Paul Hunter

Background Improving access to safe drinking water is one of the key millennium development goals. In many regions of the world shared community water points are provided rather than at-house water supply. The assumption is that reducing distance to an improved and communally shared water supply point delivers sufficient health benefits, similar to those of at-house supply, but at reduced cost. However, the health impact of fetching water from out of home sources has not been well researched. We report what we believe to be the first substantial epidemiological study of the impact of having to fetch water on people's health. **Methods and Findings** A cross sectional survey was conducted in South Africa, Ghana and Vietnam during 2012 to investigate the health impacts of fetching water from out of home water supply points. Analyses of self-reported pain and general health against history of water carriage were done using Generalised Estimating Equations (GEE) adjusted for age and sex and accounting for clustering at household and country level. Because pain areas were correlated, we undertook a factor analysis of the different pain locations and repeated GEE with linear regression for each factor, adjusting for age and gender. People who previously carried water had increased relative risk of reporting pain in the hands (RR 3.62, 95%CI 1.34-9.75) and upper back (RR 2.27, 95%CI 1.17-4.40), as did people who currently carry water (RR hand pain 3.11, 95%CI 1.34-7.23; RR upper back pain 2.16, 95%CI 1.25-3.73). The factor analysis results indicate that factor 1, 'axial compression', is correlated with pain in the head and upper back, chest/ribs, hands, feet and abdomen/stomach, and is associated with currently (0.30, 95%CI 0.17-0.43) or previously (0.21, 95%CI 0.01-0.42) carrying water. Factor 2, 'soft tissue strain', is correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs and is marginally negatively associated with currently (-0.18, 95%CI -0.32 - -0.04) carrying water. The association with pain locations correlated to 'axial compression' was more significant for those who carried water by head loading. Better ratings of general health in adults were associated with previously (RR -0.58, 95%CI -0.80- -0.35) or currently carry water (RR -0.91, 95%CI -1.12 - -0.70) and in children with currently carry water (RR -0.20, 95%CI -0.37 - -0.31). **Conclusions** The findings have biological plausibility. People who previously or currently carry water by head loading have increased risk of experiencing pain in locations which may be associated with detrimental effects of sustained spinal axial compression. However, current water carriage may have a slightly protective effect on areas of pain more typical of simple soft tissue strain. The better ratings of general health in those who carry water may indicate benefits of being more physically active, or positive social interactions associated with water carrying.

Sustainability of biosand filters implemented by EWB-USA before 2012: Content analysis of project reports and project team interviews

Jodi Gentry, US Army Corps of Engineers

Additional Authors: Benjamin Berry; Jeff Brown; Linette Figueroa; Kelly Latham; Andrew Schranck

Household water treatment using biosand filters is a well-developed technology with numerous studies documenting its ability to improve water quality. These studies typically involve establishing the removal efficiencies of a range of contaminants under different operating conditions in a controlled laboratory environment or monitoring and evaluation of the performance and usage rates of biosand filters in real-world field applications. Some field studies also include associated reduction rates in diarrhea for various populations within the community based on filter use. What is missing from many of these field studies, however, is a more holistic evaluation of the factors which affect long-term sustainability of the filters, including detailed accounts of how the overarching program was developed and implemented by the NGO or government-sponsored entity that was responsible for the filters that were evaluated. This presentation will explore the sustainability of over

700 biosand filters implemented in communities across a wide range of geographic regions and socio-economic backgrounds by Engineers Without Borders USA between 2005 and 2012. Specifically, we used a mixed methods approach that included content analysis of the planning, implementation and monitoring reports submitted to EWB-USA, followed by project team interviews with the twelve different implementing EWB-USA chapters. Our approach explored over eighty variables categorized under five commonly identified factors of sustainability (economic, environmental, institutional, technical and social), plus an additional factor to better understand how the implementing chapter's knowledge, attitudes, and practices affected functionality of the filters. The authors hope this holistic approach will shed some light on key features of successful projects as well as highlight lessons-learned from program failures.

A Framework for Monitoring and Evaluating Social and Environmental Impacts of WaSH Social Enterprises

Garrison Gordon, University of North Carolina Chapel Hill

Additional Authors: Ryan Cronk; Jamie Bartram

Sustainable service delivery of safe water, sanitation, and hygiene (WaSH) to unserved populations remains a challenge particularly in developing countries. Social enterprises, which are businesses that apply market-based principles to address social or environmental problems, are a private sector service delivery option gaining increased attention in the WaSH sector to meet the needs of unserved populations. Many WaSH social enterprises, however, lack the tools for monitoring and evaluating (M&E) their outputs, outcomes, and impacts. To address this challenge, we developed a WaSH social enterprise M&E framework. A literature review on the WaSH, health, development and social enterprise fields was conducted to identify candidate indicators for the M&E framework. Key informant interviews were conducted to identify additional financial, social, and environmental indicators of importance. The framework was pilot tested in collaboration with Sarvajal, a social enterprise based in India that provides drinking water through decentralized water treatment and distribution technologies. The framework addresses areas in which social enterprises in WaSH can improve impact, such as demographics of employment, water quality, waste management, and income distribution of the customer base. Through the process of pilot testing this framework, we present a case study evaluating the social and environmental impacts of Sarvajal. The output of this process provides WaSH social enterprises with a framework through which to collect information necessary to improve social and environmental impacts of the enterprise as well as identify constraints or opportunities to enhance the sustainability and scalability of WaSH-related products or services. This framework will allow WaSH social enterprises will make informed and effective progress toward providing services to unserved populations and contribute to meeting the Millennium Development Goals and proposed post-2015 WaSH targets.

What's so communal about communities in rural India?: Social distance, village conflict, and open defecation

Payal Hathi, Research Institute for Compassionate Economics (r.i.c.e)

Additional Authors: Dean Spears; Diane Coffey

Prominent policy models for reducing open defecation in rural communities call for local neighbors to come together to eliminate open defecation from their localities collaboratively. Even in the absence of such programs, local externalities may shape sanitation behavior: because one household's health and human capital can be influenced by neighbors' open defecation, some game theoretical models of behavior change predict that open defecation may be eliminated in coordination. On the other hand, evidence from India demonstrates that high levels of social fragmentation may detrimentally affect access to basic public goods. Open defecation

remains stubbornly persistent and widespread in much of rural India. Our paper is motivated by the observation that, in general, rural Indian villages are marked by considerable social fragmentation and hierarchy: people are divided by religion, caste, age, and sex. Indeed, the word "community" - commonly used by sanitation policy-makers to refer to geographic localities - is used to refer to one's caste or religious sub-group in Indian English. We conjecture that social distance within Indian villages may: - diminish the salience of even substantial local negative externalities, - impede collective action to change sanitation behavior, - contribute in part to explaining the persistence of open defecation. - suggest that programs that motivate behavior change based on a shared sense of community may be less effective in this context. We investigate the relationship between local social fragmentation and sanitation behavior among rural villages in the 2005 India Human Development Survey, a nationally representative social, economic, and demographic survey of 40,000 Indian households. We find that people who report their village has "a lot of conflict" are more likely to defecate in the open than people who report their village has "some conflict," who are more likely to defecate in the open than people who report that people "get along" in their village. These differences are found at all village sizes and at essentially all levels of consumption. Regression analysis shows that these differences are highly robust to the inclusion of controls, and are not driven by wealth, the respondent's own caste, or other properties of the village. The same differences are found within Indian states - that is, accounting for state fixed effects - suggesting that the result is not a spurious artifact of some other dimension of Indian human geography. Preliminary evidence further indicate that open defecation may be more common in villages that are more diverse across social and religious groups, on average, and less common in villages that are more homogeneously of one or of fewer groups. These results suggest that policy solutions for these localities cannot assume that everybody in a local area in rural India will be ready to collaborate to reduce open defecation. Instead, it may be valuable to target behavior change within "communities" as rural Indians themselves perceive them.

Probing the impacts of climate change on household water supply in Mozambique

Jeff C. Ho, Stanford University

Additional Authors: Jenna Davis

The impacts of climate change on potable water resources are predicted to be felt most acutely by those with the least means to adapt to them, i.e. by the poorest households in low-income countries. However, little evidence exists about how climate change will actually affect the availability of safe water for these vulnerable households. This case study explores the potential impact of predicted climate change on household water fetching by examining rural and peri-urban households in Nampula, Mozambique. Using data from a survey of 1826 households on seasonal usage of different water sources, we find evidence that households may switch to unimproved sources during the dry season. Since the latest findings of the Intergovernmental Panel for Climate Change indicate that in arid regions the length of the dry season may increase, this analysis indicates increased potential water-borne disease risk due to climate change. We additionally explore the potential effects of climate change on household water quantity and on the respondent's water fetching experience. Overall, this work identifies for the first time specifically how climate change may impact the poorest households in low-income countries. The results of this research characterize household vulnerability to climate change and suggest interventions to improve household resilience against its harmful impacts.

Granular Brass Media as a Technology for the Removal of Dissolved Copper and Lead from Water

David Holcomb, UNC-Chapel Hill

Additional Authors: Chuan Wang; Philip Singer; Orlando Coronell

MOTIVATION AND BACKGROUND: Dissolved metal contamination of drinking water poses a risk to human health in much of the world. While zero-valent iron (ZVI) has received attention as an inexpensive means of removing dissolved metals from water, its use in drinking water purification results in the undesirable release of iron ions into solution, for which the secondary limit set by the United States Environmental Protection Agency (US EPA) is 0.3 mg/L. Zero-valent zinc can theoretically remove metals from solution following oxidation-reduction chemistry similar to that governing metal removal by ZVI. Use of zero-valent zinc would benefit from a lower standard reduction potential than ZVI and substantially higher permissible levels of dissolved zinc in water intended for human use (i.e., the secondary limit set by the US EPA is 5 mg/L). A potential source of stabilized zinc for use in household water treatment applications is brass, which is a relatively inexpensive and readily available alloy of zinc and copper. **PROJECT OBJECTIVE:** The objective of this project was to assess the feasibility of employing granular brass media in the removal of dissolved copper and lead from aqueous solution. Batch experiments were performed to characterize the kinetics of metal removal. **RESULTS:** Granular brass was found to effectively remove copper and lead from aqueous solution. Metal removal was determined to be first order with respect to brass dose and metal concentration, with reaction rate constants of 0.0102 ± 0.0008 and 0.0049 ± 0.0001 L/g_brass/min for copper and lead, respectively. Brass media demonstrated the capacity to remove copper during five consecutive 60-minute cycles, for which copper was spiked into the test solution at the beginning of each cycle. Copper removal kinetics were consistent in all cycles. The brass surface was found to contain zinc oxides that dissolved in the test solutions, accounting for the release of zinc in waters lacking added metal ions. The solubility limit of zinc governed the total dissolved zinc concentration. **SIGNIFICANCE OF THE STUDY:** The results of this study showed that brass effectively removes metal ions from water. Therefore, granular brass should be tested in a packed-bed configuration to ascertain the media performance and longevity in point-of-use applications. Additionally, the capacity of brass to remove other metals, such as arsenic and chromium, should be assessed.

Preferences of arsenic mitigation options in Bangladesh: Stakeholder and end user perspectives

Mohammad Hossain, Christian Commission for Development in Bangladesh (CCDB)

Additional Authors: Hans-Joachim Mosler; Jennifer Inauen

Arsenic is a global public health crisis. Since its recognition in Bangladesh, the government and involved organizations (i.e., stakeholders) have made great mitigation efforts by testing wells and installing arsenic mitigation options. But many installed options are not maintained or used regularly by end users. Overall, 20 million people are still at risk of drinking arsenic-contaminated water in Bangladesh. According to past studies, mitigation is likely to fail if peoples' preferences are not taken into account. These are influenced by technical (e.g., water quality), socio-cultural and other factors. Which one is the best mitigation option is also an open debate among stakeholders. Discrepancies between stakeholders' and end users' preferences of mitigation options may be one reason for slow mitigation progress. Therefore, this study aimed at investigating both stakeholders' and end users' preferences, and addressed two research questions: (1) Which mitigation options are preferred by both stakeholders and end users? For what options do their preferences differ?, and (2) What advantages and disadvantages do stakeholders and end users perceive for each mitigation option? Three investigations were conducted in Bangladesh: one qualitative study with 22 stakeholders and two end users surveys with a total of 1268 randomly selected households. The stakeholder interviews were conducted with a semi-structured interview guideline in August 2008. Stakeholders were purposefully selected from different levels by their importance, agreement to participate, and availability. In investigating end users' preferences, unpublished data from a larger study were used. End user survey 1 was conducted in November 2009 and survey 2 in December 2010 in rural Bangladesh. Households were at risk of drinking arsenic-contaminated water and had access to at least one mitigation option: piped water supply, community and household arsenic removal filters, rainwater harvesting, dug wells, pond sand filters, well-sharing, and deep tubewells. Face-to-face

interview was conducted using a structured questionnaire which contained related qualitative questions. Results of stakeholder interviews showed that piped water supply (27.3%, n=6) and deep tubewells (22.7%) were the most preferred options. Pond sand filters and rainwater harvesting were preferred by 13.6% of each. Stakeholders' least preferred options were arsenic removal filters (9.1%) and dug wells (4.5%). Stakeholders mentioned most technical advantages of piped supply of all options, but they had some concerns regarding the costs. Similarly, stakeholders named many advantages of deep tubewells (e.g., sustainability, easy use and maintenance), while their concerns included groundwater depletion, technical feasibility, and high cost. Stakeholders suggested that pond sand filters and rainwater harvesting were suitable in the coastal regions and arsenic removal filters were valuable emergency solutions. Stakeholders also mentioned problems of these options, e.g., microbial contamination and maintenance problems for pond sand filters, feasibility and peoples' preference problems for rainwater harvesting, and sustainability, costly and maintenance problems for arsenic-removal filters. Stakeholders named only few advantages of dug wells, but their major concerns were arsenic and microbial contamination. Most end users', on the other hand, preferred deep tubewells (26%) and well-sharing (15%), whereas dug wells (6%) was the least preferred option. Other options were preferred by some: household filters (10.3%), community filters (9.2%), piped supply (8.8%), pond sand filters (8.4%), and rainwater harvesting (8.2%). The primary mentioned advantage of these options was that they provided arsenic-safe water. Of further importance was water quality in terms of taste, temperature, color and smell, particularly for deep tubewells and well-sharing. But end users also reported several problems of these options including increased distance and effort to collect water from deep tubewells, pond sand filters, well-sharing, community filters, and dug wells; use and maintenance problems for household filters; limited water availability for piped supply and rainwater harvesting; difficult social situations for deep tubewells and well-sharing; and water quality concerns for dug wells. In conclusion, piped water supply and deep tubewells were the most preferred mitigation options by stakeholders and end users, whereas well-sharing was preferred mostly by end users, but not by stakeholders. Thus, greater emphasis should be given to the installation and promotion of the most preferred options and the poorly preferred options require further technological improvement or need to be promoted with behavior change interventions. Indeed, collaboration between all involved stakeholders and taking into account end users' preferences is urgently needed to maximize the success of arsenic mitigation efforts.

Monitoring a complex latrine intervention to improve program delivery and increase acceptance in rural communities in Bangladesh

Faruque Hussain, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)

Additional Authors: Stephen Luby; Thomas Clasen; Golam Kibria; Ruhul Amin; Mominul Islam; Leanne Unicomb

Background Globally, efforts to promote latrines are being implemented on a large scale. A systematic monitoring system can identify problems and provide an opportunity to resolve them during program implementation. A latrine construction program aimed to train field staff, suppliers and masons to construct and install pour-flush dual pit latrines for 4216 households within 270 geographic clusters as part of a large-scale WASH Benefits cluster randomized controlled trial in rural Bangladesh from July 2012 to December 2013. We describe a monitoring system used to assess the delivery and quality of latrine components and construction, track progress and address operational problems during the implementation period. **Methods** From July 2012 to October 2013 we trained field staff, suppliers and masons on quality construction and installation of dual pit latrine components. Participants received all latrine components free of cost and dug two pits, transported and set up substructure components using own resources. A multidisciplinary evaluation team developed and validated a monitoring system when implementing the first 422 (10%) latrines within 6 months of program commencement. We refined five monitoring tools to ensure efficient delivery of latrines to the remaining 3794 (90%) households in the subsequent 12 months. The monitoring system used six key process and output

indicators to track production, quality, and implementation progress. The process indicators tracked the operational supply chains, component production, financial allocations, and installation activities completed. Output indicators included quality latrine component sets manufactured, and number of latrines ready for use. For weekly monitoring of the project we randomly selected manufacturing and delivery sites and used production and supply chain registers, latrine component production planning forms, construction and financial records, quality assessment and latrine installation checklists. We used hand-held metal detectors to inspect concrete ring structures and randomly broke squatting slabs and lids to identify adequate reinforcement. We discarded latrine components that did not meet prescribed specifications. In the quality monitoring process we encouraged participation of latrine recipients. The field team collected quantitative and qualitative data from the communities and suppliers to troubleshoot problems. To verify appropriate latrine installation in each geographic cluster we used a final checklist. Results We trained 32 field staff, 110 suppliers, 290 masons; reviewed data from 60 field visit reports to monitor manufacturing and implementation progress. The monitoring tools detected inconsistencies in supply chain and component production ratio with 20% manufacturers, ensured high quality components, identified delays between the implementation activities and irregular fund disbursement and payments during implementing in preceding 15% clusters. We discussed the findings with field team, sought suggestions and took steps to correct these. During quality inspections we found that 30% of the suppliers did not meet the standards set by the project. We rejected between 2-4% of various latrine components for inferior quality. During final verification of latrine construction we found that approximately 2% of households broke and removed water seals during and after installation. This was due to perceptions that the seal required much water thus filling pits rapidly, it blocked the easy flow of feces, and caused water to splash out during defecation. Among 3% of households there was resistance to destroy their existing unhygienic latrines which they planned for further use for visitors and to provide ownership to non-recipient relatives. Through dialogue with suppliers and study participants, the team successfully identified the solutions and addressed the problems visiting 65 (24%) clusters. The team explained the benefits of hygienic latrine use, demonstrated the function of water seals and appropriate squatting posture to the participants and made technical rearrangement of footrest position on the squatting slab. Despite performing regular and systematic monitoring, delays in payments to suppliers interrupted both the supply chain and implementation process, and caused delays in program delivery by 2 months. Conclusions Engaging study participants in the latrine component quality assessment and in the implementation process motivated them to accomplish shared activities on scheduled time which improved program timeline. A cost-effective and action-oriented monitoring system that emphasizes participants needs, voice, preference and insight to resolve problems facilitated delivery of a large-scale shared latrine construction program. The monitoring system and tools can be used in implementing and delivering large-scale latrine interventions in other settings.

Performance Benchmarking: A tool for improving the Urban Sanitation Services in Pakistan

Fida Hussain, Pakistan Water Operators Network (P-WON)

Performance appraisal through benchmarking is by now well-known practice to maximize the efficiency of water utilities. Sewerage coverage, wastewater management and environmental sanitation have gained more attention and encouraging achievements have been made through performance benchmarking initiatives. This paper reveals the fact that due to less sewerage coverage rate, poor collection system, and untreated wastewater disposal in the water body leading to poor sanitation services poses a high risk to people's health and the environment. This paper discusses the existing sanitation coverage, its quality and the situational overview of sewerage production, its environmental consequences and the treatment level. It describes how the poor performance of the urban utilities, a major challenge, can be improved by imparting a benchmarking scheme. The manuscript is an attempt to advocate, conclude and recommends the benchmarking as a successful tool that should be formalized through P-WOPs for the utility' service delivery enhancement which will assist in

maximizing the citizens' access to the adequate sanitation.

Performance of Biosand Filters after Relocation

Kristen Jellison, Lehigh University

Additional Authors: Julie Napotnik

Modifications have been made to the traditional concrete biosand filter (BSF) design using smaller and/or lighter casing material in an effort to minimize logistical requirements and implementation costs. The portability of these smaller, lighter designs increases the likelihood that the owner will move an installed filter and potentially disturb the system. This study investigated the effects of moving and agitation on filter performance, using mature BSFs which had been in use for over nine months prior to the move. Data were analyzed for four replicate filters of three different filter types: the traditional concrete BSF and two plastic bucket BSFs constructed in 5-gal and 2-gal buckets, respectively. Filters were moved approximately 1 km and monitored for hydraulic loading rates (HLRs) and *E. coli* removal for eight weeks following the move. Moving the filters resulted in reduced HLRs, likely due to sand compaction, but *E. coli* removal remained high ($\log_{10}$ removal ≥ 2.8 for all sizes) and increased significantly as compared to data collected prior to the move. Moving the BSF does not appear to increase human health risks from a bacterial removal standpoint; however, the greater risk appears to be in the potential for filter abandonment if the HLR drops to a level deemed unacceptable by the end-user.

Giardia infection in humans and animals in Coastal Odisha, India and environmental loading from animals.

Marion (Mimi) Jenkins, University of California, Davis

Additional Authors: Miles Daniels; Arpit Shivastava; Priyadarshi Sahu; Mitsunori Odagiri; Woutrina Miller

Globally, *Giardia lamblia*, is one of the most commonly detected intestinal parasites and is particularly relevant in developing countries like India where inadequate sanitary conditions, high population densities, and frequent contact with animals capable of carrying zoonotic pathogens can exist in both urban slums and rural areas. We present a study to estimate and compare the prevalence of *Giardia* infection in rural and urban settings for human and animal populations in a coastal area of Odisha, India, evaluate if gender or age is associated with *Giardia* infection in humans, and estimate fecal loading rates of *Giardia* cysts from animal host populations in the study area. From April to May of 2012, human fecal samples from 85 diarrhea patients presenting at three diarrhea wards and 111 pooled animal fecal samples across seven host species (cattle, buffalo, goat, sheep, chicken, cat, and dog) from urban and rural locations served by the three wards were collected. Samples were screened and fluorescent microscopy used to enumerate *Giardia* cysts per wet gram, and a subset of dog and human samples analyzed with molecular methods to identify isolate genotypes. *Giardia* cysts were detected in 12% of diarrhea patients, while 32% of pooled animal samples were positive. The diarrhea patient infection rate was likely to be higher, given the nature of intermittent shedding and testing of a single sample per patient. No difference in the *Giardia* infection rate between rural and urban patients or by gender was observed. An increasing rate of infection by age group (<5 years, 5-59 years, >59 years) was detected but lacked statistical support. Substantial support was found showing rural animals shed higher numbers of *Giardia* parasites than urban animals. Of the seven animal host groups screened, dogs and cattle, both of which have been reported to shed zoonotic genotypes of *Giardia* elsewhere in India, shed decisively more *Giardia* cysts per gram of feces, as much as 2-3 orders of magnitude greater than other animal types (adjusting for location). Molecular characterization of isolates identified host specific assemblages in dog samples and possibly a zoonotic assemblage in humans. Using current animal populations and measured *Giardia* shedding rates, we estimated

that cattle contribute >99% of *Giardia* animal cysts in the study area environment, with dogs responsible for the next largest contribution. This study found *Giardia* prevalence is similar for in diarrhea patients living in rural and urban settings in the study region, but different for animals and exposure from infected cattle and dogs may be an important public health concern.

***Giardia* and *Cryptosporidium* in community water sources in rural India: associations with source characteristics, human and animal fecal contamination, and sanitary conditions.**

Marion (Mimi) Jenkins, University of California, Davis

Additional Authors: Miles Daniels; Mitsunori Odagiri; Woutrina Miller; Arpit Shrivastava; Alex Schriewer; Priyadarshi Sahu; Pravas Misra; Pinaki Panigrahi; Stefan Weurtz; Thomas Clasen; Wolf-Peter Schmidt

In rural India where humans and livestock animals share water sources and living spaces, and sanitation is poor, exposure to the protozoa pathogens *Cryptosporidium* and *Giardia* are important potential public health concerns. We present results from a study to measure *Cryptosporidium* and *Giardia* oocysts/cysts in rural community water sources in a coastal area of Odisha, India, and evaluate associations between the detection of protozoa and concentrations of validated microbial source tracking (MST) markers of human and animal fecal contamination, fecal coliform concentrations, water source characteristics, and estimates of the loading rates of non-point sources of human and animal fecal material around each water source to shed light on likely sources and causes of protozoa contamination in the three different types of community water sources tested. Earlier work estimated mass fecal loading of *Cryptosporidium* and *Giardia* from local populations of cattle, buffalo, goat, sheep, and dog into the study area environment at 2.4×10^{10} oocysts and 3.39×10^{12} cysts per day, respectively. Two each of public ponds (used for personal and domestic hygiene), public drinking water tubewells (deep groundwater), and private drinking water tubewells (shallow groundwater) in each of 60 villages were sampled once either in the monsoon season of 2012 or 2013, except when only one of a given water source type existed in a village. A 20-L water sample was collected from each water source. Fluorescent microscopy was used to enumerate oocysts and cysts, membrane filtration culture techniques to quantify fecal coliform concentration, and MST Bacteroidales molecular assays validated for application in India used to detect and quantify concentrations of human- and livestock/domestic animal- associated fecal markers. Conditions of tubewells, types of use, and other water source observations and characteristics were recorded for each water source, and GPS data collected and analyzed to estimate the spatial densities of livestock, latrines, and people practicing open defecation. Preliminary analyses show public ponds were significantly more contaminated with parasites than public or private tubewells ($p < 0.001$, Mann-U test). *Cryptosporidium* and *Giardia* parasite concentrations were positively correlated with gene copy concentrations of the BacCow marker (validated as a combined ruminant and domestic animal fecal source marker in India) in pond water samples but negatively correlated with BacCow concentrations in public tubewell samples ($p < 0.05$, Spearman's rank test). Multivariate modeling results of associations between explanatory factors and parasite presence and counts for *Cryptosporidium* and *Giardia* in each water source type are presented. Study findings provide a better understanding of the public health risks and primary contributors of protozoan contamination of water sources in the study area for efforts to improve sanitation and public health in the region.

Effect of neighbourhood sanitation on diarrhea morbidity

Tiffany Young Mee Jung, University of Toronto

Appropriate sanitation erects a primary barrier against fecal pathogens that can otherwise cause diarrhea upon transmission. Diarrhea has consistently ranked within the top four killers of under-five children in the past

decade, killing 0.8 million under-five children in 2010. Children's diarrhea morbidity continues to be a significant health burden as well, persisting at 2-3 incidents per year per person since the 1980s. Health benefits of sanitation can be attributed to the distinct functions of household sanitation (e.g. household toilet facility) and neighbourhood sanitation (e.g. neighbours' use of appropriate sanitation). An individual may benefit from within-household control of fecal pathogen by household sanitation; in the absence of appropriate sanitation in the neighbourhood, however, the individual may still be at the risk of exposure to fecal pathogens from the neighbours. Such multi-domain operation of sanitation has been acknowledged in key sanitation literatures, yet the contributions of household and neighbourhood sanitation on diarrhea prevention have not been succinctly distinguished and compared in a systematic review. We conducted the first systematic review and meta-analyses that exclusively analyse the distinctive effect of neighbourhood and household sanitation on diarrhea morbidity. We identified studies reporting the effect of neighbourhood or household sanitation on diarrhea, by performing a comprehensive search on databases including PubMed, Scopus and Web of Science from the earliest date available to August 2013. Studies meeting pre-determined inclusion criteria were included in the meta-analysis. The reported effect sizes of neighbourhood and household sanitation were pooled by inverse variance method. Five studies on neighbourhood sanitation and 13 studies on household sanitation were included in our meta-analyses. The pooled effect estimates showed that both clean neighbourhood sanitary condition and access to household sanitation offer measurable benefits on diarrheal burden, and that the magnitude of the benefits provided by neighbourhood and household sanitation are comparable. Our systematic review presents the first pooled evidence that, in addition to the conventional interventions focusing on adoption of household toilets, investments and regulations for public sanitation infrastructures (e.g., drainage), and community level sanitation coverage (e.g. open defecation free villages) are desired to achieve the maximum reduction of diarrheal illness.

Evaluation of the school-based SOPO handwashing campaign in western Kenya

Kelly Kamm, University at Buffalo

Additional Authors: Christina Crabtree-Ide; Ann Thomas; Bridget Job-Johnson; Rufus Eshuchi; Fred Imbo; Hilda Kiritu; Pavani Ram

BACKGROUND Many programs promoting handwashing with soap employ social marketing to encourage behavior change, but published evaluations of these programs' impact on handwashing behavior are sparse. In 2010, in partnership with the Kenyan Ministries of Public Health and Education, UNICEF-Kenya piloted the SOPO handwashing campaign in primary schools in Nyanza and Rift Valley Provinces in western Kenya. The SOPO campaign was a branded, educational program targeted to children and mothers of young children that encouraged handwashing with soap at four critical times to reduce childhood diarrhea (after using the latrine, after changing a baby's nappy (diaper), before cooking or eating, before feeding the children). We evaluated the behavioral impact of a handwashing campaign delivered in 2010 using social marketing strategies in primary schools in western Kenya. **METHODS** In 2012, we used a pseudo-experimental study design to assess the impact of the SOPO campaign on handwashing behavior of children attending primary school and their mothers. We compared children attending schools in which the SOPO campaign was implemented, and mothers in neighboring communities, to children and mothers in communities in which the SOPO campaign was not implemented. We observed handwashing behavior and interviewed schoolchildren and their mothers to assess recognition of SOPO and its messages. We assessed the relationship between exposure to SOPO and observed handwashing at home and at school, accounting for multiple events within each household or school. **RESULTS** Our sample included 30 schools, 311 children, and 311 mothers exposed to the school SOPO campaign and a comparison group of 28 schools, 288 children, and 289 mothers not exposed to SOPO. Children attending a SOPO school were more likely to report recognizing the SOPO cartoon mascot or the brand name SOPO compared to children attending a comparison school (90% v. 18%) and more likely to identify the SOPO message

as related to handwashing with soap (28% v. 5%). Mothers of children attending a SOPO school were also more likely to recognize the SOPO brand (49% v. 14%) and identify the message of SOPO as handwashing with soap (32% v. 3%) compared to mothers of children attending a comparison school. A handwashing station was observed at 21 (70%) SOPO and 24 (86%) comparison schools but only 4 (13%) SOPO and 3 (11%) comparison schools had soap and water present at the handwashing station. Handwashing stations with soap and water were located in the school dining area at two SOPO schools and one comparison school. None of the SOPO schools and only two comparison schools had a handwashing station with soap and water <10 meters from the latrine. Among students, handwashing with soap after latrine use was rare in both SOPO and comparison schools (1% v. 2%). Students in SOPO schools (6%) were more likely to wash hands with soap before eating, compared to students in comparison schools (0.5%). A handwashing station with soap and water was observed at 27% of SOPO and 27% of comparison households. At 36% of SOPO and 31% of comparison households, a handwashing station with soap and water was observed in the food preparation area. Only 7 (2%) SOPO and 4 (1%) comparison households were observed to have a handwashing station with soap and water near the latrine. Although soap was observed at 75% of SOPO and 68% of comparison households, children in 44% of the SOPO households and 47% of the comparison households reported they could not always wash their hands with soap when they wanted. A lack of soap in the home and an inability to find soap were the most commonly reported barriers by children in both SOPO and comparison households. At home, children in SOPO households were less likely to wash their hands with soap at the critical times compared to children in comparison households after adjustment for maternal education and repeated measures at the household level (RR=0.75, 95% CI 0.55, 1.01). There was no difference in handwashing behavior at critical times between mothers in SOPO and comparison households after adjusting for maternal education and repeated measures at the household level (RR=1.04, 95% CI 0.92, 1.18). **CONCLUSIONS** Exposure to the SOPO campaign at school was associated with increased knowledge of SOPO among schoolchildren and their mothers but not increased handwashing at home or at school. Programs such as SOPO that employ social marketing techniques have the potential to improve handwashing behavior and should be considered when designing hand hygiene programs, after first addressing access to soap and water.

The political ecology of social disparities in groundwater contamination: the case of small water systems in Kern County, California

Seigi Karasaki, University of Tokyo

With a shifting environmental landscape and mounting ecological pressures, California now faces huge challenges to balance conservation efforts while continuing economic growth. As surface water resources dwindle, people rely more and more on groundwater for their needs, and this trend is likely to continue. Studies have shown that large amounts of agricultural runoff have collected in these very groundwater systems. Rural areas often have the highest concentrations, especially in the Central Valley. Despite this, little research has been conducted on the relationship between social disparities and exposure to non-potable water. In an effort to identify the root causes of this environmental injustice, this study depicts how historical institutions and laws contributed to limiting the migratory patterns of those at risk today. A study by Balazs et al in 2011 illustrated a significant correlation between poor water quality and percentage of population Latino in small community water systems of California's San Joaquin Valley. Although this first paper did not address why this disparity might exist, the same authors released a follow-up study that introduced a "Drinking Water Disparities Framework" based on social epidemiology in 2014. This does provide invaluable insight into the origins of this disparity, but further research is surely needed to add to the current understanding. Interestingly, the medium- and high-risk CWSs in San Joaquin Valley do not seem to exhibit any observable signs of migration or declining levels of population, contrary to what the popular academic discourse might suggest. At this point, there is minimal work on addressing why this social disparity in water contamination might exist; and practically none address why these marginalized peoples would choose to remain in an environmentally undesirable location.

With this in mind, the objective of this study is to quantitatively and qualitatively measure the significance of social institutions on the racial disparities of nitrate contamination in household water systems. In order to provide additional insight into the larger question of why this social disparity exists in levels of nitrate contamination, this study asks: What is restricting the mobility of residents living in highly contaminated systems? When and why did this disparity first take root? This study begins with a historical overview of the political economics of water management in the San Joaquin Valley, from the early 20th century until the present day. Current water politics and management in California is a reflection of a centuries-worth of convoluted state and federal boundaries, private interests, and irresponsible policy making. A historical review clarifies the origin and evolution of relevant (particularly corporate) land and water rights that likely affected housing patterns today. In particular, this study helps untangle the intertwinement between corporate land ownership, water rights, selective crop choice, and migratory patterns. A literature review of political ecology, environmental justice, and rural studies was then applied to analyse the case through two existing theories of migration: racial income inequality thesis, and residential discrimination thesis. Lastly, in order to weigh the respective significances of socio-political explanatory variables in the successful maintenance of water systems, a two-pronged approach was utilized for the analytical portion of this study: quantitative multiple regression analysis helped identify variables of particular significance, while qualitative interviewing was undertaken to further study commonalities among water districts. Regression analysis was employed to weigh the relative importance of anthropologic (political, socio-economical) explanatory variables in small CWSs. Although empirical research has indeed been done by Balazs et al, the only independent variables used in their study were percentage of population Latino and rates of home ownership. This study empirically tested for such other variables, and reinforced the conclusion by Balazs et al. The third section of this study employed qualitative analytical induction to further clarify and challenge the data found in the preceding empirical analysis. This is an integral part of this study, primarily because of the purely quantitative nature of empirical analysis - though the numbers may not lie, they are often insufficient in explaining exactly why or for what motives certain courses of actions or strategies were implemented by stakeholders. In this study, it took the shape of loosely structured phone interviews with water district managers, district representatives of the CDPH Drinking Water Program, members of the civil society, and local persons. This study concludes by suggesting possible alternative policy discourses to address water injustice in California, namely through an adjusted focus on land and housing policies.

Prioritization of Water Quality Indicators: The MWA Experience In Ethiopia

Andy Karp, Millennium Water Alliance

Additional Authors: Dennis Warner

For water schemes serving rural communities that are often small and in remote locations of developing countries, rarely, if ever, is testing done for all parameters proposed in W.H.O. guidelines or national standards. The case of Ethiopia is typical of many developing countries: In Ethiopia the government has set water quality standards for 47 parameters, consistent with W.H.O. guidelines. It is questionable whether the equipment exists in Ethiopia to test for some of these parameters. Furthermore, even if the equipment were to be brought to Ethiopia for such testing, doing such testing would take funding and staff time away from the construction and/or rehabilitation of water schemes benefiting other communities, and this would be a trade-off of dubious value. It is important to note that the W.H.O. guidelines are based solely on health considerations and not on cost or other factors that may constrain their application. For this reason, W.H.O. has always taken the position that its guidelines are health-based recommendations, but that national governments have the ultimate responsibility to determine national standards. Given the above reality, MWA-Ethiopia (see footnote) takes the position that before enforcing the need to test for all 47 GOE parameters, a program should begin only with tests for a priority list of parameters that are most likely to have a significant impact on the health of the

consumers of the water. MWA has developed a Water Quality Monitoring and Testing Protocol for use in Ethiopia, which prioritizes a limited number of parameters. The protocol is in the context of the GOE standards, insofar as it applies the GOE standards for the priority parameters, and it does not oppose testing for other parameters. The present paper discusses: * Background, including: (a) the history of minimum water quality (WQ) indicators as applied to developing countries, (b) the role of WQ monitoring in Water Safety Planning, and (c) the Ethiopian context and experience with WQ monitoring; * The need to prioritize WQ parameters; * Trade-offs and potential conflicts in the prioritization process; * The WQ Monitoring and Testing Protocol (WQMTP) developed by MWA for use in Ethiopia; * Comparison of the parameters included in the mentioned WQMTP developed by MWA, to those included in the WHO/UNICEF methodology for Rapid Assessment of Drinking Water Quality. * The experience to-date with use of the mentioned WQMTP developed by MWA. This includes (a) how it is viewed by MWA members, donors, and the Government of Ethiopia, (b) how effectively it has been applied in the field, (c) what has changed as a result, (d) problems and obstacles encountered, and (e) lessons learned; * What should be done to further improve WQ monitoring in Ethiopia and elsewhere. * Relevance of minimum WQ indicators in promoting improved monitoring in developing countries. * Application to other countries. Footnote: The Millennium Water Alliance (MWA) is a consortium of NGOs working in the water and sanitation sector. More information about MWA is available at MWAwater.org

Trace organic contaminant removal from drinking water using local char

Josh Kearns, University of Colorado-Boulder

Additional Authors: Kyle Shimabuku; Ryan Mahoney; Nathan Reents; R Scott Summers; Detlef Knappe

While microbial pathogens typically represent the most immediate threat to health, a variety of natural (e.g., microcystins) and anthropogenic (e.g. pesticides, pharmaceutical residues, fuel compounds, industrial waste chemicals) organic contaminants (OCs) impact the safety of surface waters collected for drinking in developing communities. Roughly half-a-billion tons of anthropogenic OCs are produced annually, including several million tons of pesticides. OCs thereby constitute a major impairment to water quality on a global scale; for example, "pesticide pollution" appears twice in the top ten of The World's Worst Toxic Pollution Problems Report 2011 by the Blacksmith Institute. Long-term chronic exposure to trace quantities of OCs can lead to cancer, diseases of the endocrine and reproductive systems, and damage to the liver, kidneys, or central nervous system, and other toxic effects. Additionally, naturally occurring algal metabolites (2-methylisoborneol, geosmin) and disinfectants (Chlorine) can adversely impact water aesthetics. Objectionable taste and odor has played a major role in the decline of household chlorination practices. Therefore, the development of effective, affordable and scalable "green" treatment technologies for OC removal and taste/odor control that are accessible to communities in remote regions of the developing world and in emergency/disaster relief/humanitarian crisis situations is warranted. Char filter/adsorbers have been used to treat drinking water for thousands of years and are still widely used today - particularly in rural areas of major charcoal producing countries such as Brazil, India, China, Thailand, and throughout SE Asia. Locally managed treatment with char might represent the most effective barrier to harmful OC exposure available to households and communities in remote and impoverished regions of the world, because char can exhibit properties similar to activated carbon (AC); i.e., a highly micro-porous structure with large internal surface area that provides a plenitude of adsorption sites. AC is the most widely employed sorbent medium in drinking water treatment plants in developed countries but is cost-prohibitive and inaccessible in rural, remote, and impoverished locations. Here we present research using biomass chars generated from traditional charcoal kilns and low-emission pyrolyzing cookstoves and drum-ovens for sorbing the prevalent herbicide 2,4-dichlorophenoxyacetic acid (2,4-D), the environmentally persistent pharmaceuticals sulfamethoxazole (SMX) and warfarin (WFN), the algal metabolite 2-methylisoborneol (MIB), residual free chlorine (Cl), and trihalomethane (THM) disinfection by-products. Our research indicates that contaminant sorption capacity, normalized to sorbent mass, is generally favored in highly micro-porous chars with large

internal surface areas generated at high temperatures (≥ 750 °C). High temperature chars have demonstrated trace contaminant uptake equal to that by commercial AC. Moreover, we describe development of a low-cost, village-accessible water treatment char production process that is superior to traditional kiln char production in that (1) it is more energy efficient and less polluting, (2) it can make use of a wider array of agricultural and forestry residues, (3) it can be more readily coupled with ancillary applications of emitted heat (e.g. cooking, heating water, drying crops, biofuel production), and (4) it generates a more consistent and high-performance adsorbent char for water treatment. Here we stress that harmful trace level OCs are a substantial, though often overlooked, impairment to drinking water safety in developing communities, and present an overview of the development of local and sustainable treatment options using biomass char adsorbents. We present result from laboratory studies quantifying adsorption of 2,4-D, SMX, WFN, MIB, Cl, and THMs from surface water using chars produced with both traditional kiln and improved low-cost pyrolysis technologies from a variety of biomass precursors and in comparison with commercial AC benchmark. We also present case studies and long term monitoring data from our field work with village and migrant communities in SE Asia in the design and integration of char adsorber units in decentralized locally managed water treatment trains at three throughput scales (30, 300, and 3000 L/day).

Metered hand-pumps: Privately operated hand pumps as a way to improve sustainability and service delivery

Diana Keesiga, Water for People

Additional Authors: Paul Kimera

In Uganda, Community based Management Systems dominate management of water supplies in rural areas. The main service providers are Water and Sanitation committees comprising of 7 to 10 members. However, their failure to efficiently collect user fees to cater for operation and maintenance has led to the stagnation of water coverage between 63 and 64 % for the last 6 years. In contrast piped water schemes common in urban and peri-urban areas are managed by private operators and are metered. The National Water and Sewerage Corporation, responsible for water supply to 40 towns and 34 urban centres also rely on metering to collect revenue. Overall, statistics reveal higher functionality rates for metered systems. To encourage private sector engagement in the operation of the point water sources thus improve sustainability and service delivery , Water for People and Appropriate Technology Centre have an on-going research under which a new product is being tested- a meter for hand pumps. This product has been introduced to entrepreneurs with the expectation that they will prove to be better managers of water points than the current committees. Our research indicated that the multi jet water meter would be quite appropriate for this kind of intervention. Multi-jet meters use multiple ports surrounding an internal chamber to create multiple jets of water against an impeller and are very accurate in small sizes of 1/2" to 2" sizes. Some water meters are sensitive to the momentum of the water impacting on the impeller or the turbine thus a partial blockage of the inlet strainer may affect the accuracy of the meter. Research proved that this parameter only affects domestic single jet meters, while displacement and multi jet meters are insensitive to it. The installation of a 1/2 inch multi jet water meter on the hand-pump did not affect the performance of the hand-pump but the delivery rate with each of the 3 different users requiring 42% more time on average to fill a 20litre jerrycan. It was also observed that on pumping vigorously, water overflowed above the water tank of the hand pump and therefore users were required to pump in a more restrained manner. The above shortcomings were addressed by procuring a 1" meter. This was only found to be satisfactory upon removal of the inlet and outlet screens within the meter which resulted in an improved 8% average increase in time needed to collect 20 litres of water. This increase in time almost goes un-noticed for children and women who are major users of these water points. The 1" meter was installed at 3 sites. At two of them, collections doubled from 8,000UGX to 16,000UGX per day. However, the third site had a high flow rate which caused some water to bypass the meter and overflow above the water tank. It remains the objective of

this research project however to identify and install a meter at a borehole with a similar high yield.

An online simulation environment for the collaborative design of drinking water infrastructure

Christopher Kelley, Johns Hopkins University

Can a dozen gamers design a sustainable water treatment and distribution system as well as one water engineer? Globally, billions of people must cope with water sources that are intermittent, dangerous, or far removed from their homes. While Millenium Development Goal #7 motivated and tracked progress towards universal access to sufficient quantities of potable and readily available water, much work remains (and achievements have frequently accrued least to those most in need). It is relatively simple to design small-scale water collection and storage systems; the design of robust and adequately monitored water treatment and distribution systems is much more complicated and falls traditionally within the purview of trained water engineers. Achieving universal access to adequate quantities of potable water remains an enormous task, and the quantity and availability of water treatment engineers is a bottleneck in global efforts. The author intends to demonstrate a crowdsourced solution to produce useful water treatment and distribution design plans from non-experts, by providing a collaborative online 3D simulation environment coupled with a hydraulic modeling engine. Users will be able to: evaluate real-world design problems; review available treatment, storage, distribution, and monitoring options; propose design solutions that are specific in spatial layout, parts required, and scheduling; receive real-time feedback from the hydraulic modeling engine on the feasibility of proposed solutions; and compare solutions from other users for a given design problem. Coding of this design tool is already underway, with Unity3D providing the simulation environment and EPANet the hydraulic modeling engine. Why do this? Tools such as WASHTech's Technology Assessment Framework can help lay-people collaboratively select water technologies that are appropriate to the needs of a given community (and communicate these preferences to engineers), but no analogue currently exists for design and construction of the actual community infrastructure. This means that communities have limited means to develop their own water infrastructure construction plans, or to investigate specific alternatives to the details of contracted construction plans. With the pro-poor workflow distribution software PulaCloud, the author intends to place the described design tool directly in the hands of communities struggling water safe water provision. Further, by adopting a distributed client-server architecture, the proposed planning framework can incorporate real-time streams of monitoring data. Tools to gather data on basic water quality parameters (flow rate, chemical dosage, pH, chlorine residual, and with recent work even turbidity) and communicate these data to servers (via low-costs communication methods such as the SMS-based OpenSourceWater network) are relatively inexpensive, but there are few good portals currently for tracking global real-time water quality data. The described design tool consolidates planning and monitoring into one portal, and gamifies it to attract eyes and minds to the problem of global provision of safe water. It is unrealistic to expect the small crop of water treatment engineers globally to design solutions for safe water provision that are simultaneously timely, universal, and nuanced to the needs of end users. It is likewise unrealistic to expect that communities left to construct safe water infrastructure without access to engineering evaluation will tend to succeed. The author ardently intends to provide a middle-ground solution that is both entertaining and useful; to increase attention to the global need for safe water provision and to increase recognition that the problem is tractable by providing non-experts the means to derive specific solutions.

The science behind water-oriented leadership programs: How this can affect WaSH post-2015 policy.

Rachael Kennedy, Virginia Tech

Additional Authors: Mark Burbach; Kristin Floress; Eric Kaufman

Water resources are increasingly being brought under collaborative management endeavors. The UN-Water, the United Nations inter-agency coordination mechanism for all freshwater and sanitation related matters, has identified five interconnected targets for WaSH in the Post-2015 Sustainable Development Goals. Collectively, the goals seek to provide better access, improve sustainable use, strengthen equitable, participatory water governance, improve water quality, and reduce disease and economic loss due to polluted waters. All of these, at different levels of scope and scale, are dependent on coordination of numerous actors. None of this will happen in a vacuum. Social science has a role to play in understanding how collaborative efforts can be successful and can provide insight into policy development. Developing leaders for water management is more important than ever. Many of the challenges faced go beyond technological concerns. Many are social in nature. All require adaptive and innovative sustainable water management leaders who have the ability to critically think about the interface of ecological, economical, political, and social challenges. The tasks given to our leaders require a multitude of technical and social disciplines as well as the voice of advocates seeking equitable, accountable participation. Furthermore, water resource leaders, from specific disciplines and from grassroots advocates, in addition to working collaboratively with each other, need to work closely with communities and diverse stakeholders. We argue that for the WaSH post-2015 Sustainable Development Goals to be achieved, logical and theoretically grounded leadership development programs must be developed and utilized. However, little is known about the current programs that are offered to develop such water leaders. For guidance, we conducted an exploratory study to examine water-related environmental leadership programs. Following the McCauley et al. (2010) model of leadership development we analyzed for presence of theoretical foundations, presence of assessment and evaluation, specifics on target audience, and program duration. Specifically, we sought to understand to what extent water-related leadership development programs are designed to change behavior and develop new abilities and skills. The evidence from this study indicates that most water professionals and others seeking to develop 21st century leadership abilities and skills to manage water resources are not getting the kind of leadership development opportunities they need. Results of this study call into question whether current leadership development programs are meeting their objectives, and producing leaders capable of addressing current and future water management issues. Findings from this study have implications for policy and interventions as we plan for Post-2015 WaSH Sustainable Development Goals. In brief, the water conditions of our era require that water professionals and advocates develop leadership abilities and skills beyond formal training. Thus, it is critical that leadership development programs be grounded in evidence-based theory; offer a variety of developmental experiences and the opportunity to learn from experience; and provide assessment, challenge, and support. There is an urgent need for new or revised leadership development programs for those interested in water resource management. Sharing these findings at the 2014 Water and Health Conference: Where Science Meets Policy expands the dialogue on how to achieve Post-2015 WaSH Sustainable Development Goals. Social science has a long history of translating scholarship into usable knowledge and thus informing policy. We argue that the field of leadership studies, especially that revolving around sustainable water solutions, is a prime partner during discussions of how to develop leaders for our complex and wicked water problems, including how to develop equitable, accountable, participatory models for water governance. This study begins to provide a 'behind the curtain' view of how water-oriented leadership programs can be instrumental in moving toward the goals set.

Fate of *Cryptosporidium* and *Giardia* during anaerobic digestion of swine waste.

Maureen Kinyua, University of south florida

Additional Authors: Sarina Ergas

Introduction Anaerobic digestion can be used to reduce greenhouse gas emissions, improve waste management, and improve the quality of life for those in the developing world. In the developing world applications, the biogas produced from anaerobic digestion is typically used to heat water or buildings and, cooking fuel. In addition, anaerobically digested biosolids, can be used as a soil amendment to improve plant growth. Although economically and environmentally attractive, land application of biosolids has potential health impacts due to transmission of pathogens to food and water. The protozoan parasites, *Cryptosporidium* and *Giardia*, are investigated in this study because of their prevalence in livestock and high resistance to inactivation. Apparently healthy livestock shed infective *Cryptosporidium* oocysts and *Giardia* cysts that can be transmitted to humans through ingestion (Erickson et al., 2006). Unfortunately, it is unknown whether anaerobic digestion of livestock wastes effectively decreases the number of these parasites to below the infective dose (Chauret et al., 1999), thus escalating the risk of transmission to water and food through land application of biosolids. Moreover, inactivation kinetics for *Cryptosporidium* and *Giardia* (oo)cysts have mainly been performed for soil and water. Therefore, in this study quantitative microbial risk assessment (QMRA) is used as a tool to estimate the risk of exposure to the protozoan parasites due to contact with anaerobic digestion effluents. By carrying out such a risk assessment, management practices that reduce transmission can be put in place to justify application of biosolids. A risk based management strategy is more attractive than a treatment technology based management strategy due to its versatility depending on the region, location, culture, socio-economic status and other community dependant variables. Creation of *Cryptosporidium* and *Giardia* (oo)cysts die-off rates during anaerobic digestion will be an asset to develop risk models that will provide more information on which environmental conditions during anaerobic digestion of livestock wastes increase or decrease risk of infection from (oo)cysts. Furthermore, biogas production and quality of nutrients in the effluent will also be assessed.

Methodology Swine waste will be used for this study due to prior knowledge of anaerobic digestion of swine waste (Kinyua, 2013) and an established relationship between University of South Florida (USF), Earth University and the Montverde Institute in Costa Rica. Digesters used for this study are located in the town of Monteverde in the northwest region of Costa Rica. The installed digesters are Taiwanese-model, double tubular polyethylene bag reactors with PVC piping for the biogas. The digesters are about 10m³ with a hydraulic retention time (HRT) of 16 days, a temperature of 18°C and cost approximately \$200 (Lansing et al., 2008). Standard Methods (APHA, 2012), will used to measure CH₄ content (6211 C), TN (4500- NO₃- E and 4500-P E), TP (4500-P J), BOD (5210B), alkalinity (2320 B), VS, and TS (2540 G). TAN testing method is adapted from literature as described by Kinyua (2013). Biogas volume will be measured using wet tip gas meters (Wayne, PA). *Cryptosporidium* and *Giardia* concentrations will be assessed at using EPA's method 1623. Outcomes From the preliminary work that has been performed, a solids retention time (SRT) of 21 days has shown to have excellent performance, with VS removals greater than 60%, CH₄ yield of 0.3 m³CH₄/kg VS added and CH₄ production rates of about 0.8 m³CH₄/m³ reactor-day indicating that the biogas produced would be a suitable fuel source. The total ammonia nitrogen (TAN), total nitrogen and total phosphorus concentrations in the effluent are 0.3 g NH₄⁺-N /L, 1.3 g N/L and 222 mg P/L respectively. The quality of nutrients in the effluent demonstrates that the biosolids from the digesters can be used as a soil amendment. Temperature, TAN concentrations, pH and SRT are some of the conditions in the anaerobic digester that have shown to influence the fate of (oo)cysts during digestion. Therefore, research is ongoing on the creation of kinetic models to better understand survival or inactivation of *Cryptosporidium* and *Giardia*. Reference Chauret, C., Springthorpe, S., Sattar, S. (1999). Fate of *Cryptosporidium* oocysts, *Giardia* cysts, and microbial indicators during wastewater treatment and anaerobic sludge digestion. Canadian Journal of Microbiology, 45(3), 257-62 Erickson, M.C., Ortega, Y.P. (2006). Inactivation of protozoan parasites in food, water and environmental systems. Journal of Food Protection, 69, 2786-2808. Kinyua, M.N. (2013). Effect of solids retention time on the denitrification potential of anaerobically digested swine waste (Masters' thesis). University of South Florida, Tampa, FL.

Decentralised Water and Wastewater Treatment Risk Assessment and Management Model

Lisa Kowalczyk, University of Leeds

Introduction The miscommunication of the advantages or disadvantages of decentralised versus centralised wastewater treatment is rooted in the lack of a universal, technically or institutionally explicit definition of these treatment approaches. The result of this miscommunication is the continued development of water and sanitation management strategies which do not consider decentralised and centralised systems from a holistic perspective, where the human health risks, environmental impacts, and economic impacts are uniquely assessed and compared for individual areas (Sharma, et al., 2010). Without an area specific assessment which gives a considered and fair appraisal of both treatment approaches (decentralised or centralised) a robust, accurate water and sanitation management plan can not be developed.

Methods and Problem Description The first component of this study is a review of literature exploring the definition of decentralised and centralised wastewater treatment used in academia, industry, and government. This review is necessary as there is a lack of a universal and specific definition of decentralised or centralised treatment. The result is water and sanitation management plans which frequently do not adequately address the applicability of either approach due to a fundamental misunderstanding of what a decentralised and centralized approach to water and wastewater treatment actually 'means'. The second component of this study is the development and application of a Quantitative Microbial Risk Assessment (QMRA) and cost model. The model is applied to both a hypothetical and UK case study area. The objectives of applying this model include: (1) Determine the potential health impacts resulting from the use of centralised or decentralised wastewater treatment within the study areas. (2) Determine the monetary costs associated with the respective treatment approaches modelled. (3) Develop health and cost trade-offs for the treatment approaches modelled. (4) Create a framework for assessing the applicability of centralised versus decentralised wastewater treatment approaches that will be valuable to those developing future wastewater management plans.

Conclusions Early screening results have shown that there are discrepancies in the basic definitions of decentralised and centralised treatment across relevant literature. Additionally, a QMRA assessment of a hypothetical case study location in which centralised and decentralised wastewater treatment options were considered demonstrated that health risks, environmental impacts, and costs of wastewater treatment types are complex and highly specific to the location in which these technologies are employed. Under various conditions (hazardous events, treatment failures, differing levels of water treatment) both centralised and decentralised treatment types could be identified as the 'better' solution for wastewater treatment needs. Therefore, it is vital to give full consideration to all treatment options available, the location under study (i.e. geography, hydrology, water sources, etc.), and to not discount those treatment types (either decentralised or centralised) based on pre-concieved notions of their advantages and disadvantages.

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Perceptions of Fluorosis in the Ethiopian Rift Valley

Anne Kroeger, University of Oklahoma

Global access to safe water is a key issue as approximately 900 million people lack access to safe water (Schuster-Wallace et al., 2008). It is estimated that over two hundred million people globally are drinking water from sources with fluoride concentrations above the World Health Organization (WHO) recommended level of 1.5 mg/L, most of whom are living within 25 countries across Asia and Africa (Amini et al., 2008; Reddy, 2009). Specifically in the Ethiopian Rift Valley, conservative estimates state that approximately 8 million people are affected by high levels of fluoride (Rango et al., 2012). Consistent exposure to elevated levels of fluoride results in the development of fluorosis, a chronic metabolic disorder, which can manifest as dental or skeletal fluorosis. Typically most individuals who develop skeletal fluorosis also have some degree of dental fluorosis; however, this is not always the case as dental fluorosis merely indicates an individual's exposure before the eruption of

permanent dentition, whereas skeletal fluorosis reflects an individual's chronic exposure during any period of their life (Tamer et al., 2007). Unfortunately, the relationship between fluoride exposure and skeletal fluorosis is not clear, as there are many confounding factors, including: climate, physical activity, diet, and possibly genetics (Tamer et al., 2007; Reddy, 2009). This presentation will discuss the findings from the preliminary research in the Ethiopian Rift Valley in the summer of 2012. This research was conducted in two kebeles, Sori Dollessa and Korke Aldi, which have (rainy season) fluoride concentrations of approximately 6.7 mg/L and >10 mg/L, respectively. At the time of the study, Sori Dollessa had a Nalgonda treatment plant which was installed in early 2012; however, the treatment plant was only functioning for one month and therefore the study was able to assess health as though no treatment existed. In Korke Aldi, no treatment plant has ever been built. For this preliminary study women were interviewed about their health status, pain and pain management, perception of the causes of pain, and perception of the quality of the drinking water source. Additionally, women were asked to perform a series of small exercises to gauge their perception of pain versus their actual abilities and glean information regarding key areas of health concern that should be studied in more depth. One result of the study was consistent mobility restrictions in the lumbar spine due to severe, chronic pain, which limited the ability of women to perform their daily tasks and is consistent with skeletal fluorosis. However, a more interesting finding is that the women in the two kebeles had markedly different perceptions of their drinking water. Women living in Sori Dollessa (6.7 mg/L) mostly believed their water source was adequate, while women living in Korke Aldi (>10 mg/L) were adamant that the water was causing their physical problems. This finding will be discussed in the most depth, as it may impact the uptake of fluoride mitigation technologies in areas with relatively lower (less than 10 mg/L) fluoride levels.

Launch of charity: water's Afridev Sensor

Robert Lee, charity: water

Abstract Knowing is half the battle: Remote Sensors for AfriDev Hand Pumps Robert Lee1 1: charity: water

Introduction charity: water is a non-profit organization with the goal of bringing clean and safe drinking water to people in developing nations. From 2007-2013, charity: water funded the construction of over 10,000 water projects, primarily boreholes and wells. In 2013 charity: water received the Google Global Impact Award to integrate new communication technology into M&E for WASH programs. The goals of this work are to: 1) design and implement a remote sensor capable of working with hand pumps that is low cost, reliable and works on the AfriDev hand pump, 2) inform charity: water's new programs to improve maintenance response time, and 3) to increase the transparency into WASH programs, best practices and aspects that require improvement. This presentation will focus primarily on the design and development of the remote sensor, and how this innovative technology can be integrated into future WASH programs.

Methods The product development goals for the remote sensor for AfriDev hand pumps were: 1. Measure water flows accurately 2. Communicate results in areas with limited network coverage 3. Hold power for multiple years of functionality 4. Withstand harsh environments and use conditions 5. Be low cost and accessible to anyone To achieve these goals many different design concepts were started in labs around the world, and eliminated along the product development pathway as they fell short of the design criteria above. A similar product development pathway with software developers to work together with the hardware was followed. The presentation will show the testing methods utilized to ensure these design parameters were met.

Results After completing this product development pathway, charity: water released a new capacitance sensor remote monitoring device that is completely solid-state and able to attach to the AfriDev hand pump in less than 10 minutes. The sensor integrates power saving technologies and smart algorithms embedded with simple artificial intelligence to be as efficient as possible. The sensor measures hourly water flow volumes within 10% accuracy and transmits that data in packets each week over cellular networks. If the sensor detects significant deviation from normal flow rates, the sensor will send an immediate alert, and continue to update until the issue is resolved. The battery life is estimated to last for 3-5 years. The sensor is waterproof, UV and impact resistant. Current fabrication costs are estimated at under \$100. Monthly

transmission fees are less than US\$1.50 per month worldwide, and negotiations are in process to reduce these to less than US\$0.50. Production of the units will begin in China, where the first scaled run is scheduled for August, 2014. The early production models have been installed in Ethiopia, and are functioning according to design, currently transmitting live data. This project anticipates the installation of over 2,000 sensors by the end of 2014, and plans to present the early operating data from the early models, and project data collection efficiency gains given the use of these sensors at water points in the future. Conclusions Robust and inexpensive remote sensors have the potential to drastically reduce M&E costs at water points around the world and, when combined with appropriate data management and communication platforms and capacity building, could reduce the down-time of broken water points. This presentation will present an outline of these economic and functionality impacts on future water development programs.

Household Water Treatment & Safe Storage: Knowledge Development & Diffusion in the Scientific Literature & Its Potential Impact on Practice

Laura MacDonald, Johns Hopkins University

Additional Authors: Christopher Kelley; Erica Schoenberger; William Ball

How do we do research on issues at the intersection of health, technological innovation, social and behavioral dynamics, politics and governance, environmental engineering and business? This problem faces researchers in many domains and many of us struggle to better understand how knowledge is generated, shared and built upon in this context. The authors explore these questions through the body of research on household water treatment and safe storage (HWTS). Providing safe water is one of the century's critical challenges. HWTS has been proposed as a short-term solution for populations without safe drinking water and is a valuable example of a field that lies at the intersection of the above research areas. HWTS researchers are committed to improving the lives of many in the developing world. The stakes are high. For this reason, it is important to take stock of how this body of knowledge has developed and diffused and reflect upon how we know what we think we know. Within the past decade, many critical and systematic reviews and meta-analyses have identified and synthesized key findings on water, sanitation and hygiene interventions, including their uptake and health impact. Several have focused specifically on randomized, controlled trials (RCTs) of HWTS. These latter publications take different approaches to evaluating findings and come to different conclusions. In doing so, they provide a valuable look at the current state of HWTS research. They do not, however, provide a historical perspective on the development of this literature. How do findings and metrics of success differ within this literature over time? When and where have the different methods been evaluated? What researchers, institutions, and funding organizations have played seminal roles in the development and diffusion of the concept of HWTS? We have undertaken a citation mapping and analysis to look at how issues emerge within the literature and how they're built upon over time. For this purpose, we focus on peer-reviewed articles that report on RCTs on HWTS as well as cited references of and literature citing these publications. We have identified these RCTs as a critical body of literature that is repeatedly referenced by different sector members. HWTS manufacturers, promoters and distributors point to the findings of RCTs when asked about technology effectiveness. Researchers use the findings of RCTs as well as reviews and analyses to determine gaps in the evidence and future research directions. The International Network for HWTS points to these publications when supporting HWTS as a short-term solution. This body of literature is central not only to HWTS research but also to its practical application to providing safe drinking water in developing countries. Given the potential impact of HWTS and other endeavors at the intersection of health, technical, social, political, environmental and economic fields, it is a matter of good practice to pause and reflect on how we create knowledge in this domain. Doing so allows us to look at how research is advanced and how the limited resources available can be most efficiently applied to achieve the greatest impact possible.

BioSand Filters: effects of physical disturbances on media compaction and filter performance

Naomi Mahaffy, CAWST

Additional Authors: Sarah Dickson; Raymond Cantwell; Corinne Schuster-Wallace

A lack of access to potable water makes people more vulnerable to waterborne diseases and more likely to sacrifice education or income-generating opportunities to collect water or care for sick family members. Although not an ideal long-term solution, point-of-use (POU) water treatment is one means of providing households in rural and remote communities with better control over their water quality and its effects on human health. The BioSand Filter (BSF) is one of the most popular POU interventions, currently used in over 300,000 households. The BSF is a household-scale, intermittently-operated slow sand filter housed in a concrete or plastic filter body. The concrete design (cBSF) is popular because it can be built by local people from locally-sourced aggregate and materials; however, plastic HydrAid (pBSF) filter bodies are gaining popularity due to their durability, affordability, and anticipated scalability. Without the weight and strength of a concrete case, the sand inside pBSFs may behave differently when subjected to disturbances such as side impacts or minor relocations. Because they are so much lighter, there is also a greater chance that pBSFs may be relocated or jostled. The goal of this study was to determine whether pBSFs can maintain their integrity and performance when they are impacted or moved. Eight pBSFs and two cBSFs were run in parallel for 13 weeks, and the effects of three different disturbances--one-time filter movement, one-time side impacts, and daily bucket impacts--were evaluated. Small daily bucket impacts did not affect sand compaction, flow, or filter performance. Larger one-time disturbances (moving and side impacts) caused significant ($P < 0.01$) decreases in sand column height of 6 - 9 mm for cBSFs and 9 - 29 mm for pBSFs. The median initial flow rate decreased by 18 - 84% for disturbed pBSFs but did not significantly decrease for control pBSFs or moved cBSFs. There was no evidence of preferential flow paths introduced by the physical disturbances, based on hydraulic tests and effluent quality. Effluent water quality was unaffected in the long-term by disturbances, but for the pBSFs substantial and very brief turbidity spikes were detected immediately after disturbances. The results presented here confirm the importance of installing filters in safe/secure locations where they are unlikely to be moved or bumped. To ensure safe water quality and better health of users, technicians could be trained to recognize and appropriately address problems caused by physical disturbances. Given that brief turbidity spikes were observed in this study, users should be encouraged not to consume effluent water without additional treatment for the first 1-2 charges after a disturbance.

Unreliable water supplies and household coping strategies: Revisiting Free Basic Water Services in Limpopo, South Africa

Batsirai Majuru, University of East Anglia

Additional Authors: Marc Suhrcke; Paul Hunter

Despite the vast and wide ranging efforts to provide safe and adequate water, many households in developing countries are faced with poor water services characterised by low pressure, intermittent supply and poor water quality¹. The issue of unreliable water supplies and the costs they impose on households is of profound relevance in South Africa; a country whose social policies include a Free Basic Water policy² which entitles all households to a free lifeline supply of 6,000 litres per month. Ostensibly, the Free Basic Water policy guarantees that the minimum water requirements of the poorest households - most often in peri-urban and rural communities - are met. But when the water supply is unreliable, how 'free' is Free Basic Water? Our analysis draws on a household survey conducted in peri-urban communities in the Limpopo Province of South Africa. We present findings on the reliability of water supplies, household strategies to cope with unreliable water supplies,

and the related financial costs. Our findings highlight that households spend significant proportions of their income on coping costs, and that for many households in the study area, Free Basic Water is not actually free. 1 Hunter PR, MacDonald AM and Carter RC .2010. Water Supply and Health. PLoS Med 7(11): e1000361. doi:10.1371/journal.pmed.1000361 2 Department of Water Affairs. 2007. Free Basic Water Implementation Strategy 2007: Consolidating and maintaining. Pretoria: Department of Water Affairs

The Role of Markets in the Future of Sanitation Development Efforts

Blake McKinlay, iDE

What is the goal of all the hard work invested in tackling sanitation challenges? The answer varies depending on who you ask. Some strive for 100% ODF coverage while others long for a world where every house re-uses their waste in some form. While both of these are admirable and important goals, I believe they are missing the point. The world that iDE strives for is one without diarrheal related disease - plain and simple. And in order for that world to become a reality, I would like to discuss why the WASH sector must fully embrace markets and focus on enabling the local private sector to sustainably provide everyone with affordable access to aspirational and adequate sanitation facilities. In the post MDG world, there is increasing focus on adequate sanitation, sustainability, and equity. Although markets have proven their ability to respond to customer demand, work in a variety of environments, reach scale, and be highly cost effective over the long term, they have still not been embraced fully. In fact, markets are criticized for not being able to reach the poorest of the poor or produce 100% ODF coverage. In addition, a tension remains between CLTS, subsidy programs, and sanitation marketing that continues to divide the sector. iDE believes that market development actually supports and enables all approaches to improving sanitation and is absolutely essential to achieving the proposed sanitation sustainable development goal (adequate facilities, sustainability, and equity). ? If we now strive for every household to use adequate sanitation, that which effectively separate excreta from human contact and ensure that excreta do not re-enter the immediate environment, markets are essential. They enable us to develop supply chains that provide access to the materials, manufacturing capacity, and products required to produce adequate sanitation facilities. And these supply chains actually support all sanitation development efforts. They complement CLTS by enabling households to move up the sanitation ladder beyond an un-improved latrine; they support government sanitation subsidy programs by making adequate sanitation facilities available to be given away; and they are the cornerstone of effective Sanitation Marketing programs. The increasing focus on waste management reaffirms the need for markets as these systems also inherently require a value chain that involves various service providers. ? If we now strive for sustainability in the sanitation sector, markets are essential. They have proven to meet a variety of households' development needs, including sanitation, after projects are completed. By enabling all actors in a value chain to profit, markets provide an incentive to remain involved in sanitation as long as demand exists. This sustained involvement makes adequate sanitation available to households going forward. Furthermore, as latrine maintenance, repairs, and upgrades are inevitable, markets ensure households evolving sanitation demands continue to be met. ? If we now strive for equity in sanitation access and adoption, markets are essential. Although people disagree whether markets are the best mechanism for reaching the poorest of the poor, they are in fact essential to providing everyone with adequate sanitation. Whether they are delivered through the private sector or a subsidy model, adequate sanitation facilities need to be available and markets ensure value chains exist to provide the materials, skills, and products needed to produce an improved latrine. While market development has numerous benefits and widespread applicability, what it looks like in practice varies significantly. iDE's experience developing sanitation markets in 6 countries has revealed some important insights into the various forms that sanitation market development can take. How market development actually looks depends on: ? Customers' awareness of the benefits of sanitation, preferences in latrine products, and previous experiences with sanitation ? The maturity of the sanitation supply chain and the level of sophistication of the manufacturing base ? The complexity of the value chain and the level of development of the micro-finance sector ? The desired level of engagement by stakeholders, most importantly

the national and local governments? The potential exit strategies that may be feasible within a given context. iDE's experiences and lessons learned in these areas provide valuable insights into what market development can and should look like going forward. In reality, it will not be the same in each country, and that should be encouraged. The true beauty of markets is that they are adaptable to a variety of environments and already exist in some form in every country in the world. It is time for the conversation to change from looking at what specific elements market development can support to how markets actually support all of the WASH sectors goals and approaches.

Impact and acceptability of using *Moringa oleifera* seeds and handwashing with soap to improve household drinking water and diarrhoea incidence in Poor Rural Tanzania

Frank Mng'ong'o, London School of Hygiene and Tropical Medicine

Additional Authors: Adam Biran; Jeroen Ensink

In rural Africa over 80% are reliant on unimproved surface water sources for their domestic water supply. The sources are often prone to faecal contamination, and unsafe for consumption, based on World Health Organization guidelines for drinking water. Interventions to improve drinking water at point of use (household level) have shown to be an effective way in diarrhoea prevention, but most of the available interventions are expensive. The use of natural flocculants such as crushed *Moringa oleifera* seeds which promotes rapid settlement of suspended particles and pathogens when applied to water has shown excellent promise as a cheap alternative. In addition systematic literature reviews suggest that hand washing with soap at moments of public health significance can reduce rates of diarrhoea by 42-47%. However, adequate hand washing for diarrheal prevention requires sustainable behaviour change, which is difficult and takes time. In poor rural settings hand washing with soap is uncommon, the practice is limited as a result of poor access to water, difficulties to afford soap and poor hygiene education. Where soap is available it is often controlled and kept out of reach to save it from theft, waste and spoiling. Another factor in the low uptake of hand washing with soap is the lack of a designated place for hand washing. A hand washing station brings together water and soap for convenience and easy access, influencing the chance of an individual to practice the behaviour at key times especially when placed near a toilet and cooking areas. Simple, cheap and enabling technologies such as tippy taps could avoid drinking water contamination, through cleaner hands and may be easily taken up. We present the findings from a Randomized Controlled Trial (RCT) conducted between August 2012 and November 2013 in Ngara district, Kagera region-Tanzania where diarrhoeal diseases are a serious problem, with transmission three times higher than of the national levels. Most of the population depend on unprotected water sources like open springs, open wells, seasonal streams and rivers which are more than one kilometre away for their drinking water provision. Hygiene behaviour in the area is very poor; health promotion or any hygiene intervention has not taken place. The study had an aim to assess whether the use of *Moringa oleifera* seeds and hand washing with soap could improve drinking water quality at household level. It also assessed the impact on disease morbidity, consumer acceptability and potential scalability of the interventions. To answer these research questions, the study had three arms; the first arm was provided with *Moringa oleifera* seeds to purify drinking water at household level, the second arm a hand washing (provided with tippy taps, soap and hygiene promotion) intervention to prevent in-house drinking water re-contamination, while the third arm acting as a control was provided with insecticide treated bed nets (ITNs). Combinations of both qualitative and quantitative methodologies were used; Questionnaire surveys, hand swab surveys, observations and focus group discussions. Bacteriological analysis of water samples from sources and stored drinking water in households, and from hand swab surveys were performed using membrane filtration techniques to test for *Escherichia coli* (*E. coli*) concentrations. Diarrhoea and pneumonia incidence as a secondary outcome was measured by assessing both the number of episodes and the total number of days with the disease among the study participants. Initial findings showed reduced levels of drinking water contamination in the both intervention groups, and an almost

50% reduction in levels of hand contamination in the tippy tap group as a result of higher levels of self reported hand washing with soap. Diarrhoea disease showed a decreased trend over time in all study groups. Focus group discussions showed that there was a broad uptake of the interventions especially tippy taps. Moringa oleifera seeds were highly appreciated, though there were issues with compliance in using them for water purification, most likely because people were aware of other uses/ benefits specifically the medicinal values, of the plant.

""I'm the cleanest hobo I know"": The work of hygiene and pollution in riverbottom homeless encampments and urban ecological restoration

Jennifer Mokos, Vanderbilt University

Although urban rivers in the United States have frequently been sites of long-term homeless encampments, recent efforts to restore public connection and ecological functioning to these marginal waterways have increased tensions surrounding the presence of camps. For example, in California, citizen environmental organizations and regulatory agencies have threatened or pursued actions against local municipalities for creating an water quality hazard by allowing camps to exist in floodplains without trash removal or sanitation facilities. Pressure to remove camps largely revolves around dual concerns for the health of the waterways and the health of the people. To explore this intersection between environmental health and human health, I have conducted an ethnographic study of the ecological restoration of the Ventura River in Southern California. In this paper, I draw on interviews with environmental workers, interviews with people living within the riverbottom, and observations of restoration activities and camp removals to analyze the ideological work that is performed by hygiene, pollution, and sanitation. In the Ventura River, environmental workers lead tours of camps and make-shift latrines to enroll support from volunteers, while some homeless individuals go to great lengths to distinguish themselves as "clean" in the hopes they will be allowed to stay. In this paper, I argue that hygiene does cultural work that reconfigures the relationship between environment and health as something that is deeply intertwined with knowledge production and practice, rather than an individual-level external variable.

Monitoring the inputs required to extend and sustain hygiene promotion initiatives: where are we falling short?

Leslie Moreland, London School of Hygiene and Tropical Medicine

Additional Authors: Fiona Gore; Jeroen Ensink

Hygiene promotion has until more recently been absent, or included as an afterthought, on the global WASH agenda. Yet hygiene promotion has been shown to be among one of the most cost-effective of all preventive health interventions [1]. In many countries, water and sanitation policies, plans and strategies are in place to reach vulnerable groups such as those living in poverty. However, monitoring progress in access and service provision for the poor is carried out in less than half of countries for sanitation and drinking-water [2]. It could be argued that this is even less so for hygiene promotion activities, but there is limited data available to adequately assess this. In an attempt to address this gap in information we present the results of the hygiene-specific data collected from over 80 countries as part of the 2014 UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) report (estimated publication date September 2014). Building on previous work done by Jimenez et al. on this same topic we highlight the current trends, gaps and barriers facing countries in achieving hygiene promotion targets and impact [3]. Based on these insights we present findings on how hygiene-specific information is collected, what the data indicates, and make recommendations on hygiene indicators that may be of relevance for other global monitoring initiatives, including the Sustainable Development Goals (SDGs). References 1. Laxminarayan, R., Chow, J. & Shahid-Salles, S. A. 2006 Intervention

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Killing pathogens in treatment ponds: predicting the role of sunlight from wastewater optical properties

Simón Mostafa, University of Colorado - Boulder

Additional Authors: Fernando Rosario-Ortiz; Karl Linden

Treatment ponds and constructed wetlands have been recognized to be among the appropriate technologies for the treatment of wastewater, particularly in rural contexts. These natural treatment systems (NTS) have been shown to perform well over a wide range of conditions leading to effluent qualities comparable to secondary treatment standards with respect to various constituents of concern while being relatively simple to operate and requiring minimal energy and chemical inputs. Even though these systems are usually not optimized for microbe elimination, reductions in pathogen concentrations typically range between 0.5 and 3 log. While some mechanisms contributing to pathogen reduction have been elucidated, there is still no systematic way to predict performance and improve system designs. The effect of solar irradiation in the inactivation of microbes has been clearly established and recognized to play a role in surface waters as well as SODIS processes. Within engineered systems, most of the emphasis has been placed in the UV region of the light spectrum given its relatively high inactivation potential compared to the longer wavelength (lower energy) regions. However, several studies have also reported enhanced inactivation of bacteria and viruses due to indirect exogenous photochemical processes, with singlet oxygen ($^1\text{O}_2$) playing a key role. Such exogenous processes are expected to be particularly important within NTS due to the relatively high concentrations of light-absorbing organic matter (OM) derived from wastewater and other natural sources. Thus, OM may hinder direct sunlight inactivation by reducing light penetration in the water column and creating a "shielding" effect. On the other hand, OM can act as a photosensitizer in the formation of reactive species, including $^1\text{O}_2$, which can lead to an enhancement in the inactivation of pathogens of concern. An important question for the estimation of inactivation rates in NTS, that could inform the design of these systems, is whether the light attenuation or the photosensitizing effect is greater in the presence of OM. The answer to this question depends, among other variables, on the specific microbe being studied, various water quality parameters, and will also vary as a function of depth with both attenuation and inactivation rates being wavelength-dependent properties. Since these processes are greatly affected by the interaction of OM with sunlight, its optical properties can serve as indicators of its role in inactivation. Specifically, the absorbance spectrum of OM relates to the light attenuation in the water column and thus to the reduction in direct inactivation of microbes. On the other hand, the quantum yields (Φ) describe the efficiency of OM as a photosensitizer (e.g. the number of $^1\text{O}_2$ molecules formed per photon absorbed) and such properties have been also correlated to absorbance characteristics in OM. This study investigates the relationship between optical properties of OM and photochemical behavior and explores its role in the inactivation of microbes. The inactivation rates of Enterococci and *E. coli* upon exposure to simulated sunlight were evaluated under varying conditions. Additionally, OM of various origins were characterized for absorbance and photosensitizing properties and relationships were derived that help estimate the expected inactivation rates of these indicator bacteria from relatively simple optical measurements. These results are expected to be useful in the design of wastewater treatment systems where sunlight irradiation plays a significant role by providing a simple tool for the estimation of inactivation kinetics that can better inform design parameters such

as retention time and water depth.

Cholera Transmission in Haiti: Deconstructing a Gravity Model

Alicia Mullis, University of Michigan-Ann Arbor

Additional Authors: Joseph Eisenberg

Background: Haiti has been undergoing a cholera epidemic since 2010. To control and eventually eliminate cholera from Haiti requires a mechanistic understanding of pathogen spread. We adapt a previously published model. **Objective:** To evaluate the relative importance of transmission between neighboring departments, population centers, and their joint effect on the overall eventual number of cases and the timing of outbreaks. **Methods:** The transmission model (developed by Tuite et al.) is a modified SIR model that captures the transmission dynamics within each of Haiti's 10 different departments and interaction among these departments. The model allowed for transmission from water to humans, human to humans within department, and human to human outside of the department. The inter-department transmission is modeled using a gravity model, where transmission between departments is dependent on distance and population size. **Results:** In our implementation of the model, the sequence of epidemic peaks was similar to the order obtained by the authors ($r=0.83$, $p<.01$). For departments already having cases by October 30, 2010, epidemic timing and cumulative case counts were insensitive to the choice of model strategy. However, for departments not having initial cases, considering transmission only between neighboring departments vastly overestimated the time to peak. Because of this delay, the model only accounting for nearest neighbor transmission predicted 14% fewer cases than the gravity model after 1,000 days. However, only accounting for transmission between population centers (Ouest and Artibonite) resulted in similar peak times compared with those obtained using the full gravity model ($r=1.00$, $p<.0001$). The total cumulative cases also approximated that obtained by the gravity model. **Conclusions:** These results highlight the critical importance of larger population centers as conduits for infectious disease transmission. Further, our work suggests that transmission between non-neighboring regions with smaller population sizes plays a negligible role in both the timing and sequence of outbreaks. Of the two components considered in a gravity model, it appears that population size is far more important than the distance between regions.

NEGOTIATED APPROACH IMPROVES MENSTRUAL HYGIENE MANAGEMENT AND BEHAVIOUR CHANGE IN RURAL PRIMARY SCHOOLS OF UGANDA

Agnes Namuli,

Abstract Most of the menstruating girls in rural primary schools use old clothes, while others use nappies from their siblings. In emergencies, the girls opt for handkerchiefs or dry banana leaves until they could get home and devise other means. However, using such clothes poses serious threat of infection. For the majority of girls, the only alternative is to stay at home during their menstruation periods, opting to remain in bed hence missing and dropping out of school. MWODA engages parents, teachers and primary schools girls to discuss about menstrual management. We train them in menstrual hygiene management and construct gender friendly latrines in participation of parents, school management committees and teachers. The latrines are constructed with a girls wash room for better menstrual management. MWODA is looking forward to start producing pads from natural waste materials with the objective of reducing drop out of girls in rural and poor communities, while creating a women's entrepreneur network through which pads are distributed. **METHODOLOGY** We engage schools, parents, teachers and girls and create awareness on menstrual hygiene management and behavior change. MWODA facilitate training sessions in schools to equip girls, parents, teachers and boys with basic skill on how

to make low cost re-usable menstrual pads with locally available materials. Boys are also taught about menstrual health and involved in making of low cost re-usable menstrual pads so as to reduce the social stigma surrounding menstruation and retaining the girls in schools. **RESULTS** This innovative approach has empowered girls, parents and teachers with skills to better hygiene behavior. Today, 250 girls, from 4 primary schools in addition to their teachers and parents have been trained to make re-usable pads. With the constructed gender sensitive latrines with girls wash rooms, the girls are no longer staying home during their menstrual periods. They are now retained in school. There is improved menstrual hygiene management and behavior change among these targeted schools. There is increased awareness among girls, parents, teachers, boys on basic menstrual hygiene management. There is less fear and stigma among girls of menstruating age. **RECOMMENDATION/CONCLUSION** MWODA Plans to partner with donors to scale up in producing re-usable pads from natural waste materials with the objective of improving menstrual hygiene management and behavior change. We are seeking for support to enable us have sewing machines and train the schools in the hard to reach areas of Southern Uganda in menstrual hygiene management and behaviour change

Recovery of nutrients from source-separated urine via biochar - Generating valuable and marketable end products from sanitation systems

Jeanette Neethling, University of Colorado, Boulder

In many communities, urine-diverting toilets are becoming a common method to safely collect human waste and recover valuable nutrients, however liquid urine can be expensive and difficult to transport due to its mass. Additionally, unpleasant odors can be released as nutrients are volatilized in storage or transport. Carbonized waste biomass, biochar, has been shown to be an effective sorbent of many nutrients. This material, already a useful soil amendment, can also serve as a fertilizer as it is 'pre-loaded' with bioavailable nutrients. Additionally, biochar can be generated from the solid human waste stream, killing pathogens and transforming the waste into a resource. In this study, biochars produced using a range of temperatures and feedstocks (e.g. bamboo, rice husks, pine, fecal sludge, and biosolids) were used in batch tests to test and compare sorption of key nutrient components of human urine. Biochar is a carbonized material which can be locally produced at a low cost, using waste biomass. While most current applications utilize biochar derived from agricultural wastes, this research assessed the properties and effectiveness of fecally-derived biochars in comparison with other feedstocks. Previous work has shown nutrient uptake in biochars from dilute liquid and gas streams, however this study focuses on using undiluted human urine that yields high concentrations and a complex mixture of background salts. Converting human waste to biochar has potential to reduce the spread of pathogens and harness a waste product into a resource. Additionally, biosolids from conventional wastewater treatment provide another possible feedstock for biochar production and are included and evaluated in this study. Sorption of nitrogen and phosphorus from urine to biochar was assessed in well-mixed batch reactors with varying carbon doses to assess nutrient recovery for increased agricultural benefit. Additionally, various natural sources of magnesium were mixed with biochar, increasing precipitation of phosphorus in the form of struvite (NH_4MgPO_4), a crystallized and marketable fertilizer. Finally, sources of fresh and stored urine were compared, fresh containing more soluble phosphorus and stored containing more ammonium. Bioavailability of sorbed and precipitated nitrogen and phosphorus in the various experiments was then determined by standard acid extraction. Experiments indicated approximately 50% adsorption of ammonia onto fecally-derived biochar at 400 g/L dosage, similar to performance of other feedstocks. Sorption mechanisms were determined based on char characteristics, such as pH and char surface area. It was determined that low-temperature and lower surface area chars have greater sorption capacity of ammonia, indicating that ammonium sorption is not purely physical, instead related to a low surface pH interaction. Phosphorus reduction in urine was investigated as a combination of sorption and precipitation, forming struvite (NH_4MgPO_4). This work has implications for the beneficial reuse of agricultural and human waste, both in developing and developed countries. Biochar is already a proven soil amendment, and this work displays the potential of biochars to be 'pre-loaded' with nutrients before application to soil,

simplifying farmers' application procedures for crop enhancement products. Nutrient recovery shifts the focus from phosphorus and nitrogen as contaminants and causes of algal blooms to phosphorus and nitrogen as valuable resources. This work highlights the possibility of more efficiently using this nitrogen and phosphorus, typically labeled waste, and offsetting the need for industrial produced nitrogen salts.

Evaluation of education and training in water and sanitation technology: Case studies in Nepal and Peru

Tommy Ngai, CAWST - The Centre for Affordable Water and Sanitation Technology

Additional Authors: Brittany Coff; Eva Manzano; Keith Seel; Peter Elson

Introduction A significant constraint to effective and sustainable water and sanitation provision is the "lack of capacity at the local level" (WHO, 2010). Recognizing this challenge, a range of organizations are offering education and training activities to upgrade the capacities of governments and non-governmental organizations (NGOs) responsible for water and sanitation provision. However, questions are increasingly raised on the effectiveness of these efforts, with evidence that many governments and NGOs aren't getting the education and skills needed (IWA, 2011). A global review of 100 leading capacity builders in the WASH sector found that only 1/3 reports their results (Ngai et al, 2013). Among these, the methods used are often ad-hoc and deploy prescriptive criteria to assess only whether outputs are achieved (e.g. the number of people trained), rather than outcomes or impacts. **Objective** The objective of this study was to design and trial an evaluative framework to assist capacity builders in the water and sanitation sector in capturing and interpreting their results, and in understanding how to maximise impacts. The Centre for Affordable Water and Sanitation Technology (CAWST) is a non-profit organization that provides training and consulting to organizations that work directly with populations in developing countries who lack access to clean water and basic sanitation (CAWST, 2013). CAWST and the Institute of Non-profit Studies at Mount Royal University (MRU) have collaborated to complete this study. **Method** A review of over 20 evaluation methodologies was undertaken as the first step in developing an appropriate framework. The framework is a customization of the Kirkpatrick's four levels of learning evaluation, which includes four steps in the assessment of learning processes: (1)Reaction: How did participants respond to the training? (2)Learning: Did participants experience changes in knowledge, skills, attitudes? (3)Behaviour: Can changes be observed in the participant's behaviour? (4)Results: How have organizational outcomes changed? (Kirkpatrick & Kirkpatrick, 2006). The framework was applied to evaluate the impact of CAWST's education and training activities in Peru and Nepal. Data was collected through 30 interviews with individuals who had participated in CAWST's training and consulting support activities. **Results** Specific findings differed between the case studies in Peru and Nepal; however common themes were identified through comparison of the two case studies. Generally, participants were satisfied with the education materials and training workshops delivered by CAWST and its local partner organizations. The education posters and training manuals are effective, contain plenty of illustrations, are easy to use, and are written at an appropriate technical level. However, many interviewees recommended that more follow-up visits and support from CAWST and its local partners are needed. They were also unaware of updated and new training and education materials available from CAWST. Some workshop participants had not implemented water and sanitation projects due to lack of funding, or stated that the technologies learned from the training were not appropriate for their project sites. The framework captured new information about the impacts of CAWST's training activities and filled a gap in CAWST's existing monitoring and evaluation processes. The findings demonstrate changes in CAWST's client's competencies (eg. learning about effective training techniques), in contrast to focusing on quantitative results only (eg. the number of filters implemented). There is an opportunity to make the evaluation framework more robust and comprehensive by including additional sources of data for the evaluation, alongside the interviews. This would add more rigour and systematic aspects to the assessment and reduce the reliance on interviewee 'self-reporting'. There is also potential to scale up the study by integrating the Kirkpatrick methodology to other elements of CAWST's monitoring and evaluation systems (eg. CAWST's annual client survey). There is also

potential for the framework to be applied to assist other capacity building organizations in capturing and interpreting the impacts of their education and training activities. References CAWST 2013 Summary Report on CAWST's Activities in Nepal. CAWST: Calgary. IWA 2011 Meeting the water and sanitation MDGs: a study of human resource development requirements in five countries. IWA: London. Kirkpatrick, D.L. & Kirkpatrick, J.D. 2006. Evaluating Training Programs: The Four Levels (3rd Ed.). Berrett-Koehler Publishers. WHO 2010 Global annual assessment of sanitation and drinking-water (GLAAS). WHO: Geneva. Ngai, T.K.K., Mills, O. et al (2013) A global review of capacity building organizations in water, sanitation and hygiene for developing countries. 36th WEDC International Conference, Nakuru, Kenya.

Marketing Household Water Treatment: Willingness To Pay Results from an Experiment in Rural Kenya

Clair Null, Mathematica Policy Research

Additional Authors: Annalise Blum; Vivian Hoffmann

Despite increasing availability of household water treatment products, demand in developing countries remains low. Willingness to pay for water treatment products and factors that affect demand are not well understood. In this study, we estimate willingness to pay for WaterGuard, a dilute chlorine solution for point-of-use water treatment, using actual purchase decisions at randomly assigned prices. Secondly, we identify household characteristics that are correlated with the purchase decision. Among a sample of 854 respondents from 107 villages in rural Kenya, we find that mean willingness to pay is approximately 80% of the market price. Although only 35% of sample households purchased WaterGuard at the market price, 67% of those offered a 50% discount purchased the product. A randomly assigned marketing message emphasizing child health did not have a significant effect on purchase behavior, overall or among the subset of households with children under five. These findings suggest that rural Kenyans are willing to pay for WaterGuard at low prices but are very sensitive to increasing price. Households with young children that could benefit the most from use of WaterGuard do not appear to be more likely to purchase the product, and a marketing message designed to target this population was ineffective.

Assessing market structure and demand for current and potential sanitation services: A view from slums in Nairobi

Mark O'Keefe, Eawag

Additional Authors: Robert Tobias

The Bill and Melinda Gates foundation are funding the "Re-invent the Toilet Challenge (RTTC)" which is focused on improving user interface and re-use of waste products. It is hoped that by developing new technologies, the problem of inadequate sanitation in slums can be solved. One of the technologies developed through the RTTC is the blue diversion toilet, developed by researchers at Eawag and designers at EOOS. The team developed a source separating pan, which is linked to a water recycling system. The separation of streams enables water to be recycled on site, whereas the faeces and the urine are collected and will be transferred to a resource recovery plant for processing. Similar to the design of other technologies for emerging markets, the acceptance and use of a technology is not a purely technical issue but depends on user acceptance, current socio-economic conditions and the current structure of the market in which the technology could embed. Our research aims to identify the structure of the sanitation market and the demand for current and potential sanitation services within two slums in Nairobi; Mukuru and Kibera. Through identifying the structure of the market, and who are the major providers of sanitation services it will be possible to identify the major bottle necks within the system

which could prevent the diffusion of the new product. By identifying current demand, and demand for a potential service it will be possible to understand the potential market for the new technology. We were able to understand the current market structure and demand for sanitation services through conducting a household survey. Over 1,200 people were interviewed in 12 different villages. The survey focused on general socio-economic and sanitation conditions, the different type of actors involved in the provision of sanitation services and the willingness to pay for current and potential sanitation facilities. Results indicate a current contentment with general sanitation conditions, but a lack of facilities to wash hands or materials to cleanse yourself after defecating. Two overlapping systems of provision emerged; the public pay per use system and the shared latrine system at the household. Within the public system, the private operator is the key actor responsible for the capital input, cleanliness of facilities, maintenance and emptying. In contrast, the landlords is the actor most responsible for providing latrines to households, households are mostly responsible for cleaning their latrines, but it is the landlord who is responsible for maintaining and emptying the latrine. The research illustrates that private investment from the household sustains both sanitation systems, and that any new technology development must take into consideration not just the end user but the key actors within the systems; the private operators and landlords.

Combining remote monitoring and ethnography to estimate sanitation behaviors

Kathleen O'Reilly, Texas A&M University

Additional Authors: Elizabeth Louis; Evan Thomas; Antara Sinha

This paper contributes to the ongoing international effort to improve sanitation and hygiene policy and practice by suggesting the means by which behavioral, infrastructural, and environmental change can be measured and understood. We estimated latrine usage behavior through mixed ethnographic and technical methods, specifically: 600 user interviews; unstructured observations over a 16 person-month field period; a photographic data set; and the latest generation of infrared toilet sensors, Portland State University Passive Latrine Use Monitors (PLUMs). 258 households in West Bengal and Himachal Pradesh, India participated in the study by allowing PLUMs to be installed in their houses for a minimum of six days. Participant households were interviewed about their toilet usage, toilet building history, and understandings of human waste. After data collection, we embarked on an iterative process of analysis that included returning to the field for feedback and dissemination. As the defecation and hygiene habits of families in the two study sites were systematically different, ethnographic and observational data framed the analysis of the PLUM raw data. PLUMs provided reliable, quantitative verification, while ethnographic data collection proved essential to understanding and maximizing the PLUM data set. Combining mixed-methods with an iterative analytical process produced enabled deeper insights into the data collected and more refined answers about sanitation behavior in rural India. The study's results give the policy maker, practitioner, and researcher a robust methodological approach through which to assess positive and negative health behaviors and conditions on the ground.

Optimising the performance of studies evaluating the public health impact of community water supply quality interventions

Joanne O'Toole, Monash University

Additional Authors: Martha Sinclair; Thomas Boving; Sumit Gautam; Kavita Patil; Karin Leder

Background: An adequate water supply promotes good sanitation and hygiene and there is sufficient evidence to suggest that along with drinking water quality, water quantity (access) is important for the protection of child

health. Accepting that both quantity and quality of the drinking water supply reduce diarrhoeal disease, effective treatment of contaminated drinking water to remove microbial pathogens is important to achieve maximum health benefits. Water treatment interventions need to be not only effective but also affordable, reliable, appropriate to geographical location, acceptable to the local community and sustainable, with the aim that through continuous provision of high quality drinking water, the burden of diarrhoeal disease in vulnerable communities is reduced. To this end, high quality empirical evidence is required so that the water treatment interventions that are most effective in reducing diarrhoeal disease are selected. In the scientific literature, there are numerous studies evaluating water supply interventions for their effectiveness in reducing diarrhoeal illness in low resource countries but heterogeneity in study design and outcomes have resulted in general low quality evidence. Aim: To investigate study design features that can be employed to optimise the quality of evidence about the effectiveness of community water supply quality interventions to reduce diarrhoeal illness. Specifically, we evaluate design features and outcome measures employed in water quality and other epidemiological studies to arrive at a list of strategies which can be used to reduce reporting bias and/or lead to the production of more robust data. Our motivation to undertake this investigation arose during a planned study of Riverbank Filtration (RBF) where blinding of participants to their allocated water supply was not possible but where pilot studies had shown that RBF provided an acceptable, cost effective water quality and quantity management solution -but one unproven in reducing rates of community diarrhoea. Results: Measures that have been used to improve the quality of evidence and robustness of data about water quality interventions fall into two main groups, namely ones that i) seek to optimise the effectiveness and reliability of the water treatment intervention and, ii) are specifically employed to reduce reporting bias about health impacts. Strategies successfully used to optimise water treatment interventions include piloting of water treatment interventions for their appropriateness in terms of source water quality and community acceptability; removal of barriers to interrupted water treatment (training of householders/personnel in water treatment; provision of /access to consumables, electricity; water treatment processes that are simple, affordable and time appropriate); householder education about hygiene and proper method of household water storage and, verification of water treatment effectiveness through monitoring of water quality and/or consumable (e.g. disinfectant) use. Measures specifically employed to reduce reporting bias about health impacts where it is not possible to conduct a randomised control trial or blind participants to water source include: use of stepped wedge study design and for self-reported diarrhoea as an outcome measure, use of shorter recall periods, reduced intensity and burden of surveillance to reduce fatigue and loss to follow-up, use of incentives for continued participation, verification through faecal sampling for pathogens, use of supplementary objective measures of diarrhoeal disease (e.g. hospital records) and use of falsification symptoms (i.e. questioning about symptoms not related to water supply as a measure of recall bias). Underpinning both categories of measures is good record keeping and the potential for new technology (e.g. mobile phones and electronic tablet devices) to: i) reduce data collection costs and errors in data transfer; ii) issue reminders or notify of water treatment failures so that they can be rectified as soon as possible and, iii) reduce bias in self-report diarrhoea through the use of diary format or response to questions about health in 'real time'. Good record keeping provides a means to take account of confounding factors when analysing results and, where heterogeneity in results does occur, allows potential reasons for this to be determined - overall leading to improved quality of evidence. Conclusion: Evaluations of drinking water treatment interventions are required so that the most effective, affordable and site appropriate interventions are selected. In real-world settings, it is not always possible to conduct blinded, multi-arm randomised trials due to economic, logistical or other constraints, but the highest quality data possible must nevertheless be generated. Otherwise data serve as a suboptimal basis for decision-making about water quality interventions.

Assessing the vulnerability of drinking water systems to compound climate hazards in coastal Vietnam and Philippines

Edema Ojomo, The Water Institute at UNC

Additional Authors: Aizhan Toregozhina; Jeanne Luh; Jamie Bartram

With approximately 40% of the global population living along coastlines, coastal areas represent one of the geographic regions most vulnerable to climate change due to their exposure to increasing sea level rise and exposure to increased frequency and/or intensity of tropical cyclones and precipitation. To ensure drinking water systems are not compromised, it is important to understand their vulnerability to climate hazards and subsequently implement effective adaptation methods to reduce vulnerability. Current assessments of vulnerability to climate change hazards focus on single hazards such as sea level rise or heavy precipitation. However, coastal regions represent a unique geographic location where several climate-related hazards often collide. The effect of these combined hazards is not the simple addition of the exposure to the individual hazards, but often results in more damaging and severe outcomes. Accordingly, vulnerability assessments must focus on the synergistic exposure of coastal areas to multiple climate-related hazards. This study evaluates the vulnerability of drinking water systems in Vietnam and the Philippines to the simultaneous impact of storm surges and rainfall. Key questions addressed include: (1) What is the relative exposure of drinking water systems in coastal areas of Vietnam and the Philippines to storm surges and rainfall? (2) How are drinking water systems impacted by these hazards? (3) What adaptation measures can be employed on drinking water systems for these hazards? (4) What factors contribute to the vulnerability of drinking water systems in coastal areas? and (5) How can drinking water system vulnerability be reduced? To achieve the objectives of this study, it was imperative to understand the concept of vulnerability. According to the Intergovernmental Panel on Climate Change (IPCC), the vulnerability of a system to climate hazards is a function of exposure to relevant hazards, sensitivity of the system to the hazards, and adaptive capacity. A review of existing vulnerability assessment models was carried out to also assess how these factors are combined under different situations. A model for assessing vulnerability is being developed using exposure, sensitivity, and adaptive capacity as a foundation for its development and building on previous vulnerability assessment models for single hazards. For the three model components, exposure to surge and rainfall was examined using frequency of events obtained from historical databases. The United Nations Environment Programme (UNEP) Global Risk Data Platform was used as the source for storm surge and rainfall data was obtained from the University of Delaware Center for Climate Research and analyzed by calculating the standardized precipitation index (SPI). Frequency of surge events was calculated for different administrative areas of Vietnam and Philippines using ArcGIS, where the administrative areas were defined by the Global Administrative Areas (GADM) database hosted by University of California Davis. Simultaneous rainfall and storm surge exposure is then determined by analyzing SPI values for the months that surges occurred and determining if those months were abnormally wet based on the SPI values. Sensitivity to impacts is being analyzed by assessing (1) the resilience of drinking water systems using the Vision 2030 report; (2) physical factors like elevation and distance of coast that influence how intense the impact of the climate hazards will be; and (3) land use patterns that modify the impacts of the hazards. Indicators for adaptive capacity will be determined based on a literature review on the factors reflect sub-national adaptive capacity. Adaptive capacity refers to the ability of a system to adjust to hazards and indicators generally include economic and political factors such as gross domestic product and governance factors. This study is currently being carried out and will be completed in six months. The model will be validated by field interviews with government officials, water utility personnel, and community water system operators. The results will provide valuable information for evaluating drinking water systems in coastal areas and assessing adaptation strategies to reduce vulnerability.

Transfer-ability of lessons from success stories: A review of UK water safety plans implementation

Grace Oluwasanya, Federal University of Agriculture, Abeokuta, Nigeria

Additional Authors: Alison Parker; Simon Polard

Water Safety Plans (WSP) was introduced a decade ago in international guidance documents as an effective preventative and comprehensive risk management means of ensuring the safety of drinking water supply from source to tap for public health protection. Since the introduction, WSP has been applied globally in mostly the developed nations and largely for public utilities. The level of WSP implementations in developing countries and for small systems however, generally, lags behind. United Kingdom is one of the early adopters of WSP. Major actors in the UK water industry were also involved in shaping the pathway to WSP introduction. This paper thus reviews WSP implementation in the UK with the aim to identify transferable lessons to particularly, public utilities in developing countries, particularly Nigeria. Specific objectives include identification of UK water companies with successful WSP implementation records, evaluation of drivers, opportunities and/or limitations to WSP adoption, assessment of success factors/challenges faced in WSP implementation, transfer-ability evaluation with Nigerian water utility context, and recommendation of transferable elements (if any). Descriptive comparative case study was employed. Cases selection was based primarily on WSP implementation. Other criteria are the number of years since WSP implementation, frequency of WSP review since first implementation, and utilities existing risk-free rating. Data collection involved desk study, semi-structured interviews with relevant key informants, and on-site observations through field visits to water companies. The study took place between September to November 2013. A total of 11 key informants across seven UK water companies were interviewed together with informants from other relevant agencies: regulatory organization/academic and research institutions (2); donor agency (1); independent industry professional consultants (2); Nigerian public utility (7). Findings reveal regulatory-driven requirement as an overarching key component to WSP implementation aside the issues of management and organisational buy-in, among others. WSP implementation driven by regulation however comes with a price. For instance, implementation barriers are multifaceted. There is the regulation induced barriers ensuing from limited time for compliance, which in turn resulted in utility apprehension. Worry over more work load, and complex reporting bureaucracy leading generally to the danger of implementing WSP as a 'Tick box' exercise. There is also the people problem. The issue of introducing the WSP philosophy and getting everyone to understand the concept. And the barrier of absence of WSP template or guidance. For instance 'how do you put the WSP framework on existing management and organisational structures'? The concern, which in turn resulted in varied individual water company approaches to implementation. Start up approaches range from steering group method to contracting independent consultants. Risk assessment technique varied from Public Health Impact versus Economic Impact, and Economic risk versus the 5 by 5 risk matrix. Furthermore, the paper explored the derived benefits, some of which are systems efficiency (less failures, reporting more near-misses than incidents), and the ability to keep the risk assessment fairly simple and straightforward (that is the use of common denominator for both customers and the management - e.g. risks estimated in money (£) terms). Also explored are success factors, and future of WSP. The paper identified lessons from the UK WSP implementation. Some of the lessons include taking time with internal/external stakeholders, simplification - that is removal of communication barriers such that customers have better access to information. Ownership of water safety planning by organisation, allowing enough time for implementation, create opportunity to hear others' views on how to improve the systems, and understanding that site inspection is critical, as WSP cannot be done remotely (desk study). The paper however argued that transfer of lessons from success stories may be subject primarily to local regulation and/or the lack of it. Among other considerations like privatization/government ownership of utilities, disparity in level of development in terms of expertise, funding and condition of infrastructures, and individual country cultures. Local cultures may be viewed in terms of proactive/reactive tendencies, risk appetite, and/or transparency and accountability versus corruption and gross mismanagement of public funds. The paper further reviews the role of particularly the regulation-induced barriers on the effectiveness of WSP implementation and concludes that making good use of independent surveillance may be the means of ensuring effective WSP in a regulatory driven context. Such that gaps that seeps un-noticed through howbeit careful eyes may be spotted for necessary action

An Assessment of the Acceptability of the Taste of Waterguard-Treated Water to Users in Nyanza Province, Kenya.

Boluwaji Onabolu, UNICEF

Additional Authors: Palmer Tally; Chikelu Obi

The use of household water treatment (HWT) is especially pertinent in sub-Saharan Africa where 37% of the 884 million people who use unimproved sources live. However very few studies have investigated the reasons for HWT adoption particularly from the users' perspective. Consequently even when levels of effectiveness of the different types of HWT are known, the reasons for the levels observed, remain unclear; making it difficult to review technologies and improve their efficacy at the household level. This paper reports the findings of the assessment of the taste-related acceptance of turbid water treated with sodium hypochlorite (Waterguard) by the study communities. Even though The World Health Organization has provided a taste guideline value of <5 NTU for turbidity, and has advised that levels above this are unacceptable in taste to consumers, manufacturers of chlorine-based disinfectants, such as Waterguard and Aquatab, recommend a doubling of the recommended dose when treating highly turbid water. Though the higher doses of sodium hypochlorite might improve the microbiological safety of water, the change in taste may reduce the acceptability of the treated water to users, causing them to reject microbiologically safe drinking water for less safe alternative sources. The study was carried out in April 2010 in three villages situated in Nyando and Kisumu East district of Nyanza province, Kenya. The villages are predominantly rural and have inadequate access to water and sanitation relying mainly on surface water and rainwater. A purposive sampling method was used to select the three villages with a wide range of turbidity in drinking water sources from the 15 villages in which a KAP survey had earlier been carried out. A systematic random sampling was then used to select a total of 54 respondents from all the households that use Waterguard as a household water treatment method. Data was collected using a combination of water quality analysis, questionnaire and blinded water tasting. Selected water quality parameters were measured on site before and after treatment with Waterguard. The questionnaire assessed each respondent's perceptions about water treatment, the use of chlorine to treat water, and the least preferred and most preferred taste of the different types of treated water. The turbidity of the surface water sources ranged from 500-1000 NTU, whilst the turbidity of the rainwater samples was <5 NTU. The motorized borehole also had a turbidity of <5 NTU. Each of the water sources was treated with the recommended dose for non-turbid water and for turbid water by the interviewers. The results indicate that majority (80%) of the respondents were of the view that the use of chlorine to treat water was very good, with most (90%) perceiving it as very effective in killing germs and almost all (96.30%) felt that the benefits outweighed the cost. Despite these positive perceptions, the turbidity and dose of Waterguard affected the acceptability of the taste of the water to the consumers. The most preferred taste was the rainwater aliquot treated with the dose for low turbidity water, while the least preferred taste was that of the surface water treated with the Waterguard dose for highly turbid water sources. The higher dose of Waterguard was consistently least preferred even when used to treat the same type of water source. For example, the rainwater treated with the dose for low turbidity water was chosen by almost half of the respondents (50%) as their most preferred taste in comparison to 18.52% that selected the rainwater treated with the dose for highly turbid water as their least preferred taste. Similarly, more respondents (4:1) preferred the water from the motorized borehole that had been treated with the Waterguard dose for low turbidity water than the motorized borehole water treated with dose for highly turbid water. Half the respondents (55.56%) indicated that they would only drink their least preferred tasting water under rare circumstances (33%); or if no other water was available (64.81%). The respondents were certain about their preferences with majority selecting the same water aliquot as the least and most liked during a 2nd round of blinded tasting. The positive user perception of Waterguard but low acceptability when the recommended high dose is used, underscores the importance of understanding consumer behavior on adoption and compliance with household water treatment.

Understanding the Sanitation-related Motivators and Preferences in Northern Nigeria; Towards Achieving the MDGs

Boluwaji Onabolu, UNICEF

Additional Authors: Kannan Nadar; Mynepalli Sridhar; Adegoke Yetunde

Despite the huge financial and human resource investments in drinking water supply and sanitation since 1990, in 2011, the world still remains off track in its efforts to meet the Millennium Development Goal (MDG) sanitation target set for 2015. Disparities between regions as well as between urban and rural areas also show that progress towards 2015 targets is not uniform; for example, 71% of those without sanitation live in rural areas, where 90% of open defecation takes place. Some examples of geographical disparity in progress towards 2015 is the increase in the number of people in sub-Saharan Africa practicing open defecation and the decline in open defecation in Asia, Latin America and the Caribbean regions. Several studies have been carried out on appropriate sanitation technologies and sanitation strategies in an attempt to scale up and accelerate progress towards the MDG 2015 and the post-2015 WASH targets. However, relatively few studies have assessed WASH-related behavioral factors; despite the sector's acknowledgment of the importance of human behavior on the sustainability, scaling up and effectiveness of sanitation interventions. In recognition of this gap in literature, UNICEF Nigeria commissioned a Knowledge Attitude Practices (KAP) study in Nigeria, the most populated country in sub-Saharan Africa, which is off-track in its progress towards the MDG WASH goals in order to improve the sector's understanding of the behavioural context for its water and sanitation interventions in Nigeria. The sanitation related findings of this study are reported in this paper. The Joint Monitoring Program reported that in 2011, 33% and 28% of the urban and rural Nigerian population respectively use improved sanitation facilities. An example of the geographical disparity is the 46% sanitation access in the South West Region, compared to the 18% sanitation coverage in the Northwest. This descriptive study was conducted in eight states in North Western Nigeria (Kaduna, Katsina, Kebbi, Kogi, Kwara, Niger, Sokoto, Zamfara and FCT) using a multi stage random sampling method. A total of 7,686 households were selected with an average of 854 households per state. The study population was made up of rural, small town and urban (75.2%, 24.3%, 0.5% respectively); the study respondents were the household heads. The tools used were interviewer administered questionnaires, observation spot checks, in-depth interview guides and focus group discussions. In addition to the assessment of the preferred toilet types, motivators for preferred sanitation choices, perceptions of good toilets and taboos, the study also assessed demographics, socio-economics, communication channels, the respondents' development priorities, perceived diseases; KAP in relation to drinking water sources, access and water treatment and hand washing practices. Key findings indicated that most respondents had some formal education (68.9%); the predominant occupation was farming with a zonal average of (70.5%) with only 6.0% working in the civil service. Water availability was perceived as the number one problem (73.0%); followed by water safety (40.3%). Inadequate household toilets were perceived as more of a problem (29.3%) than access to education. The majority of respondents used unimproved sanitation facilities and open defecation was the predominant form of defecation amongst the under-fives (51.7%). Perceptions of a good toilet was not consistent with the major deciding factor of the type of latrine the household actually built. For example, though the majority (50.5%) perceived privacy as a key indicator of good toilets, followed by the ability to prevent disease (43.4%), closely followed by safety (33.8%); cheapness and affordability were the two major factors that influenced the type of facility the household owned. The preferred type of facility by more than half of respondents in three study states was water-borne toilets, while in three other states less than 10% preferred them. Almost all respondents mentioned that before and after meals were critical times to wash hands with soap while only half mentioned after defecation. The results indicate that though the target communities of a sanitation intervention are aware of the health and social benefits of owning a sanitation facility, the type they actually construct is determined by economic factors. Knowledge of the motivational factors, preferences and taboos will assist the WASH sector in designing sanitation programs to speed up progress towards the MDG

sanitation targets.

Community Monitoring for Sustainable WASH: The Case of Twachiyanda, Zambia

Emmanuel Opong, World Vision International

Additional Authors: Emmanuel Kameya Nyundu ; Nonde Chama Kayula

According to Olivia McDonald (Senior Governance Advisor, Christian Aid), "Community monitoring and evaluation (CME) is a process through which communities measure the quantity and quality of public services and other government activities. The main objective of CME is not simply to collect data about the government's performance. Rather, it is a process to strengthen the relationship between citizens and the state by informing people about their entitlements, the promises made to them by the government and the tools to ensure they receive both the entitlements and the promises." Community monitoring also reinforces community ownership and investment in the long-term sustainability of WASH interventions. If community members are directly monitoring their own infrastructure and behavior, then they are more quickly able to identify breakdowns and take appropriate action - either through repair of hardware or influencing behaviors. World Vision, through the Zambia Water, Sanitation and Hygiene (WASH) Program in Twachiyanda Community, has for the past four years helped to strengthen a community-initiated project monitoring system to improve the effectiveness of water and sanitation services. The community-developed monitoring tools and procedures have assisted in the adoption of appropriate WASH practices and also the promotion of project sustainability at the community level. This paper will illustrate how community-based volunteers have played a leading role in collecting and analyzing all relevant WASH data and initiated corrective action and decision-making through local leaders and government personnel, strengthening the relationship between community members and government structures. We will also demonstrate monitoring practices employed by community members to guarantee improvements in livelihood and well-being. Community monitoring is organized around the following things: ? Water points maintenance, use of boreholes, water collection, transportation, storage, usage ? Hand washing with soap or ash at critical times ? Latrine construction, use and maintenance ? Multiple uses of water for gardening and animal watering, economic and social activities

Methodology Community monitoring is done through door-to-door household visits and inspections for sanitation and hygiene, with follow-up verification visits by sub-district and district staff using the community-led total sanitation (CLTS) approach. Community-based monitoring forms, translated into the local language, are used to capture water, sanitation and hygiene data. In addition, physical inspection of water facilities is done by the area pump minders and caretakers. The community data is aggregated and summarized according to indicator. The same process is done for institutions, such as schools and health centers. Then, all data for the whole catchment is aggregated using the summary sheets. After this is done, the monitoring team will call a monthly community or village meeting to share the findings before the data is submitted to the health center for onward submission to World Vision. Impact Reports have become more accurate and community ownership has increased. The community is able to locate where all water points are and which are functional or non-functional. This has helped the community and area pump minders in their planning for spare parts storage, maintenance, and repair of broken down wells. Because of CME, the community was able to identify special areas that they needed to focus their interventions, such as sanitation and hygiene. As a result, a total of 1949 household latrines were built by community members for their own households. Hygiene practices have also improved from 19% to about 80%. The linkage of the community monitors with government institutions has established sustainable system for monitoring the development process that is not dependent upon World Vision. This has also helped to strengthen the ministry of health information management system through regular flow of information from community monitoring and evaluation.

Peri Urban/Informal Settlements Unit-An Effective avenue of Addressing Disparities in WaSH in Informal Settlements and Peri-Urban Areas

KENNETH OWUOCHA, ATHI WATER SERVICES BOARD

Peri Urban/Informal Settlements Unit as an avenue of Improving Water services delivery in informal settlements and Peri urban areas is a concept that is developed to assist water and sanitation services providers to address disparities in provision of water and sanitation services. The concept is based on the realization of the fact that significant improvement of service delivery to the poor can sustainably be done through an institutionalized department/unit within a water services utility that specifically focuses their activities and efforts to these specific areas. A comparative analysis has been undertaken on three selected African water utilities that have peri urban units/informal settlements departments namely Lusaka Water and Sewerage Company of Zambia, The National Water and Sewerage Corporation of Uganda and the Nairobi City Water and Sewerage Company of Kenya. The analysis also considered periods before the establishment of the units, during and after the establishment. Findings indicate that these utilities have registered significant milestones as a result of having in place focal units/departments to serve the poor. Based on the positive findings of the study, utilities serving areas with informal settlements and Peri urban areas are highly encouraged to set/establish focal units to serve the vulnerable populations better. Background Information Lack of water supply and sanitation services for residents of informal settlements and Peri urban areas represents a daunting challenge to most water utilities and especially those of sub Saharan Africa. This is because large numbers of those who lack access to improved water supply infrastructure live in these aforementioned areas and those who have access to improved water supply infrastructure do not necessarily get adequate services. Water from standpipes and kiosks, which are key sources of access for the residents of these areas, are not always available on a regular basis and as a result women, especially, spend hours fetching water and must frequently adjust their work schedules and sleeping patterns, sometimes staying up late at night. Intermittent services and inadequate volumes of often contaminated water, affects the rich and poor alike. As a result, large numbers of households store water in household reservoirs and supplement piped water with water from tanker operators and water vendors. Small private service providers play a critical role in filling service gaps. They include tanker operators, private kiosk operators, household resellers, door-to-door vendors, and operators of small boreholes and private piped networks. Many provide good quality service under competitive conditions, but their prices are usually much higher than that of the main water utility. The situation for sanitation is even worse. Sanitation has historically received substantially less attention, funding, and priority than water supply in virtually every country. This is because water is viewed as life whereas sanitation is dignity, an aspect that is left at individual's purview to deal with. Lack of proper sanitation in crowded informal settlements and Peri urban areas contributes to serious health and environmental risks for the entire population, but the poor are particularly vulnerable to infection from contaminated water and other disease vectors. Governments have demonstrated that it is possible to improve water supply and sanitation services for residents of informal settlements and Peri urban areas through practical strategies that target key barriers. It is also widely recognized that focusing more attention on improving services for the poor in towns and small cities is essential to slow migration to the informal settlements around large cities. Strategies have been proposed and used to address these myriad challenges that have come out with mixed results. Of interest to this study is internalization and institutionalization of water and sanitation services delivery to the residents of informal settlements and Peri urban areas. Current Service Scenario Water utilities especially in Sub Saharan Africa find it increasingly difficult to provide adequate services to residents of informal settlements and Peri urban areas because of numerous reasons, amongst which include: Water and Sanitation Utilities are Weak; Urban and Peri Urban areas are Expanding Rapidly; The Urban Poor are a Key Strategic Challenge for Water Utilities Justification-WASH services to informal settlements and Peri urban areas have been a subject of intense interest. Utilities have been slow in taking on this subject and have often left service provision to be undertaken by non-state actors resulting to high pricing of services and sometimes services of poor quality. Theories have been advanced that the poor are a difficult segment of consumers who

are unwilling to pay, yet studies have shown the converse.

Assessment of access and practice of improved WaSH services among pregnant women in tribal, rural and slum populations: A cross sectional study in Odisha, India

BIJAYA PADHI, ASIAN INSTITUTE OF PUBLIC HEALTH

Additional Authors: Kelly Baker; Ambarish Dutta; Bibhudutta Das; Pritish Nanda; Nimai Nanda; Radha Satpathy; Pinaki Panigrahi

Access to safe water sanitation and hygiene (WaSH) is essential to all developmental outcomes across the life course and it is an important determinant of maternal and child survival and very little is known about the impact of maternal WaSH practices on pregnancy outcomes. The thematic review and annotated bibliography explored, lack of access to improved sanitation and safe drinking water affects women and girls disproportionately, by impacting on their health and dignity and contributing to their vulnerability and thereby nullifying their efforts to lead a healthy and economically productive life. Pregnant women without access and practice to improved water supplies and toilets within their homes may potentially vulnerable and the levels of service received by users in different geographical areas within the same country may be very differently with the level of education and socioeconomic status. A cross-sectional study was conducted among pregnant women in three distinct geographical locations including tribal (n= 650), rural (n=347), and slum (n=155) in Odisha, India, using a structured questionnaire. We described improved WaSH access according to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) and explored the associations between access, practice and risk factors and or disparities in terms of geography, socioeconomic, education and disability friendly facilities. Participants reported that 78.0% of the households in rural and tribal areas owns a latrine but most of the pregnant women (87.0%) prefer to defecate on the ground, either inside the household yard (37.0%) or nearby water bodies/open spaces (50.0%). However, in urban slums 86.0% respondents have access and practice to use a latrine for defecation, but none of the facilities have disability friendly and 43.0% of the slum participants used a shared facility. While 92.5% of study participants used improved source of drinking water but only 5.0% usually treat the water to make it safer to drink. Less than a quarter (21.5%) reported hand washing with soap after defecation and only 5.0% before taking food. A Chi-square analysis shows a significant association between sanitation practice and availability of water source inside the latrine together with socio-economic factors ($p < 0.005$). The study highlighted, pregnant women's equitable access to water and sanitation facilities during pregnancy and may be the key risk factors in birth outcomes. Considering the paramount role of WaSH on pregnancy outcomes, the study can be underpinned to the theme of "Addressing Disparities in WaSH: Rural, Peri-urban and Indigenous Populations" and avenues can be explored for public health interventions.

Bringing water to tribal communities - Adhikar and Water.org

Lesley Pories, Water.org

Water.org has been making waves since 2003 with its innovative model, WaterCredit: a microfinance mechanism that provides "Smart Subsidies" to local partner organizations who then offer microloans for water and sanitation infrastructure. Traditional microfinance does not necessarily reach indigenous groups, however - cultural differences and accessibility issues often make such groups amongst the most difficult to reach, literally as well as figuratively. Despite these challenges, one of Water.org's partners in India, Adhikar, has been focusing the bulk of its WaterCredit program almost entirely within tribal communities in western Odisha (formerly Orissa) since 2012. As might be imagined, the program started off slowly but its performance has been steadily increasing, with 2459 loans disbursed for water connections to date. Success with toilet loans has been much

less successful, however. In investigating the factors underlying that difference, this presentation examines the dynamics Adhikar had to take into consideration when designing a program catering towards indigenous groups and how it has adapted to these distinct cultures as it continues to scale its work in these areas. Alternative approaches to product design as well as monitoring and evaluation will be considered. Finally, the presentation will seek to answer the questions: Is any of Adhikar's experience with indigenous communities in Odisha replicable elsewhere in India or around the world? What lessons can we learn from Adhikar's approach?

PREVALENCE OF DIARRHEAL PATHOGENS ON CHILDREN'S TOYS AND THE ASSOCIATION WITH WATER, SANITATION AND HYGIENE CONDITIONS

Natasha Potgieter, University of Venda

Additional Authors: Solanka Ledwaba

Water quality, accessibility and availability together with sanitation and hygiene are highly significant to assess public health impact among children less than 5 years of age in developing countries. Toys play an important role in children and can be associated with spread of diarrheal pathogens due to poor water, sanitation and hygiene aspects. The aim of the study was to determine the prevalence of diarrheal pathogens on children's toys using *E. coli* (diarrheagenic strains) and assess the association with water, sanitation and hygiene conditions. A cross sectional study was carried out from September 2013 to November 2013. A total of 54 non-porous toys used by children under 5 years of age in rural households were collected during the initial visit and these households were provided with new toys to use for four weeks, in addition rural households without toys were given new toys for four weeks. A total of 83 toys from 6 different child care centers were collected and given new toys. After 4 weeks, the new toys were collected for assessment. Upon collection, all toy samples were treated with 110ml Phosphate buffer Saline (PBS) (pH 7.4) and total coliform and *E. coli* were determined using the Colilert® Quanti-Tray/2000 system. Pathogenic *E. coli* strains responsible for diarrhea were identified using a standardized multiplex-PCR procedure. A total of 137 existing toy samples and 109 introduced toy samples both from day care centers and households tested positive for Total coliform. Of these samples 61 existing and introduced toy samples tested positive for *E. coli* and these samples were assessed for the prevalence of diarrheagenic *E. coli*. Different diarrheagenic *E. coli* strains were obtained from the toy samples. The introduced toys in the households had more diarrhoeagenic *E. coli* strains than the existing toys which indicated that the sanitation and hygiene conditions in the household plays a major factor in the contamination of children's toys. This was corroborated with the questionnaire answers from the study households. The outcome of the study was to provide insight in the potential pathways of household toys in the spread of diarrhea in children less than 5 years. The prevalence of diarrheagenic *E. coli* strains indicates a potential health risk to transmit diarrhea in children less than five years of age.

Prevalence of Shigellosis and Antibiotic susceptibility profiles of *Shigella* species isolated from drinking waters in three towns of Sokoto State, Nigeria

Mudasiru Raji, Usmanu Danfodiyo University,

Additional Authors: Yakubu Ibrahim

The residents of Sokoto, Shuni and Tambuwal towns of Sokoto State, Nigeria, have rampant cases of water borne diseases among them as a result of their contaminated drinking waters. Hospital records available in the Primary Health Centers in the three towns were statistically analyzed. The result revealed that out of 838 cases of waterborne diseases diagnosed, 521 (62.17%) were shigellosis. Drinking water sources which include

borehole, tap, sachet and well waters available to the communities in the three towns were sampled and analyzed for the presence of some waterborne bacterial pathogens using membrane filtration technique and some biochemical tests. Out of 107 waterborne pathogens isolated, 32 (29.91%) were *Shigella* species. The susceptibilities of the isolated *Shigella* species to some antibiotics commonly used in the communities were determined by the modified Kirby Bauer method. A high proportion of the isolates were sensitive to most of the tested antibiotics (chloramphenicol, perfloxacin, amoxy-clav, streptomycin, ciprofloxacin, ofloxacin and sparfloxacin). However, 31.25%, 40.63% and 50.00% of the isolates were resistant to gentamicin, amoxicillin and co-trimoxazole respectively. Resistance to gentamicin among the people in the communities is a case that calls for concern. Awareness therefore needs to be created among the people to correct their habit of drug misuse and abuse. Presence of pathogenic waterborne *Shigella* species in the drinking waters served in the communities and above recommended limit of World Health Organization made the water unsafe and this has been the cause for rampant cases of shigellosis in the area. Drinking water in these localities therefore needs to be treated to make it wholesome.

Overview of Child Feces Disposal Practices in 25 countries

Emily Christensen Rand, World Bank Water and Sanitation Program

Additional Authors: Libbet Loughnan; Heather Reese; Louise Maule; Therese Dooley

One of the Post 2015 Sustainable Development Goal proposed targets is, "By 2025, no one practices open defecation." In order to reach this target, no one, child or adult, can have their feces left on the ground. Currently, the WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation estimates are based on nationally representative surveys and censuses recording one type of sanitation coverage per household mentioned by the survey/census respondent. As the JMP noted in their 2008 report, there are limitations to these data because intra-household disparities, not only between adult household members but also across age, may not be tracked. Due to their developmental status and the safety concerns of caregivers and children, young children may not use a toilet or latrine, even if their household has access to one. In order to stimulate conversation and develop practical program and policy guidance, WSP and UNICEF partnered to create 25 country profiles outlining current child feces disposal practices. The countries profiled include: Afghanistan, Bangladesh, Burkina Faso, Cambodia, Chad, Ethiopia, India, Indonesia, Kenya, Lao PDR, Madagascar, Malawi, Mozambique, Nepal, Niger, Nigeria, Pakistan, Philippines, Senegal, Sierra Leone, South Sudan, Sudan, Tanzania, Uganda, and Zambia. To develop the country profiles, the latest and earliest available Multiple Indicator Cluster Survey (MICS) Child Module or Demographic and Health Survey (DHS) Individual Module with child feces disposal data for each country were analyzed. Responses to the survey question, "The last time your child defecated, where were the stools disposed of?" were extracted and classified as safe disposal if the child defecated into a toilet/latrine, or after defecation the feces were disposed into a toilet/latrine, regardless of whether the toilet/latrine was improved. To maximize comparability between the two survey types, most analyses were restricted to children under three, except those where age was the background characteristic of interest. Dataset specific sample weights were used to restore representativeness, and the complex stratified cluster sample design was taken into account using cluster as the primary sampling unit and stratifying by urban/rural residence. The core MICS/DHS analysis was also supplemented with other country-specific data located through a literature review and consultations. In most of these 25 countries we found that the majority of children under three had unsafe feces disposal. For example, in Cambodia in 2010, only a quarter of households (25%) reported that their youngest child under three had safe feces disposal. Results were similar in Ethiopia in 2011, with 31% of household reporting that the feces of their youngest child under three were deposited into a toilet/latrine. While 41% reported the feces were left in the open/not

disposed of. Unsafe child feces disposal behaviors were reported even among households with improved sanitation. In Bangladesh, 53% of households with improved sanitation reported unsafe behaviors for the disposal of their children's feces. Among households with improved sanitation, the feces of 22% of children are being left in the open and those of 17% of children are being put or rinsed into drains or ditches. Marginalized households, such as rural and poorer households, and those with younger children consistently reported higher rates of unsafe disposal of child feces. For example, safe child feces disposal was virtually non-existent among the poorest 60% of households in India in 2005-6 and the rate of safe child feces disposal was five times higher in urban than rural areas. In Tanzania, only 43% of caregivers of children aged under one year reported safe disposal of feces. While 89% caregivers of 4 years old children, reported that the feces was safely disposed of. With this presentation at UNC 2014, the 25 country profiles will be launched to serve as a baseline for future efforts, and to facilitate the development of child feces management policy and programmatic recommendations.

Capture and concentration of waterborne parasites - current limitations for risk assessment

Nirmala Ronnie, Unilever Industries Pvt. Ltd.

Additional Authors: Lucy Robertson

Several protozoan parasites of public health significance have the potential to be transmitted by the waterborne route. Understanding the importance of the waterborne route of infection, particularly of *Cryptosporidium* spp. and *Giardia* spp. requires analysis of water samples for the presence of these parasites. Robust quantitative data are required e.g. for surveillance programs, outbreak investigations, to assess performance of intervention measures and as input into risk assessments where the level of risk to a population is estimated. Due to the low infective dose, individual oocysts or cysts need to be isolated and enumerated. Generally, methods used to achieve this are represented in 3 stages, capture, concentration and detection. Typically methods need to be capable of capturing low numbers of the parasites in large volumes of water and isolate them from other organisms and debris present in the water concentrate. Standard methods, such as the immunofluorescent antibody test (IFAT), have been developed and are widely used across the globe and in recent years, numerous alternative techniques and approaches have been investigated to improve performance criteria including reproducibility, specificity, sensitivity, cost and ease of use. However, a common limiting factor with the majority of methods is poor recovery rates. These have been reported to be as low as 1 - 10% for raw water, 9 - 59% for artificially inoculated water samples. These low and inconsistent recovery rates have significant impact on the ability to accurately quantify levels of these agents in waters tested and this could lead to a gross underestimation of risk. In order to improve recovery rates, various groups have been modifying existing methods and developing new methods for both capture and concentration. This paper reviews various existing and developing methods for the capture and concentration of *Cryptosporidium* spp. and *Giardia* spp. from source and finished drinking water. These include filtration and non-filtration approaches, immunomagnetic separation, flow cytometry, selective immunocapture and microfluidic devices. Advantages and limitations of each are discussed, together with a comparison of other characteristics typically used for selection in different applications.

A Case Study Evaluation of Community Health Clubs in Port-au-Prince, Haiti

Jason Rosenfeld, University of Texas Health Science Center San Antonio

Additional Authors: Jessica Brooks; Alexandra Adams; Nora Moraga-Lewy; Samy Bendjemil; Ruth Berggren

Haiti is the poorest country in the Western Hemisphere with some of the highest rates of maternal and infant mortality in the world and the lowest rates of access to improved water, sanitation and hygiene (WASH) in Latin America and the Caribbean. The rapid spread and severity of the cholera epidemic initiated in 2010 demonstrated the deadly deficiencies of Haiti's water and sanitation systems and communal hygiene practices. After an absence of over a century, cholera is now expected to remain endemic on Hispaniola until the underlying structural, behavioral and social conditions on both sides of the island are addressed. Since 2012, the Center for Medical Humanities & Ethics (CMHE) at the University of Texas Health Science Center San Antonio, in collaboration with the Haitian Eco-Eau et Jeunesse organization, has initiated a Community Health Club (CHC) program in Port-au-Prince. CHCs are grassroots community-based organizations where trained, community-based facilitators lead participatory education sessions to address the behavioral and social conditions contributing to cholera. Since the program's inception, 1,274 people have joined one of 23 CHCs in 15 Port-au-Prince communities, benefiting an estimated 6,370 people; and demand for additional CHC participation continues to grow. From May to July 2014, we will use a case study method to evaluate the impact of CHC's on WASH parameters in urban Haiti. Four communities have been selected for in-depth case study, based on the number of CHCs and CHC members in the community, the number of years the CHC has existed, and accessibility to evaluators. We will interview the 23 facilitators to obtain a qualitative description and assessment of the CHC approach. In each study community, a random sample of at least 30 CHC members and 30 non-members will be compared with respect to WASH knowledge, attitudes and practices, using a previously validated questionnaire. A thematic analysis of qualitative data and representative quotes will describe the program and its impact on intervention households and communities. Frequencies, chi squares and t-tests will highlight differences between participating and non-participating households with regards to WASH knowledge, attitudes, and behaviors. Finally, frequencies of self-reported diarrheal incidence will be reported for participating and non-participating households.

Water quality, decision-making, and disease before and after a flood: A natural experiment among an indigenous population in the Bolivian Amazon

Asher Rosinger, University of Georgia

Vulnerability to flooding is a rising phenomenon tied to global climate-change. The health consequences of flooding can lead to increased exposure to fecal material in water, infectious diseases, and vector-borne diseases. Increasing access to improved water sources is a critical aspect of Water, Sanitation and Hygiene (WaSH) goals, yet regions prone to flooding are vulnerable to water source contamination. Evidence for how flood events affect water quality and health outcomes among indigenous populations with limited infrastructure is scant. This study uses a major flood event as a natural experiment to examine how water quality changes in primary water sources and affects diarrheal prevalence among two Tsimane' communities in Lowland Bolivia. Tsimane' are a forager-horticulturalist indigenous population numbering ~15,000 in 100 villages mostly located along the banks of the Maniqui River in the Beni department. Community 1 (n=270) is close to and downriver from the market and cattle-ranching town of San Borja with open and covered wells, in addition to surface waters (river and streams). Community 2 (n=90) is two days upriver from San Borja and only has surface waters. The research communities were selected for variation of access to public health infrastructure. Prior to flooding (September-December 2013), water quality analysis (Hach Pathoscreen) and health recall with a stratified random sample of adult household heads was conducted in both communities. The flood event was declared a national disaster on February 4th, 2014. A subsequent wave of water quality and health surveys coupled with doctor examinations was conducted in March-April 2014 using near-exhaustive sampling. Prior to flooding, four water samples were collected in community 1: river (n=2, both positive for E. coli), open well (n=1, negative for E. coli, but positive for pathogenic fecal coliforms), and covered well (n=1, negative for E. coli and fecal coliforms). In community 2, three water samples were collected: river (n=2; both positive for fecal contamination), and stream (n=1; positive). During this time, 9% diarrheal prevalence was reported in

community 1 and 7% was reported in community 2, all from households using the river as their primary water source. After the flooding, the river, but not the well or pump were positive for fecal contamination in community 1, whereas fecal contamination was present in both the river and streams in community 2. Prevalence of diarrhea increased significantly in both communities after the flooding, but was lower in community 2 (30% vs 20%). In community 1, the flooding caused river water intrusion in one of the main covered wells. Interestingly, 29% of families reported switching water sources to streams in community 2, because they believed the more turbid river water was dirtier, yet probability of diarrhea was significantly associated with using stream water. Water sources in indigenous communities are susceptible to fecal contamination year-round, though flooding events increase vulnerability and are associated with increased diarrheal illnesses. To address health disparities among indigenous populations, WaSH should take into account future increased probability of flooding and build covered wells in locations less likely to be affected by floods.

Determinants of water use among urban households in Tanzania: water source access, use, and treatment

Olga Rostapshova, Social Impact

Additional Authors: Danae Roumis; Jeff Alwang

To date, efforts to evaluate safe water interventions in the developing world have emphasized smaller-scale programs in rural settings. Notably missing from the literature are evaluations of large urban-focused water projects, typically reaching many more beneficiaries and greater access disparity; and must take into account the continuity of access to water and the multiplicity of sources used by the households. Access to water is often continuous in urban areas, as numerous sources are available; water availability and access to piped water are constrained by water system capacity and access within a system can vary, affecting the source choice and water quality for each household. This study examines the roles of context and household choice in relationship to water infrastructure access in urban areas of Tanzania. We utilize data from an impact evaluation of Millennium Challenge Corporation's large-scale program to improve water infrastructure in two urban areas in Tanzania: Dar es Salaam and Morogoro. To better understand the impact of improved water supply and quality, we study mechanisms driving households' water consumption decisions. Using baseline household and water source data, we examine household water use choices, focusing on access, source selection and treatment. Half of Morogoro and 13% of Dar es Salaam residents use a tap on premises as the primary water source, yet 22% of those with a tap do not: while piped water from the public network is viewed as the preferred source for drinking water, it is often unreliable due to shortages, network disrepair, and seasonal effects. Non-piped water sources (e.g., boreholes, wells, springs, surface) are lower-quality sources; better-educated households and those from the upper socioeconomic strata are much less likely to rely on non-piped water. Households utilize multiple sources simultaneously, using water from different sources for different purposes: "clean" (non-saline) water is used for consumption, lower quality water (i.e., from boreholes) is used for household activities (washing or cleaning). In Morogoro, tap on premises is most common for all water uses; in Dar es Salaam, other piped sources are the most frequently used for drinking, and non-tap sources are most frequently used for all other activities (>50%). We construct probit and logit models to evaluate the determinants of household access to piped water on premises, choice of main drinking water source, and water treatment decisions. Our results suggest that the use of piped water sources is constrained by supply factors: the probability of piped water use is highly linked to neighborhood characteristics, suggesting large access spillovers. Modeling the household's selection of main water source (i.e., of drinking water) as a multinomial process, we find the use of own piped water is significantly correlated with household socioeconomic status (those in the upper quintile are almost 18 percent less likely than the lowest quintile to obtain water from a neighbor's tap, a kiosk or another tapped source). Access to electricity, larger dwellings, high education, and female-headed households are more likely to use tap water as the main source. We do not find evidence of substitution of piped water for treatment of non-piped water; instead, households with piped water access are more likely to treat water before drinking than

those using non-piped water, although many respondents do not treat their water at all (76% report boiling water from own tap, compared to 30% of those using non-tap sources for drinking water). Higher education, higher socioeconomic status, and female adults are positively associated with treatment probability. We use a two-stage probit model to examine treatment; the first stage specifies household water source as a function of demographics and access to piped water; in second stage, treatment is a function of the endogenous household water source and the other variables. The results show the source of water is significant: even accounting for source endogeneity, households using any piped water (10 pp) or with piped access in household (33pp) are more likely to treat their water, implying a lack of confidence in the sanitary state of piped drinking water, despite better perceptions of quality than other sources. Factors affecting the choice of water source may also contribute to the decision to treat drinking water. We find that while most urban households have some access to the piped network, whether directly or indirectly, system capacity constraints maintain spatial variability in access to water. The intervention is poised to reduce these constraints, and reallocate the households' water consumption portfolio. Impacts on disadvantaged beneficiaries are especially important, who disproportionately bear the burden of lack of piped water on premises and must rely on lower-quality, difficult to access water sources outside the home to meet their water needs.

Evaluating the Bacterial Microbiota of Reclaimed Water Using Next Generation Sequencing

Amy Sapkota, University of Maryland, School of Public Health

Additional Authors: Prachi Kulkarni; Emma Claye; Rachel Rosenberg-Goldstein; Shawn Gibbs; Mihai Pop; Michael Cummings; Cynthia Maddox; Emmanuel Mongodin

Over 2.22 billion gallons of wastewater effluent are reclaimed per day in the U.S. However, limited data exist on the pathogens and total bacterial communities that remain in this water, as well as the potential health risks from exposure to this alternative water source. Therefore, the objective of this study was to characterize bacterial communities present in wastewater and reclaimed water using next generation sequencing. Wastewater (from each step of the treatment process), final effluent and reclaimed water samples (n=94) previously collected from four U.S. wastewater treatment plants and their associated reclamation sites were tested. DNA extractions involving both enzymatic and mechanical lyses were performed on all samples, followed by bacterial community profiling using 16S rRNA gene sequencing on the Illumina MiSeq platform. Raw sequences were processed using PANDAseq to generate high-quality consensus sequences from the MiSeq paired-ends, and taxonomic assignments were performed using a new taxonomic classifier, the MC classifier, able to classify 16S reads to the species level with an accuracy of 98%. Diverse bacterial communities were present in all samples and differing bacterial communities were observed across different sample types. Predominant genera that were detected included the following, to name a few: *Shewanella*, *Pseudomonas*, *Mycobacterium*, *Streptococcus*, *Clostridium*, *Acinetobacter*, *Staphylococcus* and *Legionella*. Our approach has generated novel pilot data that can be used in future proposals, the findings of which will assist in the development of risk-based water reuse policies that move us towards a more sustainable water use paradigm and protect human health.

Business Model Innovation in the Water Sector in Low-Income Countries

CAROLINE SAUL, eawag

Additional Authors: Heiko Gebauer

Various household water treatment devices and micro-water treatment plants have been installed in order to

provide safe and affordable drinking water in low-income countries. While the efficacy and quality of the available technologies have improved considerably, organizations still face challenges in making projects for safe water provision financially sustainable. Financial sustainability can rely on the business models behind the dissemination of these water treatment technologies. This presentation makes three contributions to business model research in the context of the provision of water services. First, five business models are described: A) low-value devices given away to people living in extreme poverty, B) high-value devices sold to low-income customers, C) communities as beneficiaries of micro-water treatment plants and D) entrepreneurs as franchisees for selling water services and highlight the emergence of E) hybrid business models, which combine social and economic goals. These categories depart from the traditional distinction between business models for profit-oriented firms, social businesses, and non-profit-organizations. Instead, business models fall across a continuum of the relative importance of social and economic goals. Business models are also classified based on the level of service they provide, at the household or community level. Business models A and C are dominated by social goals, whereas business models B and D focus more on economic goals. Business model E attempts to balance social and economic goals. Second, current business model innovations such as cost transparency, secured & extended water payments, business diversification and enhancing distribution channels are explored. Cost transparency means to better estimate the costs for various activities such as water treatment, distribution, marketing and so on. A higher cost transparency would make it easier to achieve higher cost recovery and to reduce costs. More secured and extended water payments can be achieved by introducing electronic payments for water services via water ATM, accepting payments made by mobile phones, by using micro-credits for household devices, or linking payments to customer services for example, replacing water filter material or germ kits. Business diversification is about creating additional revenue streams for water businesses. Typical illustrations are using carbon credits, selling additional water services and products such as chlorine tablets, disinfection kits or selling additional value-added services such as hygiene products and groceries. These additional revenues can make the business model financially more viable, but they also require additional investments. Enhancing distribution channels refers to reaching a larger market for water services through developing a multi-channel distribution approach and defining distribution schemes for each channel, like distribution targets, distribution margins, and sales volumes. Extending distribution channels can be very costly, so the additional revenues for household water treatment devices have to be carefully balanced with the necessary costs for establishing and maintaining the channels. Finally, skills and competencies as part of capacity building for creating even more business model innovations are described. Together, these three contributions will create more awareness of the role of business models in scaling-up water treatment technologies.

Safe water for rural Africa: When science meets policy

Bastian Schnabel, University of Brighton

Additional Authors: Huw Taylor; James Ebdon

Water-related diseases remain worldwide as one of the major obstacles when it comes to sustainable development and the improvement of people's lives, especially in the least economically developed countries (LEDs). In Malawi, 17 per cent of the population still lack access to a clean and potable water source, using water from poorly protected shallow groundwater or unprotected surface waters such as lakes and rivers. Recent findings have suggested that prolonged survival and possible regrowth of thermotolerant coliforms (*E. coli*) in shallow groundwater sources could limit their use as indicators of contamination of faecal origin. Consequently, further research is needed in order to better understand water quality and the likely human health risks associated with shallow groundwater sources. Furthermore, assessing the microbiological quality of drinking water in resource-limited settings remains a challenge, due to the absence of appropriate and affordable detection methods. Therefore, this study aims to explore the development of a low-cost, low-tech water quality monitoring approach based on the modification of a previously reported and widely used

hydrogen sulphide test (H₂S) developed by Manja et al. (1982), in the hope of increasing its sensitivity and specificity for detecting the presence of fecally derived enteric bacteria. In order to investigate the regrowth potential of faecal indicator bacteria in shallow groundwater wells, the following parameters: temperature, humidity, pH level, turbidity, conductivity, phosphorus, nitrate, dissolved oxygen (DO), and assimilable organic carbon (AOC) will be measured and analysed in relation to levels of indicator bacteria being present in shallow wells. The level of AOC present in well water will be determined using an AOC-test supplied by Biomonitech. Results will be analysed to determine whether there are any significant correlations between different environmental parameters and potential regrowth of enteric bacteria. Modified H₂S tests will be trialled in warm humid tropical conditions in the field in Malawi, during both the wet and the dry season, in order to investigate seasonal differences in performance. The sensitivity of the modified tests will be compared to that of the membrane filtration standard method. It is anticipated that the results should not only help inform the WHO's water safety plan (WSP) concept within rural tropical and resource-limited settings, but should strengthen Malawi's environmental policy framework and help the country to fulfil the post-2015 targets.

Household and neighborhood-level risk factors for diarrheal disease in South Quito, Ecuador

Kate Shields, The Water Institute at UNC

Additional Authors: Sarah Park; Martha Eguiguren; Aimee Miller; Gabriel Trueba; Joseph Eisenberg

Recently, scholarship has begun to emphasize the importance of context, both social and environmental, in the transmission of diarrheal disease. However, while environmental factors are often measured at the community level, social contextual factors are usually measured at the level of the household. Some, especially in social epidemiology, have advocated returning to epidemiology's pre-germ theory roots and once again focusing on community or neighborhood level determinants of disease through multi-level studies. Household and individual-level data for this study was obtained from a cross-sectional survey in three peri-urban parroquias of south Quito, Ecuador in the summer of 2012. Data was collected for 1017 households with children under the age of five. Community-level data was compiled from the 2010 Ecuadorian National Census. Multi-level logistic regression and spatial analysis were used to explore household and community level determinants of self-reported diarrheal disease in children under the age of five. The prevalence of diarrhea in the past week in children under five was 14%. High neighborhood unemployment levels were found to be a significant risk factor for disease, with a 5% increase in neighborhood unemployment associated with a 38% increase in the odds of diarrheal disease. Socioeconomic factors were not found to be significant risk factors at the household level, but household water treatment was found to be a significant protective factor. Analysis was suggestive of an elevated risk of diarrhea for households with low water, sanitation and hygiene infrastructure, although there was evidence of some confounding by socioeconomic factors, and child age and gender. This study provides a step forward in understanding both the impact of socioeconomic status in diarrheal disease transmission, and further the multiple levels at which contextual variables may function. These findings support future multi-level studies which incorporate contextual variables at the household and neighborhood levels in order to better understand risk factors affecting disease transmission and the scale at which interventions should be undertaken. In addition, we suggest that because only slightly over half of households were treating their water and water treatment was found to lower the odds of diarrhea by approximately half, increasing household water treatment is likely to have a large impact on diarrheal disease prevalence in South Quito.

Assessing Functionality for Water Schemes in Select Areas of Ethiopia where Millennium Water Alliance Partners Operate

Sarah Sparker, Millennium Water Alliance

Additional Authors: Bekele Abaire; Girma Aboma; Kelly Alexander; Matthew Freeman; Yihenew Tesfaye; Robert Dreibelbis

Background: A significant challenge that has exacerbated efforts to achieve goals for water access in Sub-Saharan Africa is the lack of sustainability of water schemes. Previous studies have put forth theories to show what factors may lead to failed water schemes; however, many of these approaches are not empirically based. There is a lack of consensus and data on specific drivers of sustained functionality and no clear agreement in the sector on how to measure these factors. The purpose of this study was to assess the functionality of water points greater than five years old in areas supported by two Millennium Water Alliance - Ethiopia Program (MWA-EP) partners: Catholic Relief Services (Oromia) and WaterAid (SNNPR). Researchers from Emory University's Center for Global Safe Water, as well as program staff from CRS and WaterAid, developed an easy-to-use, objective tool to assess sustained functionality of water points. This tool combined prominent, existing theories on what supports community water supply sustainability (e.g. governance, life-cycle costs, role of women, etc.) as well as indicators from other water functionality literature, to test the degree to which these various factors influence functionality in the case of the selected water schemes in Ethiopia; and whether there are other important factors that have not been considered. **Methods:** Nearly 100 water schemes constructed in 2009 or earlier were visited May-July 2013. Direct observations, including recording water flow rate, were conducted at each water point. Structured interviews with members of the water committee were also conducted for each water point. Once data collection was completed, a functionality 'score' was created using various measures of functionality from the direct observations survey. We modeled functionality score of water points against potential predictors of functionality, supplied from the water committee survey. In addition, a series of semi-structured interviews were conducted with NGO, government and community stakeholders regarding their perceived roles and what they believed to be the responsibility of other stakeholders. Emory and MWA-EP used these qualitative data to cross-validate expectations of different stakeholders to determine communication gaps that could elucidate sustainability road blocks. **Results:** Findings indicate that water schemes with higher functionality scores were associated with committees having good records, regular meetings, financial audits, higher monthly fees, a paid caretaker and the capacity to perform minor repairs. Semi-structured interviews demonstrated that there are gaps in communication regarding roles and responsibilities of the stakeholders, specifically around maintenance and repair of systems. These findings point to the urgent need to harmonize understanding between actors to ensure sustainability. **Conclusions/Implications:** During the presentation, we will discuss the implications of these results for program monitoring and other ongoing activities in the field, in both MWA programs and the WASH sector as a whole.

Sanitation and health externalities: Resolving the Muslim mortality paradox

Dean Spears, Delhi School of Economics & r.i.c.e.

Additional Authors: Michael Geruso

In India, Muslims face significantly lower child mortality rates than Hindus, despite Muslim parents being poorer and less educated on average. Because observable characteristics would predict a Muslim disadvantage relative to Hindus, previous studies documenting this robust and persistent pattern have called it a "puzzle" of Muslim mortality. This paper offers a simple solution to the puzzle in the form of an important sanitation externality. Most of India's population defecates in the open, without the use of toilets or latrines, spreading fecal pathogens that can make children ill. Hindus are 40% more likely than Muslims to do so, and we show that this one difference in sanitation can fully account for the large (18%) child mortality gap between Hindus and Muslims. Building on our finding that religion predicts child mortality only through its association with latrine use, we show that latrine use constitutes an externality rather than a pure private gain: It is the open defecation

of one's neighbors, rather than the household's own practice, that matters most for child survival. This is because it is the behavior of neighbors that introduces new germs to a household. The gradient and mechanism we document have important implications for child health and mortality worldwide, since 15% of the world's population defecates in the open. To put the results in context, we find that moving from a locality where everybody defecates in the open to a locality where nobody defecates in the open is associated with a larger difference in child mortality than moving from the bottom quintile of asset wealth to the top quintile of asset wealth.

Sachet water quality and brand reputation in urban slums of Accra, Ghana

Justin Stoler, University of Miami

Sachet water has become an important primary source of drinking water in West Africa despite concerns over environmental impact and social justice, but little is known about bacteriological quality and improvements to quality control given the recent, rapid evolution of this industry. This paper reviews the highlights of two recent micro-studies. The first study examines basic bacteriological indicators for 60 sachet water samples from two urban slum communities in Accra, Ghana, and explores the relationship between local perceptions of brand quality and bacteriological quality after controlling for characteristics of the vending environment. No fecal contamination was detected in any sample, and 82% of total heterotrophic bacteria (THB) counts were below the recommended limit for packaged water. Sachets from brands with a positive reputation for quality were 90% less likely to present any level of THB after controlling for confounding factors. The second study examines an additional 80 sachet samples for an additional indicator, *Pseudomonas aeruginosa*, in four other slum communities. In addition to similar brand effects as seen in the first study, we observe the presence of *P. aeruginosa* in sachet water samples in which there is no detectable fecal contamination. Results from both studies contrast with much of the recent sachet water quality literature and may indicate substantial progress in sachet water regulation and quality control, with some reservations about equipment maintenance.

Geospatial Patterns of Well Water Contamination in Northern Malawi

Paula Strassle, Rollins School of Public Health, Emory University

Additional Authors: Kyu Han Lee; Rochelle Holm

Background: Water-related diseases are responsible for 80% of all illnesses and deaths in developing countries and over 5 million deaths every year worldwide. In Malawi, 21% of the population lack access to improved water and 50% of all illnesses are due to water-related diseases. Peri-urban areas, defined as high density, unplanned land use outside of large cities, are especially at risk due to both limited service access which also results in poor sanitation access. As a complement, and at times alternative to the public water supply, shallow hand dug wells are often used for everyday household needs. Water contamination may occur when wells are located close to potential hazards including pit latrines and solid waste landfills. This study utilizes water quality and geospatial data to examine potential relationships between geospatial features and the microbiological quality of shallow hand-dug wells in a peri-urban area outside of Mzuzu, Malawi. Methods: Between June and July 2013, a study was conducted to assess the water quality and sanitation practices of area 1B (an unplanned, peri-urban area outside of Mzuzu, in northern Malawi) following a risk communication program. Area 1B is indicative of many peri-urban sprawls across the country, with no sewer system and limited access to piped water services. Water samples were collected from 29 shallow wells and tested for *Escherichia coli* and total coliforms using the Hachm-ColiBlue24 membrane filtration method. During sample collection, a questionnaire on sanitation practices and water use was administered, a visual inspection of land use was conducted, and GPS coordinates recorded.

The visual inspection included measuring distances to nearby structures, including latrines, and counting the number of households within 50 meters. This current study utilizes the visual inspection data and contamination results acquired as part of the larger study, to analyze potential geospatial patterns in well water contamination. A geographic information system was utilized to visualize microbiological data with respect to roadways, distance to latrine, surface slope, land cover, and number of houses within 50 meters. Fisher exact tests and Spearman correlations were conducted to confirm any notable observations. Results: Although a small study, results suggest wells located >50 meters of primary roads are characterized by fecal contamination. 4 out of 12 wells located ≤ 50 meters from primary roads had ≥ 1 fecal cfu/100 mL, which is significantly less ($p=0.0177$) than the 14 out of 17 wells located >50 meters away; moreover, two routes of high fecal contamination and three routes of high total coliform contamination were identified in the community. Although there were no significant correlations between distance to the nearest latrine and both fecal ($p=0.7362$) and total ($p=0.1680$) coliform contamination, we were able to identify 8 and 11 wells that expressed high levels of fecal and total coliforms, respectively, which may be due to close proximity to latrines. Surface slopes reveal a cluster of high fecal contamination and a cluster of high total coliform contamination which overlap each other on the face of a single hill, suggesting a common source of contamination at a higher elevation. Though maps suggest differences in fecal and high total coliform contamination based on land cover, Fisher exact tests show no significant difference ($p=0.1150$ and $p=0.0540$, respectively). There were no significant correlations between the number of households within 50 meters and levels of fecal ($p=0.6883$) and total ($p=0.6947$) coliform contamination. However, three wells with the greatest number of households were characterized with high total coliform colony counts ($\geq 3,375$ cfu/100 mL) and two of these wells had high fecal colony counts (≥ 250 cfu/100 mL) as well. Discussion: While these wells are not often used for drinking purposes, the high levels of contamination are worrisome, as during droughts, power outages, or water shortages families are often forced to drink from the household shallow well. Additionally, households reported using these wells to water crops, bathing, and cleaning. As such, they pose a risk for waterborne diarrheal diseases. We identified multiple geospatial factors that may be potential sources of contamination for wells. Since this initial assessment of geospatial patterns was small, additional research is needed to better understand geospatial patterns and environmental factors that can impact water quality in peri-urban, and other community, settings in developing countries. However, this study highlights the use of GIS as a tool for integrating microbiological and geospatial data to identify potential sources of contamination in water quality assessments and intervention planning.

Changes in Water Quality and Behaviors after Intervention in Northern Malawi

Paula Strassle, Rollins School of Public Health, Emory University

Additional Authors: Rochelle Holm; Golden Msilimba

Background: Around the world, approximately 783 million people are without access to improved drinking water. Not only is water considered a human right and essential for life, but lack of clean water can lead to serious waterborne infectious diseases. Malawi, located in southeast Africa, currently has 20% of its population without access to potable water. Malawi has a high population growth rate which further compounds the challenge of poor sanitation practices and limited access to safe water. Sanitation is particularly problematic in peri-urban areas, characterized by high population density and unplanned land use on the sprawling edge of an urban city, due to interactions between shallow wells and poorly built latrines. In early 2012, a field study was performed to assess the burden of water contamination and sanitation practices in a peri-urban area outside of Mzuzu, Malawi. After analysis, a risk communication program to help participants with unreliable water sources protect themselves from disease and other adverse public health outcomes was implemented. This study was a follow-up assessment of the water quality and sanitation practices in the area to determine if any changes in water practices had occurred. **Methods:** In February 2012, an initial assessment of water quality in Area 1B (an unplanned, peri-urban community outside of Mzuzu, Malawi) was conducted. Area 1B is representative of many

urban sprawl areas in Malawi, with strained water services and uncontrolled sewage disposal through pit latrines, septic systems and surface disposal. Thirty shallow wells were identified and tested in duplicate for total coliform and *Escherichia coli*. Bacterial testing was performed using the Hach m-ColiBlue24 membrane filtration method. Simultaneously, a visual inspection of land use and questionnaires on water quality and sanitation practices were conducted on 53 households using the shallow wells being tested and household drinking water samples collected from a subset, $n=30$. The structured questionnaire was based off of WHO core questions on drinking water and sanitation; all participants were at least 18 years old. All testing was done in-country. Between June and July 2013, the same analysis was conducted on the shallow wells initially sampled and households using them. Participants and households included in the follow-up assessment were not necessarily the same as the previous analysis due to the rapidly developing area and movement of individuals in and out of the area. Fisher's exact tests were used to compare the results from each assessment. Results: Overall, 29 of the 30 original shallow wells were resampled and 33 households were included in the analysis. On average, there were over 5 people living in each household, and at least one (mean=1.67) was under the age of 12. 31 of the 33 participants (94%) reported using an improved water source (either piped water to their yard or a public tap) as the main source of drinking water. Every household utilizing an improved water source reported paying for their access, on average \$3.04 per month. Only two participants reported treating their water in the home. 72.7% (24/31 water samples collected) were free of *E.coli*, and 27.3% (11/31) were free of total coliforms. When asked about how water contamination occurred, only 18% (5/28) reported it was from having a pit latrine located near a well; similarly, only 14% (4/28) understood that chemicals used in farming could contaminate their water. Compared to the initial assessment of the area, households were 5 times more likely to report using improved water sources for drinking water than the prior year, $p=0.02$. No significant difference in reported household treatment use was seen after the risk communication program, $p=0.11$. While households were 2.6 times more likely to have less *E.coli* in their drinking water, $p=0.05$, there was no significant improvement in the number of homes with *E.coli*-free water, $p=0.10$. Similarly, no significant difference in total coliform contamination was seen, $p=0.10$. Discussion: While almost all households reported using improved water sources for their drinking water, there was still considerable contamination at point-of-use in the home. This may indicate either improved water sources are not reliable or contamination is occurring during transport or storage. Non-significant differences in water contamination could be explained by seasonality. Although a small scale study, no overall difference in water treatment or knowledge of water contamination was observed after the risk communication program; however, those included in the follow-up analysis were not necessarily those that received the intervention. Additional research into household water treatment options and storage in peri-urban areas and long-term risk communication programs is needed to improve drinking water quality in Malawi.

The construct validity of a novel method for quantifying water consumption in slum settlements in Mumbai, India

Ramnath Subbaraman, Brigham and Women's Hospital / Harvard Medical School

Additional Authors: Laura Nolan; Kiran Sawant; Tejal Shitole; Shrutika Shitole; Mahesh Nanarkar; David Bloom; Anita Patil-Deshmukh

BACKGROUND: Inadequate water consumption is associated with adverse health outcomes. Quantifying water consumption at the household level is difficult in slums, however, as water meters are often absent and hundreds of people may use a single tap. We developed a simple, rapid method for assessing water quantity at the household level, using a detailed inventory of water storage containers, the volume of water each container can hold, and the number of times each container was filled in a one week recall period ("the container enumeration method"). Construct validity is an assessment of the extent to which a test measures a given construct, based on pre-specified observation-based hypotheses about the construct. We assess the container enumeration method's construct validity as applied in a slum of 12,000 people in Mumbai, where most people

have water delivered via hoses on an intermittent basis by informal water vendors ("water hose recipients") and a smaller proportion of people fetch water ("water fetchers") from taps outside of the slum. **METHODS:** We used ethnographic observations from three years of fieldwork in the slum along with data from 40 qualitative interviews and six focus group discussions collected in July and October 2011 to develop hypotheses regarding the determinants of severe water poverty (i.e., ≤ 20 liters per capita per day or LPCD). Specifically, we hypothesized that severe household water poverty is a positive function of: (a) water costs, (b) the number of people in a household, (c) the infrequency of securing water, and (d) renting (as opposed to owning) one's home. In addition, water fetchers appear to obtain water more frequently than water hose recipients, despite the strenuous work required. We therefore hypothesized that water fetchers consume a greater absolute quantity of water over a week but are more likely to suffer from severe water poverty after controlling for other covariates. In February-March 2012, we used a random number generator to randomly select 521 households from a comprehensive database of all slum homes. A single measurement of water quantity consumed in the last week was obtained for each household using the container enumeration method. A questionnaire captured information on other covariates. Water consumption in LPCD was calculated by dividing the value obtained using the container enumeration method by the number of people in the household and then by seven, to get a daily estimate of water consumption per household member. We compared characteristics of water hose recipients and water fetchers using chi-squared tests for categorical variables and the Wilcoxon test for continuous data. We performed a multivariate logistic regression analysis to identify predictors of severe water poverty (consuming ≤ 20 LPCD), along with their odds ratios (OR) and confidence intervals (CI). **RESULTS:** In this sample, the median (IQR) water consumption was 23.4 (13.9-38.6) LPCD; 42% use ≤ 20 LPCD and 84% use ≤ 50 LPCD. Thirty percent of water fetchers obtain water four or more times a week as compared to 8% of water hose recipients ($p < 0.001$). As a result, water fetchers have a higher absolute median water consumption of 31.3 LPCD as compared to 19.7 LPCD for water hose recipients ($p < 0.001$), and only 27% of water fetchers used ≤ 20 LPCD compared to 50% of water hose recipients. In the multivariate logistic regression analysis, the following predictors had statistically significant (all $p < 0.001$) associations with the outcome of using ≤ 20 LPCD of water: water cost, with those paying Indian rupees (INR) 200+ per 1000 liters having OR=73 (CI 28-190) as compared with those paying less than INR 100 per 1000 liters; number of people in the household, with those with 5+ residents having OR=23 (CI 9.7-53.3) compared with those with 3 or fewer residents; frequency of obtaining water, with those getting water 3+ times a week having OR=0.05 (CI 0.02-0.16) compared with those getting water once a week; renting one's home, with renters having OR=2 (CI 1.1-3.8) compared with owners; and method of obtaining water, with water fetchers having OR=4.2 (CI 2.2-8) compared with water hose recipients. **CONCLUSIONS:** The container enumeration method for quantifying water consumption yields findings that are consistent with hypotheses based on qualitative data, suggesting this method has strong construct validity. This method may be useful in settings in which water supply is highly intermittent, precluding slum residents from using water directly at community taps, and requiring storage of most water prior to use. Limitations of this method include its inability to capture water consumed outside of the household (e.g., at workplaces). This method may provide a useful tool for rigorous epidemiological studies of water quantity and disease outcomes. It may also facilitate monitoring of water service delivery in slums by slum residents, non-governmental organizations, or the government.

CO2 for H2O: An evaluation of carbon credits to finance household water treatment

Sarah Summers, The George Washington University

Additional Authors: Jay Graham; Rochelle Rainey; Maneet Kaur

Carbon credits are an increasingly prevalent market-based financing mechanism used in global health development projects. These credits are used to subsidize the distribution of improved environmental technologies, including cleaner-burning cook stoves and household water treatment technologies (HWTs). By

replacing water boiling as a water treatment practice with a zero emissions technology, such as a water filter, development organizations can claim carbon credits for reduced air pollution and partially offset the cost of the HWTT. The process for selling carbon credits associated with household water treatment and safe storage is multifaceted and requires rigorous monitoring and evaluation to ensure households are appropriately and consistently using the HWTT and thus achieving desired health benefits. The use of carbon credits to finance HWTTs has been criticized as a circuitous path to emissions reductions that neither provides clean water nor effectively reduces emissions. The focus of these criticisms is the lack of transparent, independent and verifiable monitoring of baseline and project data on technology usage and emissions reductions. The application of carbon credits for HWTTs is relatively new and there are few experts who exist at the nexus of the two fields of water and carbon. The goal of this study is to elucidate the perspectives - including commonalities and differences - among these two groups with respect to the monitoring and evaluation methodologies. The Gold Standard methodology certifies projects to receive carbon credits. Due to rigorous requirements set forth in the methodology, carbon credits issued by Gold Standard are considered high-value credits. Utilizing the Gold Standard methodology for voluntary emissions reductions as a case study for carbon credit methodologies experts in WASH and carbon credit development participated in semi-structured, open-ended interviews focused on specific portions of the Gold Standard methodology. These interviews were analyzed for patterns and key themes with the aim of providing a road map for next steps in the conversation on the utilization and improvement of carbon credits for household water treatment.

Controlling fecal odors: Factors influencing hydrogen sulfide adsorption onto biochar during pyrolysis of feces

Elizabeth Travis, University of Colorado

Additional Authors: Karl Linden; Tesfa Yacob; R. Scott Summers

Odor serves as a significant barrier to increasing sanitation coverage in the developing world. Sulfides, the largest odor nuisance emitted during fecal pyrolysis, can also be highly corrosive and toxic at high concentrations. Treatment of odorous exhaust using activated carbon is common practice in industries that require fecal processing and storage. Less is known about the effectiveness of bio-char, a relatively inexpensive alternative to activated carbon that can be prepared and replenished locally, as an adsorbent material for odor treatment. This research evaluates the impact of feedstock and temperature on biochar's surface properties and odor adsorption capacity. For this research hydrogen sulfide was chosen to represent odorous compounds. Different feedstocks were examined for their efficacy including raw feces, sewage sludge, and wood. Pyrolysis temperature's impact on the adsorption capacity and surface properties of biochar was examined by assessing the adsorption capacity of wood biochars pyrolyzed at multiple temperatures between 300 and 900 °C. For each experiment, 180 ppm hydrogen sulfide was passed through columns filled with various types of biochar at a controlled flow rate. The effluent gas was then analyzed for hydrogen sulfide content using a chemical sensor and odor using an olfactometer. These results were used to calculate the adsorption capacity of each biochar column and ensure sufficient odor removal. BET analysis, which measures nitrogen multilayer adsorption as a function of relative pressure to calculate surface area, and scanning electron microscope imaging, which produces high resolution surface images, were performed on each biochar to correlate the adsorption results with specific surface properties. Characterizing the effectiveness of biochars created from different feedstocks and pyrolyzed at different temperatures for hydrogen sulfide adsorption is highly relevant in the sanitation field. By elucidating the effectiveness of inexpensive, renewable, locally available adsorbent material for fecal odor treatment, the research provides an appropriate mechanism for decreasing odor and increasing the attractiveness of feces combustion as a sanitation solution in developing countries.

Uncovering the challenges to menstrual hygiene management in schools in Mali

Victoria Trinies, Emory University

Additional Authors: Bethany Caruso; Matthew Freeman

Background: The challenges associated with managing menstrual hygiene while in school have been shown to have a serious impact on girls' education, including limited participation in class and lost class time. A multi-country study was recently undertaken in Rwanda, Bolivia, Sierra Leone, and the Philippines to identify the range of challenges that lead to these educational impacts across different settings and cultural contexts. This study adapted the tools and methodologies from the multi-country study to identify the challenges that school girls face in Mali, a culturally diverse and largely Muslim country. **Methods:** We adapted interview guides from the multi-country study for use in Mali. The guides covered knowledge of puberty, menstruation, and menstrual hygiene management; management practices; the changes in a girl's life once she has reached menarche; sources of support; the impacts of menstruation on school participation; and soliciting suggestions for ways that schools could enhance their support for girls while they were menstruating. We conducted interviews in four urban and four rural schools across the Sikasso and Koulikoro regions in southern Mali. At each school, we conducted in-depth interviews with 3-4 girls, held a focus group discussion with 3-6 girls, and conducted a focus group discussion with 4-6 mothers. We also conducted key informant interviews with teachers at five of the study schools. **Results:** Final analysis of data will be conducted once data collection is completed in April 2014. Preliminary analysis indicates that the majority of girls report missing a half-day or more of school every month. This is often because they want to wash and change menstrual hygiene materials at home to ensure that no one has access to their menstrual blood, as they believe it can be used to cast spells that cause infertility. Teachers are not aware that menstruation causes girls to be absent so frequently, and schools do not always have systems in place to assist girls to make up for the lost instruction time. There is no formal reproductive health education or menstrual hygiene management instruction in primary school; girls reported receiving information on how to manage and understand their periods from a few conversations with relatives or peers. None of the girls knew what their period was when it first came, causing fear and anxiety. Many girls reported feeling shame around talking about their periods, which prevented them from seeking further information. Despite the taboo nature of the topic of menstruation within the cultural context, mothers and teachers were all supportive of increased education for girls within the school setting. **Conclusions:** Initial analysis suggests the greatest psychological challenge that menstruation poses for school girls in Mali is fear and shame caused by lack of knowledge and a lack of established support systems. Cultural practices, specifically around the need to protect access to blood, limit the capacity for girls to manage their periods at school during the school day. Furthermore, lack of communication between pupils and teachers means that teachers are unaware that the girls need additional support. Data from this study will be compared to the multi-country study to understand the similarities and differences in the challenges that girls face in Mali compared to other cultural contexts.

Planning for sustainable water delivery in Kenya's arid and semi-arid lands

René van Lieshout, IRC

Additional Authors: Melanie Carrasco

This paper presents the results of an innovative approach that integrates the management of water resources and services in a pastoralist context in Northern Kenya. The work is part of the two-year Kenya Arid Lands Disaster Risk Reduction--Water, Sanitation, and Hygiene (KALDRR-WASH) program, supported by USAID and the Netherlands. It is implemented by a consortium of the Millennium Water Alliance, Agua for All, Acacia Water, IRC, CARE, Food for the Hungry, Catholic Relief Services and World Vision. The paper focuses on the approach

developed and tested in the programme: using local, participatory water planning to match water resources with water demand. In the program, this integrated planning then informs strategies for recharging, retaining and reusing (3R) shallow groundwater to create stronger water buffers for bridging prolonged droughts. The approach is tested in four pilot areas in Marsabit, Moyale, Turkana and Wajir. In Kenya's arid and semi-arid lands, the total demand for water often exceeds the water available to people and livestock. This problem is compounded by weak support from government and competition for resources amongst water users, which creates the potential for armed conflicts. Most water-related interventions are short term and target a single problem, rather than the whole complex of problems that communities face. The benefits are therefore often short lived and dwarfed by the remaining problems. Although Kenyans experience periods of severe water scarcity, annual rainfall is actually sufficient to support their livelihoods. The gap arises because a large portion of the water disappears unused through surface runoff, flooding and evaporation. A new approach is needed to unlock the potential of water sources, and use and manage them in a strategic and sustainable way. The first key concept that is used for the overall water assessment of an area is the RIDA framework (for Resources, Infrastructure, Demand and Access). This framework evaluates on one hand the potential of water resources and existing supply infrastructure, and on the other hand the total water demand and water access challenges. This integrated, area-based approach encompasses all local water uses (domestic, livestock, agriculture), all local water resources and all local water stakeholders (operators, users, government). With this it builds on the planning cycle of the second concept that is used: the Multiple Use Services (MUS) approach. Local stakeholders develop a water master plan that matches resources, infrastructure, demand and access for the long term. Based on field assessment and research, an estimate is made of the actual water gap for the coming ten years, for all water uses. Next, strategies are developed to meet these gaps through strategies that cover water infrastructure (including the 3R strategy), water governance, water service management, and capacity development. Stakeholders divide responsibilities for coordinating the different strategies of the water master plan. Cost estimates for the strategies are based on the life-cycle costs approach (LCCA) analysis of water services. This contributes to a better understanding of the complete cost picture--including the costs of operation, maintenance, rehabilitation and eventual replacement--for each intervention, and promotes agreement on ways to finance these costs. The 3R and LCCA are the third and fourth important concepts that are used for planning for sustainable water service delivery. The first experiences with the methodology are encouraging with the following promising findings and initial successes from the pilots: - Local, participatory water master planning is a strong tool for guiding interventions and building resilience to drought. - The methodology can be replicated and scaled up to other areas, to estimate what resources and infrastructure are needed to meet future demand. - In Wajir, the participatory planning meeting addressed and defused conflicts over water and land. The mapping of the water gaps informed discussions on options for grazing land strategy in both wet and dry seasons. Participants agreed to create new water sources near homesteads to avoid conflicts with neighbouring clans with migrating herds. - In Marsabit, county planners were very positive about using new tools and insights to set priorities. - In Moyale, stakeholders said that the tools provided an excellent opportunity to integrate traditional water management practices, which are neglected in most other planning processes. - In Marsabit, Wajir and Turkana, government representatives recognised the link with Kenyan planning mechanisms, and said the new tools would help them translate county plans into actions. By the time of the conference the first experiences of how the local water master plans are used by the stakeholders for planning of their future water related interventions and its'potential for up-scaling will be shared.

Managing Infants' and Young Children's Sanitation: Formative Research from Cambodia

Lindsay Voigt, WaterSHED

Additional Authors: Molly Miller-Petrie; Lyn Mclennan; Mimi Jenkins; Sandy Cairncross

Globally, the dangers of open defecation have been well documented. More recently, studies have shown

inadequate sanitation to be associated with increased child morbidity and stunting in places as diverse as Bangladesh, Burkina Faso, Indonesia, Lesotho and Cambodia (Shordt 2006, Kov et al. 2013). These findings provide further impetus for promoting models such as market-based approaches that can accelerate sustainable access to safe latrines by virtue of improved efficiency and efficacy. Even in the presence of an improved latrine, a significant population largely continues to practice open defecation in and around households: infants and young children. Many latrine designs are not suitable for use by small children, so it is easier for parents to allow them to defecate outside. Feces often remain in the open where children run the highest risk of direct contact and ingestion. This risk is compounded by the widespread perception in the developing world that children's excreta are not dangerous, so concerns about safe disposal remain low. In reality, children's feces are more infective than those of adults (Gil et al. 2004). Indeed, several studies have concluded that when sanitation is improved, the largest single factor contributing to improved health is the safe disposal of children's stools (Buttenheim 2008; Ezzati et al. 2005; Shordt 2006; Yeager et al. 1999). Despite the dangers posed to children, their families, and members of the wider community by continued open defecation by children near the home, surprisingly little research has been done in this field. In an effort to close the knowledge gap around children's sanitation in Cambodia, WaterSHED, in conjunction with the London School of Hygiene and Tropical Medicine, undertook formative research on this topic 2014. The research aimed to gain a clear picture of how rural families in Cambodia manage their small children's sanitation, as well as insight into the psychological and cultural drivers behind practices. Furthermore, the research sought to assess the market potential of products and services that aid in the safe management of children's sanitation. WaterSHED conducted household surveys with approximately one hundred and twenty caregivers of small children across diverse regions of Cambodia about managing their infants' and small children's feces. The surveys used closed and open-ended questions to uncover common practices and to draw out deeper psychological and cultural drivers of behavior, as well as barriers to practicing safe feces management with children. Focus group discussions with caregivers shed light on consumers' reactions to a variety of available products for managing children's sanitation. Using the findings of this formative research, WaterSHED plans to identify market-based opportunities to promote products and/or services that can facilitate improved safe children's sanitation management. As a step in understanding children's sanitation management practices worldwide, a global search of enabling products was conducted, and an inventory was compiled of existing children's toileting products, in order to help inform new product designs and offerings. This session will share the results of this formative research and possible implications for the wider WASH sector: what are current children's sanitation management practices in rural and peri-urban Cambodia? What are the barriers that caregivers face in safely managing their children's toileting? What factors and understandings are motivating behavior around children's sanitation? What is the interaction between existing sanitation hardware and safe children's sanitation management? And how can current sanitation interventions be tailored to meet the needs of infants and small children? References: Buttenheim, A. M. (2008). The sanitation environment in urban slums: implications for child health. *Population and Environment* 30, 26-47. (43) Ezzati, M., Utzinger, J., Cairncross, S., Cohen, A. J., & Singer, B. H. (2005). Environmental risks in the developing world: Exposure indicators for evaluating interventions, programmes, and policies. *Journal of Epidemiology and Public Health*, 59, 15-22. Gil, A., Lanata, C., Kleinau, E. and Penny, M. (2004) Children's Feces Disposal Practices in Developing Countries and Interventions to Prevent Diarrheal Diseases: A Literature Review. *Environmental Health Project of USAID Strategic Report* 11, 1-67. Kov, P. et al. (2005) Growing taller among toilets: Evidence from changes in sanitation and child height in Cambodia, 2005-2010. 1-26. Shordt, K. (2006) HIP Review of safe disposal of feces. *Hygiene Improvement Project (USAID)* 1-27. (3), Yeager, B. A. C., Huttly, S., Bartolini, R., Rojas, M., & Lanata, C. F. (1999). Defecation practices of young children in a Peruvian shanty town. *Social Science & Medicine*, 49(4), 531-541.

Transforming Sanitation Coverage: Civic Champions Inspire Sustained Change

Lindsay Voigt, WaterSHED

Additional Authors: Lyn McLennan; Daroath Phav; Mai Sieng

WaterSHED implements the Hands-Off market-based approach to support an increase in access to improved sanitation in rural Cambodia. In a 3-year period, over 75,000 improved latrines have been purchased at full cost by rural consumers from local businesses. Since inception, WaterSHED has appreciated that market agents alone cannot shift social norms. In several communes and districts, we have witnessed the emergence of local leaders who, in spite of the many challenges facing their communities, have led their communities to rapidly achieve full sanitation access. Leadership development of elected local officials (commune councillors) in rural Cambodia has been limited to date. Support from national agencies for local government is primarily centred on building basic infrastructure and administrative capacity. Non-Governmental Organisations (NGOs) in the water, sanitation and hygiene (WASH) sector that train local government officials tend to focus on specific administrative skills that help to ensure that NGO project outputs are achieved. Unfortunately, data about the quality of such trainings and their general applicability beyond individual projects is extremely limited. With an estimated 1.8M households still lacking access to safe sanitation in rural Cambodia, the need to address consumer barriers and motivations is critical. The Cambodian MDGs call for 30 percent of the population to have access to improved sanitation by 2015, 60 percent by 2018 and 100 percent by 2025. While the country is on track to meet the first goal, achieving the latter is highly unlikely at the current pace. Supply chain development work by WaterSHED and others, combined with social marketing activities and CLTS inspired programs are helping to address the problem. However, persistent acceptance of open defecation as a cultural norm is proving to be a challenge. Under the Hands-Off sanitation marketing program, rapid improvements in some communities and not others led WaterSHED to investigate other determinants of change. Whilst proximity to markets and alternative, non-seasonal incomes are indicators of the likelihood of early sanitation adoption, not all communities were accelerating coverage at the same pace when controlling for those factors. Inspired by local leaders who have motivated their communities to make transformational change in sanitation coverage, WaterSHED is undertaking a proof-of-concept leadership development project. Self-selected participants from two 'treatment' districts in rural Cambodia pay a fee to engage in a cyclical program of leadership conferencing and coaching. Transformational change is promoted and rewarded through a combination of output-based financial and non-financial incentives. Participants set their own ambitious targets for improving sanitation coverage, with some targeting 100 percent. WaterSHED is evaluating the effectiveness of the methodology to catalyze so-called 'Civic Champions' to enable more rapid and cost-effective acceleration of sanitation coverage. Among other indicators, we are measuring the number of latrines sold and are using neighboring (non-treatment) districts as reference points for comparison. Qualitative evidence of transformation is captured, through the mentoring program, documentary videos and short case studies. This innovative leadership development project is showing promising signs of success. Already communities are increasing sanitation coverage and upgrading to improved toilets. Over 2,000 unsubsidized improved latrines have been installed in treatment areas. Five communities have self-declared 100% sanitation access. Qualitative change is also palpable. Commune leaders talk about the opportunity to learn from others, developing greater self-awareness, growing in confidence and developing a network for advice and support. Sanitation is more frequently on the agenda of commune and village meetings, stronger connections are being forged with local businesses and there is a sense that these emerging Civic Champions can make the impossible possible. The program builds on the government's strategy that promotes 'those that can pay should pay'. It is integrated within a larger program that promotes sustainable change by tapping into existing local market-based mechanisms. Total program expenditures will be tracked as in order to evaluate the cost-effectiveness of the concept. WaterSHED's current sanitation marketing program cost of less than \$20 per latrine will serve as the benchmark. The additional change in coverage inspired by the participating leaders will enable a direct cost comparison. The Civic Champions project is first and foremost a leadership development program. These leaders can apply the learning from this focused effort to any of the development challenges facing their communities. The early indications suggest that enabling civic officials to enhance their leadership capacity is cost-effective, sustainable and applicable beyond sanitation.

Open defecation, population density, and child height in Madhya Pradesh, India: An ecological analysis of new data on over 22,000 children

Sangita Vyas, Rice Institute

Additional Authors: Aashish Gupta; Gregor von Medeazza; Dean Spears

India is home to 17 percent of the world's population and 60 percent of the world's open defecation, according to joint UNICEF and WHO 2014 estimates on total open defecation for 2012. Within India, the state of Madhya Pradesh has an exceptionally high rate of open defecation. Approximately 5 percent of the open defecation in the world occurs in Madhya Pradesh alone. If the state were to eliminate open defecation altogether, India would be around 50 percent closer to achieving the Millennium Development Goal for Sanitation. An accumulating body of research, both experimental and cross-sectional, highlights the importance of sanitation for infant mortality, height, and cognitive achievement. Given that the average height of children in Madhya Pradesh is well below the heights of healthy children, does a similar relationship exist in Madhya Pradesh? This paper seeks to investigate whether children growing up in districts of Madhya Pradesh where there is more open defecation are shorter than children growing up in districts where there is less open defecation. In this ecological analysis, we use the most recent large-scale dataset on height to quantitatively assess the importance of the link between open defecation and nutritional outcomes among children. A similarly representative study at the state level or higher has, to our knowledge, not been conducted since India's 2005 National Family Health Survey. We combined this district-representative dataset of 22,913 Madhya Pradesh children under the age of 5 collected in 2010 by the National Institute of Nutrition, Hyderabad, with district-level data from India's Census 2011, the National Sample Survey 2005-2006, and District Level Household and Facility Survey 2007-2008. We performed an ecological analysis using multi-variable regression to explore the association between the exposure to fecal pathogens and the nutritional status of children under the age of 5 at the district level. We include district level regression controls for the sex composition of children, breastfeeding rates, calorie consumption, poverty, demographic make-up, and education. The analysis finds that exposure to fecal pathogens robustly predicts child height. On average, districts in which open defecation per square kilometer is low are the same districts in which children below the age of 5 are taller. This relationship is robust to including the control variables. The coefficients we estimate are quantitatively important: reducing open defecation per square kilometer from the 75th percentile to the 25th percentile is associated with an increase in height of 0.71 centimeters for a 5 year old boy, using the most conservative model estimate. This study has several methodological limitations. Since we use cross-sectional data, we are unable to show a causal association between open defecation and child height. Second, this is an ecological study, using data that are aggregated at the district level. Thus, our analysis may be vulnerable to residual confounding. However, the robustness of the results across the models and the consistency with the findings from other studies suggest that the association is not driven by happenstance. This suggests that policy makers interested in improving nutrition in Madhya Pradesh should consider sanitation as an important part of their toolkit.

Does open defecation contribute to antibiotic resistance?: A cross-sectional study of antibiotic usage in India

Sangita Vyas, Rice Institute

Additional Authors: Dean Spears

The growing prevalence of antibiotic-resistant diarrheal disease in the developing world has been widely noted. Antibiotic resistance is of great global health concern because it reduces the options for safe and effective treatment of disease. According to WHO recommendations, diarrhea in children exhibiting dehydration should always be treated with oral rehydration therapy (ORT) and zinc supplements. The WHO only recommends the

use of antibiotics if there is blood in the stool or if the child is suspected to have cholera and is severely dehydrated. Usage of ORT and zinc in India, however, is low. Not even one-third of children who had diarrhea within the 2 weeks prior to being surveyed in India's 2005 National Family Health Survey (NFHS) were given ORT and less than a percent were given zinc. About half of children who suffered from diarrhea were given antibiotics even though only 10 percent had blood in the stool, suggesting that antibiotics are used much more frequently than they should be. There is also some evidence from studies of hospitals and clinics within particular localities in India suggesting that providers prescribe antibiotics at very high rates. Poor sanitation has important implications for the health and nutritional status of children, and substantial research in the fields of medicine and epidemiology have shown an association linking poor sanitation to diarrhea and intestinal worms. India has exceptionally poor sanitation, with over 50 percent of the population defecating in the open. In this paper, we seek to investigate whether higher rates of open defecation are associated with greater usage of antibiotics to treat diarrhea. In this analysis, we use data on children under 5 from India's 2005 NFHS to quantitatively assess the importance of the link between exposure to open defecation and reported antibiotic usage to treat diarrhea in the last 2 weeks. Because the fecal germs of one person can make anyone sick, we use the fraction of households defecating in the open in the child's locality as our dependent variable of interest. We use multi-variable analysis to explore this relationship, and include a number of control variables including age, sex, relationship to the household head, birth order, mother's education, household sanitation infrastructure, water source, household wealth, religion, and whether the household lives in an urban or rural area. Children under 5 who live in areas in which a higher fraction of households defecate in the open are more likely to have had diarrhea in the past 2 weeks, and are also more likely to have been given antibiotics to treat their diarrhea. These results are robust to the inclusion of controls. The coefficients that we estimate are quantitatively important. If there were no open defecation, the number of children given antibiotics to treat diarrhea would be one-third less than if everyone defecated in the open. Eliminating open defecation in India altogether would linearly predict one less round of antibiotics for more than one-fifth of India's children per year. There is already a growing literature linking sanitation to infant mortality, child nutrition, and cognitive achievement. This is the first paper, to our knowledge, to link sanitation to antibiotic usage. The results of our study suggest that policy solutions for preventing antibiotic resistance could be strengthened by addressing usage of sanitation. Not only is eliminating open defecation important for human capital accumulation, but it is also important for preventing bacterial resistance.

What does religion have to do with the demand for sanitation?: Explaining variation in sanitation between India and Bangladesh

Sangita Vyas, Rice Institute

Additional Authors: Payal Hathi; Dean Spears

Accumulating evidence suggests that open defecation has detrimental impacts on child health and human capital later in life, including stunted height, less years of completed schooling, lower adult productivity, and higher rates of mortality. South Asia has the highest rates of open defecation worldwide. However, there are stark differences between the progress that various countries in the region have made in addressing the problem. From the early 1990s until 2011, Bangladesh decreased its rate of open defecation from 30 percent to just under 5 percent. During the same period, India saw a much slower decrease, with still over 50 percent of the population defecating in the open in 2011. Despite Bangladeshi households being poorer, on average, than Indian households, poor Bangladeshi households are more likely to use a toilet than poor Indian households. Within poor households that have a dirt floor and no electricity, 84 percent defecate in the open in India while only 28 percent do in Bangladesh. That the poor in Bangladesh have been willing to spend their time and money to build sanitation facilities suggests that resources may not be the main constraint driving the lack of sanitation in India. There may instead be differences in people's demand for sanitation. This paper seeks to understand the

difference in demand for sanitation between households living in India and those living in Bangladesh. One of the main differences between the two countries, aside from income levels, is the religious identification of the majority of their citizens: India is predominantly Hindu while Bangladesh is predominantly Muslim. The well known 'puzzle of Muslim child mortality advantage' in India records that despite Muslims being poorer and less educated than Hindus on average, mortality among Muslim children is about 18 percent lower than among Hindu children. This pattern has existed for decades, and cannot be explained by many expected factors such as education, wealth, family demographics, or health infrastructure. A recent paper by Geruso and Spears (2014), however, shows that the gap between Hindu and Muslim child mortality in India can be fully explained by the negative externalities of poor sanitation. The insight that differences in sanitation can explain differences in mortality rates between Hindus and Muslims motivates our analysis. Given that sanitation is so important for human capital accumulation, the reasons for differences in the demand for sanitation are important to explore. We first pool data from the India Human Development Survey (2005) with data from the Household Income and Expenditure Survey (2010) in Bangladesh to explore differences between Hindus and Muslims, regardless of where they live within South Asia. We look at differences between Hindus and Muslims within each country separately. By estimating demand using linear regression analysis, we find that within India, Muslims are 20 percentage points more likely to use sanitation than Hindus, even after controlling for income. Within Bangladesh, Muslims are 3 percentage points more likely to use sanitation than Hindus, even after controlling for income. These estimates are significant at the 1 percent level. Using different decomposition techniques, we find that the difference in the fraction of Muslims between the two countries can statistically explain between 24 and 33 percent of the difference in sanitation between the two countries. Further work is needed on how to increase demand, but quantifying these differences makes it clear that programs to address the challenge of open defecation in South Asia will need to be strengthened by targeting demand creation more directly.

Water quality assessment of large-volume samples from small water supplies in Alabama

Jessica Wedgworth, University of Alabama

Additional Authors: Julie Olson; Christine Stauber; Joe Brown; Mark Elliott; Pauline Johnson

Evidence suggests that small water supplies in North America may be at greater risk of microbiological contamination than larger systems. Despite this, monitoring data remain scarce. As part of a larger study on water and health in rural water systems in Alabama, we conducted a water quality assessment of 12 water systems within three Alabama counties. To evaluate the efficacy of water treatment, we chose 10 sample locations at each of the 12 public utilities that reflected catchment to consumer delivery. Sample locations included well heads and surface water extraction points, main trunk lines, line termini, and other key points (e.g., pumping stations or storage tanks). At each location, 100 liter water samples were collected on 3 sampling dates and water quality measures including total chlorine, free chlorine, pH, turbidity and pressure were recorded in the field. The 100 liter samples were processed using ultrafiltration and the 250 ml concentrate was analyzed for microbiological indicators and pathogens including heterotrophic bacteria, total coliforms, *Escherichia coli*, enterococci, coliphage, *Cryptosporidium parvum* and *Giardia lamblia*. To date, 300 water samples have been collected and processed. Of these 300 water samples, 143 (47.7%) were found to be positive for total coliforms. Eleven of 143 samples (7.7%) were also positive for *E. coli*. Greater than 79% (n=238) of all samples were positive for the presence of heterotrophic bacteria and less than 12% (n=34) were positive for coliphage. Approximately 44% (n=133) of all samples were also positive for enterococci. For pH, 96 (32%) samples were found to have a pH of less than 6.5, with the pH of 67% of samples falling within the normal range of drinking water, 6.5-8.5. The mean pH of all samples was 6.98. Less than 3% (n=7) of samples taken post chlorination (n=253) did not contain detectable levels of free chlorine (<0.1 mg/L). Turbidity values ranged from 0-32.9 NTU with a mean of 1.73 NTU, and mean pressure was 71.5 PSI (10-200 PSI range). Data collection will be completed in May 2014 allowing us to conduct temporal and spatial analyses of the influence of collection time

and location within and between the water distribution systems. Results of these analyses will be useful in risk assessments of specific locations within small water distribution systems.

Effectiveness of a school based intervention to improve knowledge, attitudes and practices of water, hygiene and sanitation among school children in Kiran Batticoloa Sri Lanka

Marakande sepali Wickrematilake, Ministry of Health

Additional Authors: K Pethiyagoda

Inadequate sanitary conditions, lack of water facilities and poor hygiene practices play major roles in the increased burden of communicable disease within developing countries. One of the targets of the Millennium Development Goals is to halve the proportion of people without sustainable access to safe drinking water and sanitation by 2015. The UNICEF state that 1,299 out of 9,662 schools do not have functional sanitation facilities. Due to the war situation the WASH facilities in the north and east of Sri Lanka was underdeveloped and it is important that water sanitation and hygiene are given high priority. This combined with other aspects of the impact of the war, have conspired to create the current state of affairs and hygiene practices unsatisfactory, resulting in persistent outbreaks of Diarrhoea, and other water borne diseases. Children are more receptive to learning and can be used as agents of communication to their family and to their community. Therefore school based hygiene education is important to reduce the rates of transmissible diseases. Purpose: The current study was carried out in two secondary schools in the eastern province of Sri Lanka, with the objective of evaluating the effectiveness of a school based education intervention to school children in improving knowledge, attitudes and practices of water sanitation and hygiene WASH. Methodology: A self-administered pre tested survey questionnaire was used to assess knowledge, attitude, practices (KAP) among grade seven students. An interactive educational intervention was carried out for all grade seven students through health promoting clubs. Specific activities were carried out through four sub committees of Suwatha clubs. The impact of effectiveness of educational intervention among school children was evaluated by comparing the different variables in the questionnaire before and after health education intervention. The chi-square test was used for statistical calculations. Results: In the study a total of 64 students were responded in the pre KAP survey but only 62 from the initial 64 students responded the post KAP survey questionnaire. The results of the baseline survey showed that students knowledge was poor in the areas of boiling water that kills germs, water borne diseases, water contaminated caused by open defecation, use of toilet as a measure of diarrhoea, importance of using soap when washing hands. Students had unfavourable views on availability of water and sanitation services, their accessibility to soap in hand washing Students personal hygiene was very poor that majority 75% reported they have a bath once in three days and only 50% reported of having a separate toilet, and 51% had access to a safe drinking water source. Post intervention result showed that knowledge was improved significantly in improving knowledge in the subject areas like importance of drinking boiled cooled drinking water, water borne disease, importance of hand washing with soap ($p < 0.001$). Positive views towards good hygienic like washing hands after using toilet were reported. There was no statistically improved effect on students reported hygienic practices Conclusion: Imparting the knowledge by means of educational intervention would improve their knowledge and positive views towards good hygienic practices like hand washing before meals and after using toilet. However their good hygienic practices are affected due to the unavailability of resources, like safe water, sanitizers like soap. Until the area gets a proper water supply scheme ongoing health club activities should be carried out to facilitate transfer of sound water and sanitation practices in the community.

Undoing Inequity: inclusive water, sanitation and hygiene services that deliver for all in Uganda and Zambia

Jane Wilbur, WaterAid

Additional Authors: Lilly Munkombwe Kabwela

INTRODUCTION Persons with disabilities, chronically ill and older people (collectively referred to as 'vulnerable' people) face similar barriers when accessing water, sanitation and hygiene (WASH). For instance, inaccessible sanitation can force people with physical impairments to crawl on the floor to use a toilet or defecate in the open. Vulnerable groups often lack accessible information on their rights to services as well as awareness of inclusive designs. They also face stigma when attempting to use shared facilities or community water points. These barriers can negatively affect people's self esteem, dignity and self respect. Vulnerable people are often excluded from decision making processes. This lack of consultation and participation can lead to inappropriate WASH design, meaning that access does not improve. WaterAid, WEDC and LCD are collaborating on the Undoing Inequity project (funded by SHARE). Working with implementing partners, DAPP in the Mwanza West ward in Zambia, and WEDA and CoU-TEDDO in Amuria and Katakwi districts in Uganda the project aims to: 1. Understand the barriers and opportunities that vulnerable groups and their families face when accessing WASH services. 2. Develop and test an approach that addresses those barriers. 3. Evaluate the impact that improved access to safe WASH has on the lives of the target group. **PROBLEM STATEMENT** Globally, 748 million people live without access to safe water and 2.5 billion people lack access to adequate sanitation (WHO / UNICEF, 2014). A growing body of evidence reveals specific groups face WASH poverty, stigma and social exclusion (WHO/UNICEF, 2014; Satterthwaite et al, 2012). These include an estimated 1 billion people worldwide who live with a disability (WHO, 2011), 740 million people who are aged 60 and over and the estimated 34 million people living with HIV (WHO, 2013). National surveys rarely disaggregate data by disability, so the extent to which disabled persons lack access to safe WASH is often unknown (Trevett and Luyendijk, 2012). Nor is there any evidence about the benefits of inclusive approaches at scale. This research aims to contribute towards filling this knowledge gap. In an attempt to address the barriers faced by vulnerable people, an 'inclusive WASH' approach was designed and tested. This responds to the varying needs and requirements of people and the local context, rather than promoting a 'one size fits all' approach. Initially participatory barrier analyses were conducted at the community, district and national levels. Accessibility audits were conducted with a vulnerable people to evaluate the usability of existing WASH facilities. Identified changes or improvements were acted on. Innovative low cost and low tech accessible WASH designs were constructed. These were documented in an accessible resource catalogue for households. Participatory approaches applied meant vulnerable people could attend community meetings, and that they could speak and be listened to. Information was shared in accessible formats (pictures for people who cannot hear or read and audio for those who cannot see) and in local languages, so that everyone had access to relevant information. **RESEARCH METHODS** An action research approach is being used, which applies a mixed methods approach to gather evidence before and after WASH interventions in one Ward in Zambia and in two Districts in Uganda, to assess the impact and benefits for the target group. Implementation progress was monitored throughout the intervention phase. A mid-term review will be conducted in June 2014; this will be followed by a full evaluation in 2016. **FINDINGS** A description of the inclusive WASH approach and the mid-term review findings, showing the early impact on the target population will be presented at the Conference. Early indications show that inclusive WASH can increase vulnerable people's access to services, autonomy, self esteem and social interactions, thereby challenging stigma and discrimination. **IMPLICATIONS** The data collection surveys conducted in this project gathered information from heads and vulnerable members of the household. Importantly this revealed disparities in WASH access and use at inter and intra household levels. Ensuring WASH services are accessible for all is vital, but it is not enough. Vulnerable people still may be excluded from using the facilities if negative beliefs are not tackled, so the root causes of stigma and discrimination must always be understood and addressed (IDC, 2014; World Bank, 2013; OHCHR, 2012). This can only be done through meaningful consultation and involvement of vulnerable groups throughout WASH programme cycles. This process will take longer and progress will be harder to measure, but arguably it can lead to more equitable and sustainable WASH services and poverty reduction for the 'bottom quintile' (World Bank, 2013).

Microbiological and chemical quality of packaged water in bottles and sachets and household stored drinking water in Freetown, Sierra Leone

Ashley Williams, The Water Institute at UNC

Additional Authors: Michael Fisher

While packaged drinking water has long been consumed in high-income countries, packaged water in bottles and plastic bags/sachets is increasingly ubiquitous in many low- and middle-income countries. Packaged water (PW) products are widely consumed in Freetown, Sierra Leone, with producers ranging from large-scale industrial operations to small cottage industries. Government oversight of the production, storage, and distribution of such products is extremely limited, and no formal surveillance of the chemical or microbiological quality of PW in Sierra Leone is currently conducted. This study of the chemical and microbiological quality of PW products sold in Freetown, Sierra Leone found little evidence of chemical contamination sufficient to threaten human health, among the 10 parameters studied. By contrast, 18% of 49 PW products sampled at 49 manufacturing facilities contained detectable *Escherichia coli*, although only two samples contained concentrations in excess of 10 CFU/100 mL. The microbiological quality of PW products was found to deteriorate slightly along the supply chain, with microbiological contamination detected more frequently and at higher concentrations in PW products at the point of sale than at the manufacturing facility. Products sampled from street vendors were not found to be more frequently contaminated than those collected from retail stores ($p = 0.1784$ and 0.3711 for *E. coli* and total coliforms, respectively). The concurrent analysis of stored drinking water samples from 60 households in Freetown suggests that PW products from manufacturers are significantly less likely to contain *E. coli* and total coliforms than stored water ($p < 0.001$), and have significantly lower concentrations of both fecal indicators ($p < 0.001$). While these results highlight the need for additional regulatory oversight in order to safeguard public health, they also show that PW can often be safer than other alternatives.

Hypospadias and maternal exposure to atrazine via drinking water

Jennifer Winston, Carolina Population Center

Additional Authors: Thomas Luben; Robert Meyer; Peter Langlois; Peter Weyer; Bridget Mosley; Michael Emch; National Birth Defects Prevention Study

Hypospadias is a relatively common birth defect of the male urinary tract. It is believed to have a multi-factorial etiology, where genetic susceptibility may combine with environmental factors to increase risk. Hypospadias occurs when normal urethral closure during fetal development is disrupted. Because urethral development depends upon binding of testosterone to the androgen receptor and subsequent action by the androgen receptor, it has been suggested that endocrine disrupting chemicals might increase hypospadias risk. Atrazine, one of the most widely used herbicides in the United States, is a potential endocrine disrupting chemical that has been examined for a possible association with hypospadias. The existing evidence surrounding such an association is mixed, however. Using data the National Birth Defects Prevention Study, a population-based case-control study, our study considers the role of maternal exposure to atrazine (an herbicide) via drinking water in the etiology of 2nd and 3rd degree hypospadias. Atrazine is metabolized relatively quickly by humans, but can remain stable in the environment following runoff into streams or leaching into vulnerable groundwater. This suggests that mothers might be exposed to atrazine repeatedly via drinking water obtained from affected water sources. We use data collected by the National Birth Defects Prevention Study on 343 hypospadias cases and 1,422 male controls in North Carolina, Arkansas, Iowa, and Texas from 1998-2005. We use catchment level stream and groundwater contaminant models from the US Geological Survey to estimate atrazine

concentrations in public water supplies and in private wells. We assign case and control mothers to public water supplies based on geocoded maternal address during the critical window of exposure for hypospadias (i.e., gestational weeks 6-16). We incorporate maternal questionnaire data about water consumption and drinking water in order to estimate total maternal consumption of atrazine via drinking water. We then include additional maternal covariates, including age, race/ethnicity, parity, and plurality, in logistic regression analyses to consider an association between atrazine and hypospadias. The median estimated atrazine consumption is similar among cases and controls (0.066 and 0.073 $\mu\text{g/L}$, respectively). When controlling for maternal characteristics, hypospadias is found to be marginally associated with daily maternal atrazine consumption during the critical window of genitourinary development (odds ratio = 1.033, 95% CI= 0.997 to 1.066; $p = 0.054$ per 0.25 $\mu\text{g/L}$); that is a 0.25 $\mu\text{g/L}$ increase in estimated atrazine consumption during early pregnancy is associated with a 3.3% increase in the odds of having a baby with hypospadias (or a 1 $\mu\text{g/L}$ increase in estimated atrazine consumption is associated with a 13% increase in the odds of having a baby with hypospadias.) This research illustrates the possible utility of US Geological Survey models and residential address in estimating exposure to contaminants in drinking water for health studies. This study was supported by a cooperative agreement from the Centers for Disease Control and Prevention. The views expressed in this abstract are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency or the Centers for Disease Control and Prevention

An in-demand reuse option for human waste: Feces briquettes

Emily Woods, Sanivation

Additional Authors: Andrew Foote; Hana Lokey

In 1990, improved sanitation coverage in sub-Saharan Africa was 26%. The Millennium Development Goals sought to halve the amount of people with improved sanitation and achieve 75% improved sanitation coverage by 2015. In sub-Saharan Africa, sanitation coverage in 2012 was estimated at 30%. It is well recognized that sanitation systems have had difficulty scaling. One reason is due to the lack of effective business models in sanitation and the cost to dispose waste safely. Both international and local attempts to offset the costs of treatment, via production of biogas, fertilizer, or aquaponics feed, have not been widely successful often due to infrastructure requirements or transport costs. In Kenya specifically, only 5% of the human waste in Kenya is treated before being released into the environment. From working in Naivasha, Kenya, Sanivation has recognized the need for an affordable household fuel and has begun to transform human feces into a burnable briquette that demonstrates similar heat production and less CO emissions when compared to charcoal. Dried feces has a calorific value of 12-23 MJ/kg and with proper treatment can be transformed into a valuable fuel. Sanivation prepares waste to be transformed into a burnable briquette by using its solar waste treatment process. Research on Sanivation's solar waste treatment with Centers for Disease Control and Prevention has shown substantial reductions of *E. coli* (up to $>8.3 \log_{10}$), *C. perfringens* spores (up to $>5.0 \log_{10}$) and helminth ova (up to $>3 \log_{10}$). After being treated and dried, human feces is combined with carbonized agricultural waste in a 1:3 ratio to create a charcoal briquette. Feces acts as the binder, allowing carbonized waste to be densely combined and adding calorific value. Briquettes are pressed with a compound wooden lever press. The current process is entirely manual without using electricity. Charcoal briquettes created from feces have been evaluated on a variety of parameters including durability for transportation, density, carbon monoxide and particulate matter emissions, and calorific value. Emissions data was measured using Easy Log-USB-Carbon Monoxide Data Logger and University California Berkeley Particle Monitor. Feces briquettes had an average of emissions of 60 ppm for carbon dioxide which is significantly lower than wood charcoal which has an average of 300 ppm. Calorific value was measured on two different briquettes by Zurich University of Applied Sciences. The charcoal briquettes created from feces had calorific values from 11.389 to 12.850 J/g. In urban areas in Kenya, the demand for charcoal has doubled and the price has increased six fold in the past 10 years; households spend 15-

20% of their income on charcoal. With similar heat output, less emissions and lower projected costs than charcoal, feces briquettes have the potential to be a sustainable charcoal substitute. By substituting charcoal, feces briquettes may increase sanitation access by incentivizing waste collection and treatment. Future studies are underway to evaluate the marketability of briquettes and testing of feces briquettes created from improved industrial processes.

A case study: Design Outreach LifePump™ hand pump provides water in two Malawian villages with ultra-deep wells

Abraham Wright, Design Outreach

Additional Authors: Greg Bixler; Thom Haubert; Rich Arthur

Introduction: Hand powered water pumps are commonly used to provide safe drinking water to communities in developing countries. However, of the 345,071 hand pumps installed in Sub-Saharan Africa, reportedly 124,709 are no longer functioning¹. Many of the pumps remain broken due to low water tables that cause pumps to operate beyond design specifications². In search of a scalable solution, nonprofit Design Outreach developed a strategic team of academic, nonprofit, donor, and industry partners to design a more reliable and deeper reaching (up to 100 meters) hand pump, the LifePump. The LifePump hand pump is designed to meet the needs of communities around the world who need access to water in ultra-deep wells and also to meet the needs of WASH (water, sanitation, & hygiene) program managers that serve these communities. The purpose of this case study is to describe the installation of two LifePump hand pumps in Malawi and to share preliminary results and feedback. **Methods:** In June 2013, a Design Outreach team traveled to Malawi on a fact-finding trip to learn about the need for an ultra-deep well pump in this region of Africa. The team discovered that many areas in Malawi do not have hand pumps simply because the standardized pump option, the Afridev, is only capable of pumping water from a maximum depth of 50 meters. WASH program managers in Malawi report that up to 40% of the wells drilled have water levels in that exceed the Afridev's capability. It was determined that a new pump option was needed not only to provide water for communities with ultra-deep wells, but also to improve WASH program efficiencies in providing villages with functional boreholes. The Design Outreach team returned in November 2013 to install two LifePump hand pumps in the villages of Zolomondo and Chilekwa (Figure 1). In Zolomondo, the borehole depth was 63 meters with a dynamic water level of 52 meters, and the pump was set at 58 meters. In Chilekwa the borehole depth was 100 meters with a dynamic water level of 51 meters, and the pump was set at 82 meters. Following installation, daily follow-up was conducted on the pumps for one month to measure ergonomics and robustness to usage. Ergonomics was measured by surveying three groups of users (women, children, and elderly) whether they could "pump easily" and a yes or no answer was recorded. Robustness was measured by monitoring the number of handle rotations required to fill one 20 liter bucket over time. Additionally, flow rate was calculated by measuring the time to fill a 20 liter bucket after one month of usage. **Results:** Ergonomics survey results demonstrated that all women and children users were able to "pump easily". The elderly group was capable of using the pump but some difficulty was reported. No degradation in the performance was observed. The Zolomondo and Chilekwa pumps required an average of 110.4 (SD 1.8) and 118.4 (SD 1.9) handle turns, respectively, to fill a 20 liter bucket. After one month the Zolomondo and Chilekwa pumps produced a flow rate of 16.7 and 15.2 l/min, respectively. During the first pump installation, the Design Outreach team trained the national WASH technicians team how to install the LifePump. The national team was then able to successfully install the second pump without assistance of Design Outreach. The implementing partner was satisfied that the LifePump met their requirements and a larger scale pilot is planned for 2014-2015. **Discussion:** Millions of people around the world depend on hand pump technology for their water supply. However, options for deep to ultra-deep wells are limited. The majority of the deep well hand pumps currently available on the market were designed to lift water only 50 meters or less. A smaller number of pumps are designed to lift water 100 meters or less, and none of them are optimized to meet all of the end-user and WASH

program requirements for performance, ergonomics, robustness, and sustainability². The LifePump hand pump was designed to meet all of the requirements and challenges associated with ultra-deep wells for both the people in the communities who will use the water supply and the WASH programs that will install and maintain the pumps. References: 1) Rural Water Supply Network (2009), "Handpump Data, Selected Countries in Sub-Saharan Africa." 2) Cornet, Lucas (2012), "A Comparative Evaluation Of Ultra Deep-Well Hand pumps." Cranfield University, MSc Thesis.

Pyrolysis Kinetics of Fecal Sludge: Experiments and Modeling

Tesfayohanes Yacob, University of Colorado

Additional Authors: Richard Fisher; Ryan Mahoney; Barbara Ward; Karl Linden; Alan Weimer

The treatment of fecal sludge from improved latrines is one of the post 2015 sanitation goals. Various innovative treatment and reuse methods are being researched to achieve this goal. One such method is the pyrolysis of fecal sludge. This method of processing is advantageous due to its high temperature destruction of pathogens, potential for energy production, significant mass reduction and useful end products. Other waste streams such as agricultural waste are currently being pyrolyzed in various systems around the world for energy, heat and biochar production. Pyrolysis is the thermal decomposition of biomass in a low-oxygen environment reaching peak temperatures between 300 oC and 1000 oC. Treatment of fecal sludge by pyrolysis results in the production of char, tars and oils, and energetic gases. The relative proportion of these components is partly determined by the rate of heat application and final operating temperature. Understanding of this relationship helps in designing a pyrolysis treatment system that yields the desired end product at an optimum energy input. Although previous pyrolysis kinetic models of other biomass such as wood and sewage sludge exist, none is available for fecal sludge. Due to the unique nature of fecal sludge, research was warranted with this feedstock to develop a kinetic model. Fecal sludge was furnace dried at 105 oC, pulverized to a size of less than # 40 mesh, mixed, and kept in a desiccator until use. About 40 mg was then put into a Thermogravimetric Analyzer (TGA) with attached Differential Thermal Analyzer (DTA) and a Mass Spectrometer (MS) and run under 40 SCCM (standard ml/min) argon gas. To determine kinetic parameters, isothermal and non-isothermal methods were used. For the non-isothermal kinetics, the waste was heated at 1, 2.5, 5, 7.5, and 10 K/min to a temperature of 750 oC and held for 2 hours. For Isothermal runs, a 20 K/min heating rate was used and the waste heated to 300, 500, and 750 oC and kept at these temperatures for 2 hours. The data collected was sample mass loss, differential temperature measurement compared to a reference, as well as pyrolysis gas composition and concentration. The data was analyzed and input into a kinetic model to determine apparent activation energies and pre-exponential factors for various assumed reaction functions. DTA and pyrolysis gas release data were used to explain the reaction mechanisms and chose reaction functions for the kinetic model. The developed kinetic model is a useful tool for the design of a pyrolytic reactor for fecal sludge treatment.

Life Cycle Assessment of Adsorbents for Fluoride Removal from Drinking Water in East Africa

Teshome Yami, University of Oklahoma

Additional Authors: Junyi Du; Laura Brunson; Jim Chamberlain; Elizabeth Butler; David Sabatini

Life Cycle Assessment of Adsorbents for Fluoride Removal from Drinking Water in East Africa T.L. Yami, J. Du, L.R. Brunson, J.F. Chamberlain, E.C. Butler, D.A. Sabatini Abstract Various fluoride adsorbents have been studied to

remove excess fluoride from drinking water to the World Health Organization Guideline value of 1.5 mg/L. Production of these adsorbents emits harmful contaminants which can affect human health and environment, but the extent of these impacts is currently unknown. This study evaluates the environmental impacts of four adsorbents: activated alumina, bone char, aluminum oxide amended wood char, and alum waste, which are low-cost, and easy to use. The environmental impacts of these adsorbents were evaluated using life cycle assessment (LCA). The results indicate that the environmental impacts of these adsorbents vary greatly and a key determining factor is the fluoride adsorption capacity of the media. Aluminum oxide amended wood char has the highest impact in all impact categories, followed by bone char and activated alumina. The environmental impacts of the adsorbents can be reduced by increasing their fluoride adsorption capacity and/or carefully selecting key process components, such as the transportation distance and means of transportation, particularly for activated alumina.

Implementing Dispensers in Emergencies: Recommendations from Research in Haiti, Sierra Leone, DRC, and Senegal

Travis Yates, Tufts University

Additional Authors: Elise Armitage; Lilian Lehmann; Daniele Lantagne

Introduction The Chlorine Dispenser System (Dispensers) is a source-based water treatment system comprised of: 1) hardware installed next to communal water sources; 2) sensitization, including a local Promoter to encourage use; and 3) a bulk supply of chlorine. During randomized, controlled trials, 50-61% of households with free access to Dispensers had detectable total chlorine residual compared with 6-14% of control households who purchased bottled chlorine. Based on these positive results, more than 6,000 Dispensers have since been installed in Kenya, Uganda, and Malawi, with an average current confirmed use rate of 43%. Safe drinking water is also an immediate need in emergencies. While Dispensers have been shown to be effective in the development context, the application of Dispensers in emergencies remained untested until Innovations for Poverty Action (IPA) received funding to investigate Dispenser use in emergencies from The Bill & Melinda Gates Foundation. The project was a collaboration between IPA, Tufts University, and four international emergency response organizations to implement and evaluate four Dispensers in emergencies programs. The final project goal was to "distill and disseminate recommendations to organizations implementing programs in emergencies based on lessons learned".

Methods The team implemented and evaluated Dispensers programs in four emergencies. The evaluation was a mixed-methods protocol, including: 1) Dispenser site visits; 2) structured observations; 3) household surveys; 4) water quality testing, including sampling of turbidity, free chlorine residual (FCR), and E. coli in treated and untreated stored household drinking water; 5) key informant interviews; 6) focus group discussions; and 7) partner data review. To complete the final dissemination goal, the project team collaboratively developed a "Handbook for Program Implementation" (Handbook) by distilling lessons learned from implementation strategies and evaluation results at a 2-day project-end meeting.

Results Dispensers were implemented in response to: 1) a cholera outbreak in Sierra Leone; 2) endemic cholera in DRC; 3) a food crisis in Senegal; and, 4) cholera in Haiti. Evaluations were conducted within 2 months of initiation and 3-6 months afterward. Across the seven evaluations (Haiti only had a sustained evaluation), 70 Dispenser sites were visited with 161 individual Dispensers evaluated; and 9 water point observations, 2,057 household surveys, 13 focus group discussions, and 8 key informant interviews were conducted. Program metrics varied across contexts, with FCR in household stored drinking water ranging from 5-87% and effective use (the percent of households improving their water quality from contaminated to uncontaminated using the Dispenser) ranging from 0-81%. The partner organizations concluded that Dispensers in emergency programs were more successful when seven criteria were met. 1) Appropriate emergency context: Dispensers were more successful when they were installed in appropriate contexts (emergencies with high diarrheal disease risk), appropriate water sources (low turbidity, low pH, centralized water points for community, installed at the source), and with experienced

program staff. 2) Chlorine supply chain: Organizations that centrally manufactured the chlorine solution and delivered it directly to Promoters were less likely to have empty Dispensers. 3) Installation and maintenance of hardware: Installation of the imported tank, valves, and casings was straightforward for organizations, although valve clogging was noted when chlorine was manufactured directly in the tank by Promoters daily. 4) Project implementation: Projects were more successful when staff and communities were well trained. 5) Training of Promoters and users: Promoters that were well-trained, had reasonable job descriptions, and were paid were more successful at educating communities. 6) Monitoring and evaluation: Organizations that regularly monitored household FCR, and adapted program based on the results, were more successful. 7) Project close: Organizations that transitioned programs to well-trained, continuously involved local partners were more successful than organizations that handed programs over to governments or the community at project end. Each of these criteria were subsequently developed as one chapter in the Handbook and provides information necessary to follow these criteria. Discussion These results indicate that Dispensers can be - but are not always - an appropriate and effective tool in emergency response. The collaboratively-developed Handbook provides the resources necessary to: 1) determine if Dispensers are an appropriate intervention in a particular emergency response, and 2) if so, to implement a Dispensers in emergencies project. This Handbook provides an example of translating research to actionable efforts to improve water treatment programs in emergency contexts.

Factors affecting cleanliness and functionality of communal toilets in low income settlements in Dhaka, Bangladesh; addressing trash disposal and water availability problems for a community intervention

Farzana Yeasmin, icddr,b

Additional Authors: Stephen P. Luby, Fosiul A. Nizame, Guy Norman, Anita Layden, Abdus Shaheen, Habibur Rahman, Notan Chandra Dutta, Abdullah-Al Masud, Dalia Yeasmin, Leanne Unicomb, Peter J. Winch

Introduction: Dhaka, Bangladesh is one of the most rapidly growing cities in the world, with 5,000 slums that lack connection to any sewage system. Despite considerable investment in construction of communal toilets, residents of low-income communities struggle to maintain their cleanliness and functionality. Among the barriers are lack of systems for regular emptying of fecal sludge, the practice of dumping household waste in toilets, which causes them to become blocked and non-functional, and lack of water for proper flushing after use. We identify factors affecting cleanliness and functionality of communal toilets, and efforts to address the various hurdles to effective toilet maintenance. Methods: We conducted a formative study in a low-income community with access to toilets that are poorly maintained and unhygienic and where an international NGO is piloting a toilets improvement intervention. The team conducted in depth interviews and focus groups on the acceptability and feasibility of proposed ways to prevent the disposal of paper, rags, and other trash in toilets, and improved flushing practices. The interviewees included adult male and female residents of the community including landlords, and operators who perform fecal sludge emptying. The team designed a pilot intervention including hardware and behavior change communication messages after receiving feedback from residents of the community. Results: Operators who offer fecal sludge emptying services reported that toilet content removal was hindered by the presence of rags, plastic bottles, plastic bags, packets of detergent and shampoo, children's feces wrapped in plastic bags, pads and pieces of cloth used for menstrual management, condoms, toys, broken brushes, pieces of brick. All of them reported that if these items are not removed manually before emptying liquid sludge, their machine collection pipes become clogged. Participants reported that children's feces collected in plastic and paper bags or collected in potties are disposed of in nearby lakes, bushes, or in toilet pits. They reported that menstrual pads and cloth are sometimes disposed in toilets and sometimes wrap them in plastic in order to hide them prior to disposal. Adults use cloths, pieces of mud, and tissue paper to clean themselves after urination/defecation and place these items in plastic bags before disposing of them in toilets. Residents recommended providing waste bins in toilets that had lids to prevent foul odor and were lined with plastic bags to improve appropriate disposal practices. They recommended that waste bins with lid be

placed adjacent to toilets and that posters illustrating how to appropriately dispose of waste be placed just outside communal toilets. In two sites comprising approximately 20 households each, we have piloted two bin models for use within toilet cubicles and promoted regular disposal of bin contents. The signs prepared by a professional artist were placed inside toilets with community input. The signs show what type of waste should be thrown into the waste bin and not in toilet pit, and how to use the bin. Project staff has visited households twice a week for message delivery through inter-personal communication and to perform waste bin spot checks. Trash disposal systems in this area are highly variable. In some areas the trash collection van does not have access through narrow lanes and indiscriminate trash disposal (lake, roadside) is very common. The waste collector charges 30 Bangladeshi taka (US\$0.40) per month which is not affordable for many households. In some areas the waste collector disposes the waste in the nearby lake which discourages them to pay for poor service. Water scarcity restricts flushing and toilet cleaning; water in the community is often available intermittently and located at a distance from the communal toilets. Mostly toilet users do not remove feces on the pan and report that flushing and pan cleaning would be possible if there was sufficient water inside or near the toilet. Our discussion among focus group participants pointed to the demand for water reservoirs near communal toilets that can be conveniently filled during periods when water is supplied to these communities. Conclusion: Limited options for trash disposal and scarcity of water constrain effective function and maintenance of shared toilets in urban Dhaka. Interventions to improve maintenance of shared toilets should account for the variability of facilities and service in slum communities.

A novel method for collecting and analyzing fecal exposure transmitted by the housefly in urban Accra, Ghana

Sasha Zaharoff

Additional Authors: Habib Yakubu; Joseph Ampofo; George Armah; Christine Moe; Kelly Baker

Introduction: Like many urban cities throughout sub-Saharan Africa, the population of Accra, Ghana is rapidly growing without adequate parallel growth in basic water and sanitation service infrastructure. As a result, many city dwellers rely on public toilets that serve thousands of people, and open defecation is rampant. Additionally, the city lacks a septage containment and treatment system, so disposal of untreated septage into the environment is common. Houseflies can be important vectors for infectious disease transmission and may be particularly significant in urban slums where poor sanitation coverage and service leads to high levels of exposed fecal contamination in the environment. This study measured the quantity of fecal microorganisms mechanically transmitted by houseflies that could be ingested by humans in urban Accra, Ghana over a timed exposure period. Additionally, it assesses whether neighborhood-level sanitation coverage and area within neighborhood affect concentrations of transmitted microbes. Methods: Common methods for isolating microorganisms from flies involve plating whole fly extracts or rigorously washing the bodies and legs of flies. These methods may overestimate the actual quantity of microorganisms that a fly deposits during a food-contact event or over time. We developed a simple, novel method that allowed flies to land on a brown sugar media surface, transfer microorganisms, and fly into a separate trap for fly density enumeration. Control traps that prevented flies from landing on media plates were employed simultaneously to measure wind-borne background contamination. We employed these traps in multiple locations of interest in four neighborhoods with a range of compound-level sanitation coverage. Study neighborhoods included those with moderate sanitation coverage in Alajo (58%) and Shiabu (47%) and low sanitation coverage in Bukom (6%) and Old Fadama (1%). *E. coli* and *Vibrio* spp. colony forming units (cfu) were enumerated by membrane filtering 3 serial dilutions of media from traps, and culturing membranes on BBL[®] MI agar and TCBS agar, respectively. Human adenovirus was quantified by isolating virus from media using the absorb-elute membrane filtration method, extracting DNA from the elute, and performing quantitative PCR for human adenovirus sequences. Microbial counts/hour were compared between neighborhoods and between location types using Wilcoxon Rank Sum. Results: Control traps demonstrated that wind can be a pathway for transmitting *E. coli* (median=0.8 cfu/hour, range=0-63, n=16) and *Vibrio* spp.

(median=0.7 cfu/hour, range=0-72, n=16). Although *E. coli* and *Vibrio* spp. were detected in 69% and 81% of all control traps (n=16) respectively, human adenovirus was not detected. *E. coli*, *Vibrio* spp. and human adenovirus were detected in 77%, 81%, and 74% of all traps with flies (n=31) respectively. Median levels of *E. coli* and *Vibrio* spp. increased by 7.6-fold and 1.7-fold in traps that were accessible to flies, compared to control traps. Neighborhoods with moderate levels of compound-level sanitation coverage (Alajo and Shiabu) had less windborne *E. coli* ($p=0.03$) and *Vibrio* spp. ($p=0.03$) contamination compared to neighborhoods with low levels of coverage (Bukom and Old Fadama). The neighborhoods with moderate levels of compound-level sanitation coverage also had less *E. coli* contamination compared to neighborhoods with low levels of coverage, for contamination isolated from open fly traps ($p=0.001$). There were no significant differences in *Vibrio* spp. ($p=0.38$) and human adenovirus ($p=0.20$) in open fly traps from neighborhoods with moderate levels of compound-level sanitation compared to those that had low levels of compound-level sanitation. *E. coli* and *Vibrio* spp. cfu/hour, and adenovirus units/hour were not significantly different in open drains, markets, households, and public latrines. Conclusion: This study employed a new quantitative method for measuring wind and fly-borne bacterial and viral contamination for exposure assessment. The findings reinforce the importance of houseflies in the spread of fecal contamination, and particularly human adenovirus as an indicator of human feces. Wind also seems to contribute to low levels of fecal spread for bacteria. Residents of poorer urban neighborhoods where sanitation coverage is inadequate may be particularly at risk from transmission of fecal contamination from wind and flies. Low levels of sanitation coverage correlated with increased wind and fly-borne general fecal contamination, although this trend was not observed for the adenovirus marker of human fecal contamination. Within these urban neighborhoods, we found that microbial counts per hour were similar for locations that could serve as sources for contact with human feces (latrines and drains), and areas where people eat (markets, households).