Evaluation of Chemical Exposures at a Vape Shop

Leonard M. Zwack, ScD
Aleksandr B. Stefaniak, PhD, CIH
Ryan F. LeBouf, PhD, CIH

HHE Report No. 2015-0107-3279
July 2017

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Contents

The employer is required to post a copy of this report for 30 days at or near the workplace(s) of affected employees. The employer must take steps to ensure that the posted report is not altered, defaced, or covered by other material.

The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from the owner of a vape shop. The employer was concerned about employees' potential exposure to vaping chemicals in the shop.

What We Did

- We evaluated the vape shop in January 2016.
- We collected air samples for flavoring chemicals (diacetyl, 2,3-pentanedione, 2,3-hexanedione, acetaldehyde, and acetoin), nicotine, formaldehyde, and propylene glycol.
- We took wipe samples for nicotine and metals on commonly touched surfaces.

We evaluated concerns about exposure to vaping-related chemicals in a vape shop. Exposure to flavoring chemicals (diacetyl, 2,3-pentanedione, acetaldehyde), formaldehyde, nicotine, and propylene glycol were all below occupational exposure limits. We found that not all employees wore chemical protective gloves when handling liquids containing nicotine. We saw chemicals being stored in a refrigerator used for food.

What We Found

- Employees vaped at work.
- Concentrations of vaping-related chemicals in our air samples were below occupational exposure limits.
- Not all employees wore chemical protective gloves when they were working with liquids that contained nicotine.
- The bottle of stock nicotine solution was stored in the same refrigerator used to store employees' food.

What the Employer Can Do

- Implement a policy prohibiting vaping in the shop with e-liquids that contain diacetyl and 2,3-pentanedione. These chemicals are often found in dairy flavorings, brown flavorings such as butterscotch and caramel, and some fruit flavorings.
- Do not store chemicals such as nicotine in the same area where food is stored or eaten.
- Provide disposable funnels to prevent liquid nicotine from spilling during transfer between containers.
- Inspect and maintain the shop's exhaust ventilation systems.

What Employees Can Do

- Wear nitrile gloves whenever handling liquids that contain nicotine.

- Wear nitrile gloves, a long-sleeve laboratory coat, and goggles when handling the stock nicotine solution.

Abbreviations

µg/100 cm^2	Micrograms per 100 squared centimeters
µg/m^3	Micrograms per cubic meter
ACGIH®	American Conference of Governmental Industrial Hygienists
cc/min	Cubic centimeters per minute
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
mL	Milliliter
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppb	Parts per billion
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
VOC	Volatile organic compound

This page left intentionally blank

Introduction

The Health Hazard Evaluation Program received a request from the manager of a vape shop. We were asked to evaluate employees' exposures to chemicals associated with vaping in the shop. We visited the shop in January 2016. During our visit we met with employer and employee representatives and measured employees' exposures to vaping-related chemicals.

Background

Vaping is the process in which liquid is heated by an atomizer housed in an electronic nicotine delivery system or "e-cigarette." The liquid becomes an aerosol of liquid droplets in air (commonly referred to as vapor) that is inhaled by the user. The liquid (known as e-liquid or e-juice) is typically comprised of propylene glycol, vegetable glycerin, nicotine, and flavoring chemicals. Chemicals that have been associated with vaping include flavorings, nicotine, glycols, glycerin, other volatile organic compounds (VOCs), metals, and ultrafine particles composed of these chemicals, among others [AIHA 2014]. Diacetyl and its substitute, 2,3-pentanedione, are widely used flavoring chemicals. Serious respiratory disease and decreased lung function have been reported in employees exposed to diacetyl [NIOSH 2016]. Other flavoring chemicals that can be used in e-liquid such as acetaldehyde and acetoin can also have adverse respiratory health effects [NIOSH 2016]. Recently, a laboratory study has shown that diacetyl and 2,3-pentanedione are present in the heated vapor produced by e-cigarettes [Allen et al. 2016]. Other studies have directly measured exposures to vaping-related chemicals in well-characterized rooms and chambers, though they often did not sample for flavoring chemicals [Czogala et al. 2014; Maloney et al. 2016; Schober et al. 2014; Schripp et al. 2013].

The vape shop began operating at its current location in 2014. They sell e-cigarettes as well as the e-liquids that are used in the e-cigarettes. The employer estimated that the facility was approximately 1,000 square feet, with about 800 square feet devoted to retail and lounge space. The lounge area was a place for customers to congregate and vape. At the time of our visit, the company had 10 employees, including the owners who also worked in the shop. The shop was open from 11 a.m. to 8 p.m. Monday through Thursday. On Friday and Saturday, the shop was open from 11 a.m. to 9 p.m. On Sunday, the shop was open from 12 p.m. to 5 p.m. Shift lengths were variable, with employees working 3 to 10 hours, depending upon the day. Generally two employees worked in the shop at any one time.

This vape shop purchased pre-mixed e-liquids from a supplier and resold them to customers. They also hand mixed custom e-liquid blends according to the customer's taste, nicotine, propylene glycol, and vegetable glycerin preferences. Hand mixing of chemicals potentially exposes employees to concentrated levels of liquid nicotine. All employees generally performed the same tasks each day. The primary task was hand mixing of e-liquids for customers at a location referred to as the juice bar (Figure 1). Employees used syringes to transfer the flavoring chemicals into 10-milliliter (mL) and 30-mL bottles that the customers purchased. The syringes used for the flavoring chemicals, propylene glycol, and vegetable glycerin were washed each night and disposed of weekly. The syringes used for transferring nicotine were reportedly disposed of nightly.

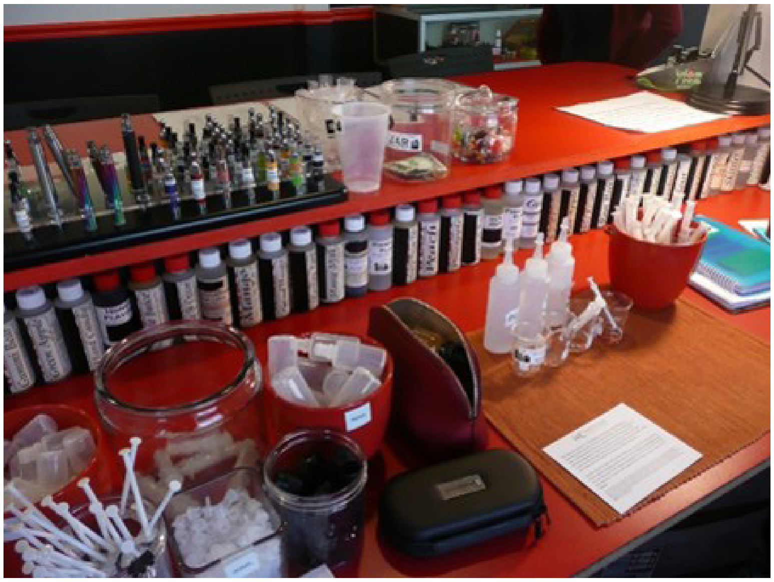

Figure 1. Photo of juice bar mixing station.

The shop employees and manager reported that the flavoring chemicals make up approximately 20% of the e-liquid. The remaining 80% is propylene glycol, vegetable glycerin, and nicotine. The vegetable glycerin to propylene glycol ratio can be specified by the customer, and it was reported that customers typically use more vegetable glycerin than propylene glycol. The amount of nicotine added was based upon the amount a customer requested. If customers did not know how much nicotine they wanted, the employees discussed the customer's previous cigarette or cigar smoking history and made a recommendation based upon how much they typically smoked. The shop's stock nicotine solution is 100 milligrams per milliliter. The stock solution is diluted to shop-defined concentrations that correspond to smoking from one half of a pack up to 2.5 packs of tobacco cigarettes. This nicotine level can be adjusted according to customers' preferences.

Methods

Our primary objective was to evaluate employees' potential exposures to chemicals associated with vaping in the shop. Our work involved (1) sampling air for specific flavoring chemicals associated with respiratory disease; (2) sampling air for nicotine, propylene glycol, formaldehyde, and other VOCs; (3) sampling work surfaces for metals and nicotine; and (4) observing work practices.

Air Sampling for Vaping-related Chemicals

We collected personal air samples for specific flavoring chemicals on three employees during their full work shift on day 1, and on four employees on day 2. We also collected full-shift personal air samples for formaldehyde on two employees on day 1 and on three employees on day 2. We selected two locations in the shop to sample general room air (referred to as "area" air samples). One set of area air samples was collected directly behind the juice bar (Figure 2). The other was taken in the front of the shop, near the lounge area (Figure 3). Area samples behind the juice bar were collected for nicotine, propylene glycol, flavoring chemicals, and formaldehyde. Lounge area samples were collected for nicotine, flavoring chemicals, and formaldehyde.

Figure 2. A National Institute for Occupational Safety and Health (NIOSH) investigator preparing to collect an air sample. An area sampling station is next to the window behind juice bar. Photo by NIOSH.

Figure 3. Area sampling basket in the front lounge area. Photo by NIOSH.

Flavoring Chemicals

We measured flavoring chemicals using two air sampling methods, evacuated canisters and silica gel tubes. Using evacuated canisters, we collected personal and area air samples for diacetyl, 2,3-pentanedione, 2,3-hexanedione, and acetaldehyde. The evacuated canister sampling setup consisted of a 450-mL evacuated canister equipped with a restricted flow controller set to collect a 9-hour air sample.

The canister air samples were analyzed using a preconcentrator/gas chromatograph/mass spectrometer system according to a published method validation study [LeBouf et al. 2012] with the following modifications: the preconcentrator was an Entech Instruments Model 7200 and four additional chemicals, acetaldehyde, diacetyl, 2,3-pentanedione, and 2,3-hexanedione, were included in the analysis. The limit of detection of the sampling and analytical method is the lowest mass that can be currently measured. The limit of quantitation is the lowest mass that can be reported with acceptable precision. The analytical limits of detection were as follows: acetaldehyde, 0.3 parts per billion (ppb); diacetyl, 0.3 ppb; 2,3-pentanedione, 0.4 ppb; 2,3-hexanedione, 0.6 ppb. The limits of quantitation were as follows: acetaldehyde, 0.89 ppb; diacetyl, 0.86 ppb; 2,3-pentanedione, 1.2 ppb; 2,3-hexanedione, 2.1 ppb. These detection and quantitation limits were multiplied by the individual sample pressure dilution factors to obtain the minimum detectable and quantifiable concentrations displayed in the results table footnotes.

We collected full-shift area air samples for acetoin, diacetyl, 2,3-pentanedione, and 2,3-hexanedione using sets of two silica gel sorbent tubes in series with pumps calibrated to a flow rate of 50 cubic centimeters per minute (cc/min), at both area sampling locations over 2 days. These samples were analyzed for flavoring chemicals in accordance with Occupational Safety and Health Administration (OSHA) Method 1013 [OSHA 2008] and OSHA Method 1016 [OSHA 2010a]; however, an alternate detector (mass spectrometer) was used to increase method sensitivity [LeBouf and Simmons 2016]. The analytical limits of detection were as follows: acetoin, 0.04 micrograms per sample (µg/sample); diacetyl, 0.03 µg/sample; 2,3-pentanedione, 0.03 µg/sample; and 2,3-hexanedione, 0.04 µg/sample. The limits of quantitation were as follows: acetoin, 0.14 µg/sample; diacetyl, 0.088 µg/sample; 2,3-pentanedione, 0.094 µg/sample; and 2,3-hexanedione, 0.13 µg/sample.

Formaldehyde in Air

We collected full-shift personal and area air samples for formaldehyde using SKC UMEx 100 passive badges. The air samples were collected and analyzed in accordance with OSHA Method 1007 [OSHA 2005].

Nicotine in Air

We collected area air samples for nicotine using XAD-4 tubes with pumps calibrated to a flow rate of 200 cc/min. The air samples were analyzed in accordance with NIOSH Method 2551 [NIOSH 2017].

Propylene Glycol in Air

Area air samples for propylene glycol were collected and analyzed in accordance with NIOSH Method 5523 [NIOSH 2017].

Volatile Organic Compounds in Air

VOCs in the air were measured by two methods. First, we collected area air samples to qualitatively screen for VOCs using thermal desorption tubes with pumps calibrated to 50 cc/min. The samples were collected for up to approximately 3 hours as VOC concentrations were assumed to be low. The air samples were analyzed according to NIOSH Method 2549 [NIOSH 2017]. We collected these samples at the area sampling location behind the juice bar.

We collected short-term task-based samples using evacuated 1-liter canisters that were analyzed via Environmental Protection Agency (EPA) method TO-15 for VOCs [EPA 1999]. For these task-based air samples, we placed the inlet of the flow controller as close as possible to the employees (within approximately 3 feet) as they performed their work task. The flow controller was designed to fill the canister over a 15-minute period. In this method, each canister was analyzed for 65 target compounds. Additional compounds were tentatively identified using the Wiley Registry 9th edition/National Institute of Standards and Technology 2008 mass spectral library (John Wiley and Sons, Hoboken, NJ).

Surface Sampling for Elements and Nicotine

We collected wipe samples for elements (minerals and metals) from several surfaces in the vape shop that employees commonly touched during their work. These samples were collected using premoistened Palintest® Dust Wipes following NIOSH Method 9102 [NIOSH 2017]. We used a disposable template to collect each wipe sample over an area of 100 square centimeters. The wipe samples were analyzed according to NIOSH Method 7303 [NIOSH 2017].

We collected surface wipe samples for nicotine using sterile cotton swabs (ITW Texwipe Model STX705W) that were field desorbed in 1 mL of ethyl acetate. Most samples were collected using a disposable template, covering an area of 100 square centimeters. Some samples required a smaller template of 25.8 square centimeters. The wipe samples were analyzed according to NIOSH Method 2551, which was modified to incorporate the use of cotton swabs [NIOSH 2017].

Results

Workplace Observations

Employees and customers vaped inside the shop. During our site visit, we observed no haziness or lingering vapor clouds in the shop. However, employees reported that it could get "cloudy" or hazy inside the shop when many people were vaping simultaneously. On the days of our visit, we observed that most of the vaping inside the shop was from the employees vaping while working. Customers would sometimes vape while sampling flavors at the juice bar, but this practice was infrequent. When customers did sample flavors, they stood directly across from employees working at the juice bar. Customers could use the company's e-cigarette and tank along with a disposable safety tip to try different e-liquid flavors (Figure 4). The disposable safety tip was not reused between customers. The employer reported that each night employees cleaned the individual e-cigarettes with Lysol® wipes, as customers sometimes neglected to use the safety tips.

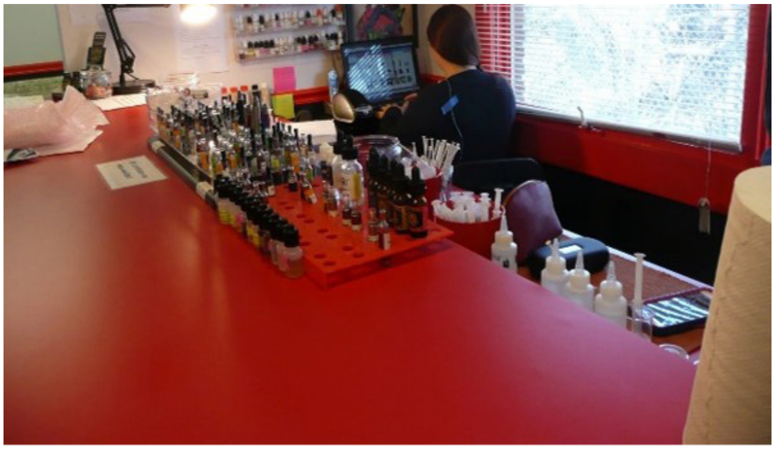

Figure 4. Assortment of e-liquid tanks and e-cigarettes customers used to sample different flavors at the juice bar. Photo by NIOSH.

Ventilation in the shop was provided by an air handling unit in the attic that delivered ducted supply air to the entire shop. Supply vents were located in the ceiling. Employees had blocked airflow from several of the vents because they felt that airflow was excessive. The shop had an exhaust vent fan in the ceiling above the juice bar. Employees turned on the exhaust fan at the beginning of the workday and turned it off at the end of the workday. The employer reported that the exhaust fan was vented into the attic.

Employees reported that they cleaned floors, counters, displays, and the juice bar each night with cleaning agents including Windex®, Simple Green®, Mop & Glo®, and bleach. The windows were cleaned weekly using Windex. The floors were swept nightly and were mopped with bleach four times per week. While we were at the shop, we observed employees cleaning the juice bar multiple times throughout the day.

On our first day at the shop, 18 customers entered the shop over the course of the day. Of these 18 customers, 12 did not vape inside the shop. On our second day of sampling, we noted nine customers entering the shop, two of whom vaped in the shop. On both days, all employees vaped throughout the day.

We observed that the stock (100 milligrams per milliliter) nicotine solution was stored in a refrigerator also used for food storage (Figure 5).

Figure 5. Stock nicotine solution stored in the bottom of a refrigerator that was also used to store food. Photo by NIOSH.

Personal Protective Equipment

Employees were provided with nitrile gloves for use when mixing e-liquids and when working with chemicals. We observed that not all employees wore gloves during these tasks. When wearing gloves, employees generally used a new pair for each bottle of e-liquid they were mixing, and did not reuse gloves between juice-making tasks. We observed only one employee transferring nicotine from the stock bottle to smaller transfer bottles. This employee wore new gloves when transferring nicotine.

Air Sampling Results

Flavoring Chemicals

Table 1 presents the results for personal air monitoring for flavoring chemicals using evacuated canisters. None of the personal air samples for the flavoring chemicals were above any 8-hour time-weighted average (TWA) occupational exposure limit (OEL). The lowest OEL for these chemicals was the NIOSH recommended exposure limit (REL) of 5 ppb for diacetyl, and 9.3 ppb for 2,3-pentanedione. Appendix A describes these and other OELs in more detail.

Table 1. Personal air sampling results for flavoring chemicals (ppb)*

Job title	Day	Sample duration (minutes)†	Acetaldehyde	Diacetyl	2,3-Pentanedione	2,3-Hexanedione
Employee 1	Day 1	514	5.9	[0.8]	[1.4]	ND
Employee 1	Day 2	180	26	ND	ND	ND
Employee 2	Day 1	345	6.7	[1.1]	ND	ND
Employee 2	Day 2	335	ND	ND	ND	ND
Employee 3	Day 1	180	9.9	ND	ND	ND
Employee 3	Day 2	165	28	ND	ND	ND
Employee 4	Day 2	337	ND	[1.7]	2.4	2.5
ACGIH TLV			25,000 (ceiling)	10	—	—
NIOSH REL			—	5.0	9.3	—
OSHA PEL			200,000	—	—	—

ACGIH TLV = American Conference of Governmental Industrial Hygienists threshold limit value

OSHA PEL = OSHA permissible exposure limit

ND = Not detected

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration was 1 ppb for acetaldehyde and 1 ppb for diacetyl. It ranged from 1–2 ppb for 2,3-pentanedione and from 2–4 ppb for 2,3-hexanedione. The minimum quantifiable concentration ranged from 2.8–4.7 ppb for diacetyl and from 3.7–6.6 ppb for 2,3-pentanedione.

†Employee shift lengths varied. For each employee sampled, we sampled for their entire shift.

We also measured flavoring chemicals in general room air using evacuated canisters at the juice bar. These results, presented in Table 2, show very low or non-detectable concentrations.

Table 2. Area air sample concentrations (ppb) of flavoring chemicals using canister sampling*

Location	Day	Sample duration (minutes)	Acetaldehyde	Diacetyl	2,3-Pentanedione	2,3-Hexanedione
Juice bar – morning	Day 1	218	4.6	[2.3]	3.3	[3.1]
Juice bar – afternoon	Day 1	239	ND	[1.0]	ND	ND
Juice bar – morning	Day 2	223	ND	ND	ND	ND
Juice bar – afternoon	Day 2	232	17.3	ND	ND	ND

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration was 1 ppb for acetaldehyde, diacetyl, and 2,3-pentanedione, and ranged from 2–3 ppb for 2,3-hexanedione. The minimum quantifiable concentration ranged from 3.4–3.7 ppb for diacetyl, and from 7.9–8.6 ppb for 2,3-hexanedione.

The results for the area air samples taken over the entire work day in the juice bar and lounge areas using silica gel tubes are presented in Table 3. Diacetyl, 2,3-pentanedione, 2,3-hexanedione, and acetoin were not detected in the lounge area. For the full-shift area air samples taken behind the juice bar using silica gel tubes, we found detectable, but not quantifiable, concentrations of 2,3-pentanedione on day 1. We did not find detectable concentrations of any of the other flavoring chemicals in the other juice bar samples.

Table 3. Area air sample concentrations (ppb) of flavoring chemicals using silica gel tubes*

Location	Day	Sample duration (minutes)	Acetoin	Diacetyl	2,3-Pentanedione	2,3-Hexanedione
Juice bar	Day 1	464	ND	ND	[0.73]	ND
Juice bar	Day 2	509	ND	ND	ND	ND
Lounge area	Day 1	434	ND	ND	ND	ND
Lounge area	Day 2	498	ND	ND	ND	ND

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration was 1 ppb for acetoin. It ranged from 0.6–0.9 ppb for diacetyl, from 0.6–0.8 ppb for 2,3-pentanedione, and from 0.8–1 ppb for 2,3-hexanedione. The minimum quantifiable concentration ranged from 2.0–2.8 ppb for 2,3-pentanedione.

Formaldehyde in Air

Table 4 presents the personal air sampling results for formaldehyde. None of the employees we monitored had exposures to formaldehyde above OELs.

Table 4. Personal air sample results (ppb) for formaldehyde*

Job title	Day	Sample duration (minutes)†	Formaldehyde
Employee 1	Day 1	471	3.8
Employee 1	Day 2	172	[4.3]
Employee 2	Day 1	292	ND
Employee 2	Day 2	317	7.0
Employee 4	Day 2	319	7.0
NIOSH REL			16
OSHA PEL			750

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum quantifiable concentration ranged from 3–8 ppb for formaldehyde.

†Employee shift lengths varied. For each employee sampled, we sampled for their entire shift.

Table 5 presents the area air sample results for formaldehyde. Concentrations of formaldehyde in the air in the juice bar and the lounge area were very low and similar to those found in the personal air samples.

Table 5. Area air sample results for formaldehyde (ppb)

Location	Day	Sample duration (minutes)	Formaldehyde
Juice bar	Day 1	470	4.3
Juice bar	Day 2	467	6.0
Lounge area	Day 2	466	5.4

Nicotine in Air

Table 6 presents the results for the nicotine area air samples. Nicotine was not detected in the air in the lounge area. At the juice bar, airborne nicotine concentrations were detectable, but below the minimum quantifiable concentration.

Table 6. Area air sample results for nicotine (micrograms per cubic meter [μg/m^3])

Location	Day	Sample duration (minutes)	Nicotine*
Juice bar	Day 1	344	[0.69]
Juice bar	Day 2	494	[0.80]
Lounge area	Day 1	435	ND
Lounge area	Day 2	478	ND

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration ranged from 0.3–0.4 μg/m^3, while the minimum quantifiable concentration ranged from 0.97–1.4 μg/m^3.

Propylene Glycol in Air

Table 7 presents the results for the propylene glycol area air samples. Concentrations of propylene glycol in the air at the juice bar were low.

Table 7. Area air sample results for propylene glycol (μg/m^3)

Location	Day	Sample duration (minutes)	Propylene glycol
Juice bar	Day 1	445	426
Juice bar	Day 2	488	389

Volatile Organic Compounds in Air

Laboratory analysis of the samples we collected inside the vape shop using thermal desorption tubes indicated the presence of 102 chemicals. Many of the chemicals could be from sources other than vaping such as cleaning products or personal care products. The primary chemicals identified included isopropanol, limonene, and decamethylcyclcopentasiloxane. Other chemicals detected at lower relative concentrations included acetone, ethanol, propylene glycol, toluene, and glycerin. Trace amounts of a variety of flavoring chemicals, including diacetyl, were identified.

Table 8 presents the results for the 15-minute, task-based evacuated canister sampling and lists the compounds that were quantified using EPA Method TO-15. Although these were area samples, we positioned the sample media as close as possible to the employees (within approximately 3 feet), and we consider these results to be representative of employees' potential exposures. Employees' exposures to all of the compounds quantified were well below OELs. In addition to the VOCs quantified in the table, 30 other chemicals were tentatively identified in the canister air samples.

Table 8. Task-based (15 min) area air sample concentrations (ppb) for VOCs using evacuated canisters

Task	Acetone	Benzene*	Ethyl acetate	Ethyl benzene*	Isopropyl alcohol	m & p xylene	o-xylene*	Toluene
Employee making e-juice and vaping	16	ND	3.4	ND	970	2.7	ND	5.4
Employee making e-juice and vaping	19	1.2	3.1	ND	1,400	3.3	1	6.6
Employees cleaning at end of day	17	1	32	0.96	1,400	4.1	1.3	7.4
ACGIH TLV-STEL	NA	2,500	NA	NA	400,000	150,000	150,000	NA
NIOSH REL-STEL	NA	1,000	NA	125,000	500,000	150,000	150,000	150,000
OSHA PEL-STEL	NA	5,000	NA	NA	NA	100,000	100,000	NA

STEL = Short-term exposure limit

*The minimum detectable concentration for benzene, ethylbenzene, and o-xylene was 1 ppb.

Elements on Surfaces

Surface wipe samples for elements (minerals and metals) were taken throughout the vape shop. This included surfaces that employees or customers touched and included both sides of the juice bar counter, display cases, and areas near the cash register. Quantifiable concentrations of calcium (15–94 micrograms per 100 squared centimeters [µg/100 cm^2]), copper (ND–0.49 µg/100 cm^2), iron (ND–1.8 µg/100 cm^2), and potassium (ND–17 µg/100 cm^2) were identified in the wipe samples. Detectable, but not quantifiable, concentrations of chromium, lead, magnesium, nickel, phosphorus, strontium, and tellurium were also identified in some samples.

Nicotine on Surfaces

Surface wipe samples for nicotine were taken throughout the vape shop in locations similar to where the metal wipes were taken. We also wiped the bottle containing the stock nicotine solution, as well as a transfer bottle that is kept at the juice bar. None of the surfaces sampled had detectable concentrations, with the exception of the nicotine transfer bottle. There are no OELs for dermal exposure to nicotine.

Discussion

None of the airborne concentrations of the specific flavoring chemicals we measured were above applicable OELs although we detected low levels of two flavoring chemicals, diacetyl and 2,3-pentanedione, in the personal and area air samples. NIOSH has an action level for diacetyl of 2.6 ppb [NIOSH 2016] but our sampling method (evacuated canisters) does not measure exposures at this level. Therefore, some of the personal air sampling results for diacetyl could have been above the NIOSH action level. When diacetyl exposures are above the action level, NIOSH recommends that employers develop a medical surveillance program and implement engineering and work practice controls to keep exposures below the REL [NIOSH 2016].

Formaldehyde is a breakdown product of propylene glycol, which is present in the e-liquids used in e-cigarettes. Personal air sampling results for formaldehyde were well below the OSHA PEL and OSHA action level. They were also below the NIOSH REL, which is much lower than the OSHA PEL. Area sampling results showed that background formaldehyde concentrations were similar to the personal sampling results. Low concentrations of formaldehyde exist in many indoor environments because of off gassing from furnishings, clothing, and other materials.

In addition to the specific flavoring chemicals we looked for in the air samples (diacetyl, 2,3-pentanedione, 2,3-hexanedione, acetoin, and acetaldehyde), we also identified other flavoring chemicals and VOCs in the air of the vape shop. Results from the area air samples we collected using thermal desorption tubes showed very low concentrations of 102 chemicals. These included chemicals found in cleaning products used in the shop (limonene, isopropanol), chemicals that are common ingredients in personal care products (decamethylcyclopentasiloxane), and other chemicals that could be classified as flavoring chemicals. Background concentrations of airborne nicotine, propylene glycol, and VOCs in the air of the shop were also very low.

Over the 2 days of our evaluation, we observed that very few customers vaped inside the shop. In contrast, we found that employees vaped throughout the day. Therefore, most of an employee's exposure to vaping-related chemicals inside this vape shop was due to direct inhalation of vaping-related chemicals from their personal e-cigarette, as well as secondhand emissions from coworkers' e-cigarettes. Our air sampling only measured vaping chemicals present in the air from the emissions of e-cigarettes and exhaled breath. We did not measure chemical concentrations directly inhaled from an employee's own e-cigarette. However, the concentrations of vaping chemicals directly inhaled during vaping would likely be higher than the concentrations from second-hand emissions. Although our air sampling results showed very low exposures to vaping chemicals, exposure would have been even lower if employees had not been vaping in the shop.

We detected the presence of metals, such as chromium, lead, copper, and nickel on surfaces in the shop. This finding was not surprising given that these metals have also been measured by other researchers in e-liquids (chromium, lead, and nickel) and in vapor from e-cigarettes (chromium, nickel, and copper) [Hess et al. 2017; Williams et al. 2013]. Some of the other elements that we detected on surfaces are found in human sweat (calcium, potassium, magnesium, and phosphorous). It is unknown if their presence on surfaces was from e-cigarettes, people touching surfaces, or both.

We found detectable levels of nicotine on the outside surface of a nicotine transfer bottle. This may have occurred because employees did not use a funnel when transferring liquid nicotine. We did not find nicotine on other surfaces that we sampled. It is important to use good chemical handling procedures whenever working with the stock nicotine solution. Exposure to nicotine can occur by inhalation, skin absorption, and ingestion. Nicotine is a potent and potentially lethal toxin that is quickly absorbed from all routes of entry, including the skin or eyes [Brandon et al. 2015]. If nicotine gets on the skin, employees should immediately wash the affected area with soap and water. Research has shown that it only takes 3 to 5 minutes for nicotine to be absorbed through the skin [Zorin et al. 1999]; after that length of time, nicotine cannot be washed off and remains in the skin where it continues to be absorbed into the body.

Few standards define "acceptable" levels of workplace surface contamination. Wipe samples, however, can provide information regarding the effectiveness of housekeeping practices, the potential for exposure to contaminants by skin absorption or ingestion (e.g., surface contamination on the juice bar counter that is also used for food consumption), the potential for contamination of employee clothing and subsequent transport of the contaminant outside the workplace, and the potential for other activities (e.g., sweeping) to generate airborne contaminants. Overall, we found very low levels of some surface contaminants during our evaluation. We attribute these low levels to the effectiveness of the cleaning practices we observed, with employees wiping down commonly touched surfaces multiple times throughout the day.

The health effects associated with vaping are not well understood. According to the U.S. Surgeon General's report on e-cigarette use among youth and young adults, e-cigarette aerosol is not harmless as it contains nicotine, flavorings, other additives, and ultrafine particles [DHHS 2016]. The United States Food and Drug Administration has warned consumers about potential health risks associated with e-cigarettes and has finalized a rule extending their regulatory authority to cover electronic cigarettes [FDA 2013, 2016]. Flavoring chemicals such as diacetyl and 2,3-pentanedione have been associated with serious respiratory disease [NIOSH 2016]. One way to reduce exposure to these chemicals is to not use products containing them. Studies have shown that even flavors that are reported as being free of diacetyl may still contain it [Allen et al. 2016; Rutledge 2015]. The health risks of flavoring chemicals that may be used as substitutes for diacetyl and 2,3-pentanedione may not be known, and precautionary measures such as engineering controls are recommended to protect employees exposed to these substitutes [NIOSH 2016; OSHA 2010b].

This evaluation had limitations that could influence the generalizability of our findings. First, sampling occurred over 2 days in the winter of 2016, and our measurement results may not be representative of all other times or seasons. Over these 2 days, we did not observe a large number of customers vaping. The lounge area was not used during this time, and very few customers were present at the shop on the second day of sampling. If more customers were present and vaping inside of the shop, concentrations of vaping-related chemicals in the air may have been greater. Moreover, we do not know the chemical composition of the e-liquids employees and customers vaped over the course of our evaluation. The low air concentrations of flavoring chemicals that we measured may be due to the fact that the e-liquids used during our evaluation happened to contain very little of the specific flavoring compounds we measured.

Conclusions

Employees were exposed to detectable levels of diacetyl and 2,3-pentanedione in the air while working in the vape shop. Although the measured concentrations were below all applicable OELs, to better protect the health of employees we recommend that the employer implement a policy prohibiting vaping in the work place with e-liquids that contain diacetyl and 2,3-pentanedione. The concentration of other vaping-related chemicals that we measured were also below their relevant OELs. Employees should be trained on proper chemical handling procedures and the need for consistent use of chemical protective nitrile gloves when handling liquids containing nicotine.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the vape shop to use an employee-employer health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the vape shop.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix A). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Implement a policy prohibiting vaping in the shop with e-liquids that contain diacetyl and 2,3-pentanedione.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Do not store nicotine in the same refrigerator where food is stored, as this could lead to accidental ingestion of the nicotine solution or contamination of food with nicotine. Purchase a separate refrigerator to store nicotine. Clearly label the separate refrigerators with labels such as "Food use only" or "Nicotine storage only."
2. Use a disposable funnel to help prevent nicotine from spilling during the pouring of the stock nicotine solution into the transfer bottles.

3. Transfer nicotine from the stock solution to the transfer bottles in an area away from customers. Do this task in an area where a spill could be easily contained and cleaned up, and that has adequate ventilation.
4. Vent exhaust from the exhaust fan above the juice bar directly outdoors. Regularly inspect and maintain the exhaust fan above the juice bar and the air handling unit in the attic to ensure that they are working properly.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Instruct employees who get nicotine on their skin to wash the affected area immediately with soap and water. Nicotine is absorbed through the skin in only 3 to 5 minutes; after that the nicotine cannot be washed off.
2. Ensure that employees understand the potential hazards in the vaping industry (such as flavorings, nicotine, and formaldehyde) and how to protect themselves. OSHA's hazard communication standard [29 CFR 1910.1200] requires that employees are informed and trained of potential work hazards and associated safe practices, procedures, and protective measures.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Train employees and require them to wear chemical protective gloves made out of nitrile whenever working with nicotine. Because nicotine can break through the glove material in as little as 6 to 9 minutes, develop and enforce a policy against employees reusing gloves and requiring a clean pair of gloves each time employees start a new task involving nicotine.
2. Provide long-sleeved lab coats and goggles and instruct employees on their use to prevent contact with the eyes, skin, or clothing when handling the stock nicotine solution, such as when transferring from the stock solution container to another container.

Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States is the ACGIH TLVs. The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2017].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German

Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

Hierarchy of Controls

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Diacetyl and 2,3-pentanedione

Diacetyl (2,3-butanedione) and 2,3-pentanedione, a diacetyl substitute, are VOCs with an intense buttery flavor. Exposure to diacetyl is associated with an increased risk for severe lung disease and lung function decline [NIOSH 2016]. Irreversible lung disease, such as obliterative bronchiolitis, has been reported in employees in industries with diacetyl exposures [Kreiss 2007; van Rooy et al. 2007]. Severe airway damage and disease has also been observed in laboratory animals after exposure to diacetyl or 2,3-pentanedione [Hubbs et al. 2008; Morgan et al. 2012]. Because of the potential health effects associated with diacetyl and 2,3-pentanedione exposure, NIOSH has a REL and 15-minute STEL for both of these flavoring chemicals. The NIOSH REL is 5 ppb for diacetyl with a STEL of 25 ppb. NIOSH also has an action level of 2.6 ppb for diacetyl. The REL for 2,3-pentanedione is 9.3 ppb, and the STEL is 31 ppb [NIOSH 2016]. The higher REL and STEL for 2,3-pentanedione does not imply that 2,3-pentanedione is of lower toxicity than diacetyl. Rather, the REL and STEL for 2,3-pentanedione are based upon the lowest level at which the substance reliably can be detected using the existing validated analytical method [NIOSH 2016].

References

ACGIH [2016]. 2016 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2014]. White paper: electronic cigarettes in the indoor environment. Falls Church, VA: American Industrial Hygiene Association.

AIHA [2016]. AIHA 2016 emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

Allen JG, Flanigan SS, LeBlanc M, Vallarino J, MacNaughton P, Stewart JH, Christiani DC [2016]. Flavoring chemicals in e-cigarettes: diacetyl, 2,3-pentanedione, and acetoin in a sample of 51 products, including fruit-, candy-, and cocktail-flavored e-cigarettes. Environ Health Perspect *124*(6):733–739, http://dx.doi.org/10.1289/ehp.1510185.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Brandon TH, Goniewicz ML, Hanna NH, Hatsukami DK, Herbst RS, Hobin JA, Ostroff JS, Shields PG, Toll, BA, Tyne CA, Viswanath K, Warren GW [2015]. Electronic nicotine delivery systems: a policy statement from the American Association for Cancer Research and the American Society of Clinical Oncology. Clin Cancer Res *21*(3):514–525, http://dx.doi.org/10.1158/1078-0432.CCR-14-2544.

Czogala J, Goniewicz ML, Fidelus B, Zielinska-Danch W, Travers MJ, Sobczak A [2014]. Secondhand exposure to vapors from electronic cigarettes. Nicotine Tob Res *16*(6):655–662, http://dx.doi.org/10.1093/ntr/ntt203.

DHHS [2016]. E-cigarette use among youth and young adults: a report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, https://e-cigarettes.surgeongeneral.gov/documents/2016_SGR_Full_Report_508.pdf.

EPA [1999]. Compendium Method TO-15, Determination of volatile organic compounds (VOCs) in air collected in specially-prepared canisters and analyzed by gas chromatography/mass spectrometry (GC/MS). In: Compendium of methods for the determination of toxic organic compounds in ambient air. Cincinnati, OH: Center for Environmental Research Information, Office of Research and Development, U.S. Environmental Protection Agency Publication No. EPA/625/R-96/010b, https://www3.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf.

FDA [2013]. FDA warns of health risks posed by e-cigarettes, https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm173401.htm.

FDA [2016]. Vaporizers, e-cigarettes, and other electronic nicotine delivery systems (ENDS), https://www.fda.gov/TobaccoProducts/Labeling/ProductsIngredientsComponents/ucm456610.htm.

Hess CA, Olmedo P, Navas Acien A, Goessler W, Cohen JE, Rule AM [2017]. E-cigarettes as a source of toxic and potentially carcinogenic metals. Environ Res *152*:221–225, http://dx.doi.org/10.1016/j.envres.2016.09.026.

Hubbs AF, Goldsmith WT, Kashon ML, Frazer D, Mercer RR, Bateeilli LA, Kullman GJ, Schwegler-Berry D, Friend S, Castranova V [2008]. Respiratory toxicologic pathology of inhaled diacetyl in Sprague-Dawley rats. Toxicol Pathol *36*(2):330–344, https://dx.doi.org/10.1177/0192623307312694.

Kreiss K [2007]. Flavoring-related bronchiolitis obliterans. Curr Opin Allergy Clin Immunol *7*(2):162–167, https://dx.doi.org/10.1097/ACI.0b013e3280298235.

Lebouf RF, Stefaniak AB, Virji MA [2012]. Validation of evacuated canisters for sampling volatile organic compounds in healthcare settings. J Environ Monit *14*(3):977–983, http://dx.doi.org/10.1039/c2em10896h.

LeBouf RF, Simmons M [2016]. Validation of evacuated canisters for sampling volatile organic compounds in healthcare settings. J Occup Environ Hyg (in press). http://dx.doi.org/10.1080/15459624.2016.1252846.

Maloney JC, Thompson MK, Oldham MJ, Stiff CL, Lilly PD, Patskan GJ, Shafer KH, Sarkar MA [2016]. Insights from two industrial hygiene pilot e-cigarette passive vaping studies. J Occup Environ Hyg *13*(4):275–283, http://dx.doi.org/10.1080/15459624.2015.1116693.

Morgan DL, Jokinen MP, Price HC, Gwinn WM, Palmer SM, Flake GP [2012]. Bronchial and bronchiolar fibrosis in rats exposed to 2,3-pentanedione vapors: implications for bronchiolitis obliterans in humans. Toxicol Pathol *40*(3):448–465, https://dx.doi.org/10.1177/0192623311431946.

NIOSH [2010]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2010-168c, http://www.cdc.gov/niosh/npg/.

NIOSH [2016]. Criteria for a recommended standard: occupational exposure to diacetyl and 2,3-pentanedione. Cincinnati, OH: U.S. Department of Health and Human Resources, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2016-111, https://www.cdc.gov/niosh/docs/2016-111/pdfs/2016-111-all.pdf.

NIOSH [2017]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, http://www.cdc.gov/niosh/nmam.

OSHA [2005]. Sampling and analytical methods: Method 1007 – formaldehyde, https://www.osha.gov/dts/sltc/methods/mdt/mdt1007/1007.html.

OSHA [2008]. Sampling and analytical methods: Method 1013 – acetoin and diacetyl, http://www.osha.gov/dts/sltc/methods/validated/1013/1013.html.

OSHA [2010a]. Sampling and analytical methods: Method 1016 – 2,3-pentanedione, http://www.osha.gov/dts/sltc/methods/validated/1016/1016.html.

OSHA [2010b]. Occupational exposure to flavoring substances: health effects and hazard control, https://www.osha.gov/dts/shib/shib10142010.html.

Rutledge R [2015]. Gasping for action: lab tests reveal popular e-cigarette liquids contain harmful chemicals. Milwaukee Journal Sentinel, October 20, http://archive.jsonline.com/watchdog/watchdogreports/lab-tests-reveal-popular-e-cigarette-liquids-contain-harmful-chemicals-b99583582z1-334833961.html.

Schober W, Szendrei K, Matzen W, Osiander-Fuchs H, Heitmann D, Schettgen T, Jörres RA, Fromme H [2014]. Use of electronic cigarettes (e-cigarettes) impairs indoor air quality and increases FeNO levels of e-cigarette consumers. Int J Hyg Environ Health, *217*(6):628–637, http://dx.doi.org/10.1016/j.ijheh.2013.11.003.

Schripp T, Markewitz D, Uhde E, Salthammer T [2013]. Does e-cigarette consumption cause passive vaping? Indoor Air *23*(1):25–31, http://dx.doi.org/10.1111/j.1600-0668.2012.00792.x.

van Rooy FG, Rooyackers JM, Prokop M, Houba R, Smit LAM, Heederik D [2007]. Bronchiolitis obliterans symdrome in chemical employees producing diacetyl for food flavorings. Am J Respir Crit Care Med *176*(5):498–504, http://dx.doi.org/10.1164/rccm.200611-1620OC.

Williams M, Villarreal A, Bozhilov K, Lin S, Talbot P [2013]. Metal and silicate particles including nanoparticles are present in electronic cigarette cartomizer fluid and aerosol. PLOS ONE, *8*(3):1–11, http://dx.doi.org/10.1371/journal.pone.0057987.

Zorin S, Kuylenstierna F, Thulin H [1999]. In vitro test of nicotine's permeability through human skin. Risk evaluation and safety aspects. Ann Occup Hyg *43*(6):405–413, http://dx.doi.org/10.1093/annhyg/43.6.405.

Keywords: North American Industry Classification System 453991 (Tobacco Stores), New Jersey, Vaping, E-Cigarette, Diacetyl, 2,3-Pentanedione, 2,3-Hexanedione, Formaldehyde, Nicotine, Metals, Propylene Glycol, Acetaldehyde, Acetoin, VOCs, Vape Shop

The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 (29 U.S.C. § 669(a)(6)). The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations (42 CFR Part 85).

Disclaimer

The recommendations in this report are made on the basis of the findings at the workplace evaluated and may not be applicable to other workplaces.

Mention of any company or product in this report does not constitute endorsement by NIOSH.

Citations to Web sites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. NIOSH is not responsible for the content of these Web sites. All Web addresses referenced in this document were accessible as of the publication date.

Acknowledgments

Analytical Support: Jennifer Roberts, Bureau Veritas North America
Desktop Publisher: Shawna Watts
Editor: Ellen Galloway
Industrial Hygiene Field Assistance: Kathleen Attfield
Logistics: Donnie Booher, Kevin Moore

Availability of Report

Copies of this report have been sent to the employer and employees at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

Recommended citation for this report:
NIOSH [2017]. Evaluation of chemical exposures at a vape shop. By Zwack LM, Stefaniak AB, LeBouf RF. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2015-0107-3279, http://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0107-3279.pdf.

Delivering on the Nation's promise:
Safety and health at work for all people through research and prevention

To receive NIOSH documents or more information about occupational safety and health topics, please contact NIOSH:

Telephone: 1–800–CDC–INFO (1–800–232–4636)

TTY: 1–888–232–6348

CDC INFO: www.cdc.gov/info

or visit the NIOSH Web site at www.cdc.gov/niosh

For a monthly update on news at NIOSH, subscribe to NIOSH eNews by visiting www.cdc.gov/niosh/eNews.

SAFER • HEALTHIER • PEOPLE™