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EFFECTS OF OXIDIZING METHODS ON THE FLOTATION OF COAL

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ABSTRACT

In studies involving the induced oxidation of coals by heating or chemical methods, it is important to understand direct effects of oxidation by isolating secondary effects which depend on the methods adopted to oxidize. In the case of gaseous oxidation, secondary thermal effects need to be differentiated from the primary oxidation. In chemical oxidation, effects of various by-products of the oxidation reaction need to be isolated. Experiments designed to separate these influences show the important role of thermal effects during short oxidation periods, atmospheric moisture, and of dissolved products of chemical oxidation in determining surface properties and floatability of bituminous coal.

Keywords
Coal; oxidation; flotation; zeta potential

INTRODUCTION

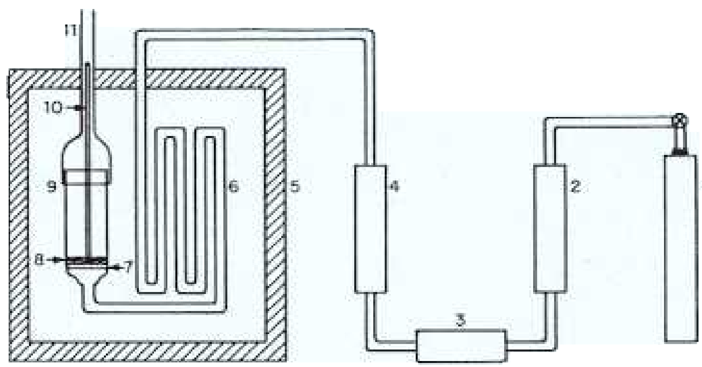
In their natural state, most coals are susceptible to various forms of weathering. Oxidative weathering is by far the most important phenomenon which affects many surface based processes employed in coal preparation and coal utilization [1,2]. Coal oxidation is particularly important in coal flotation since it can drastically affect the wettability and decrease the floatability of the coal [1]. In the future oxidation will become even more important since advanced flotation processes will require fine grinding to liberate maximum ash and sulphur and particles produced by fine grinding are susceptible to extensive surface oxidation. Apart from reduced floatability, oxidation of coals also results in reduced quality and property of coke, reduced stability of coal-water mixtures and decreased efficiency of fine coal dewatering.

Considerable effort has been devoted in the past to study the effects of oxidation on coal properties [3-9]. Studies on induced oxidation of coal can be broadly divided into two categories, viz. chemical or wet oxidation and gaseous or dry oxidation. It is to be noted that most studies of gaseous oxidation do not isolate the effects of heating from the actual oxidative effects. Similarly in the case of chemical oxidation no differentiation has been made between the effects of the by-products formed during the chemical treatment and the effects due to the increase in the surface oxygen of the coal. A recent study [10] reports that treatment of coal with either an oxidizing or reducing agent, or even with an acid or alkali can bring about depression of coal floatability. Clearly flotation depression cannot be attributed to oxidation only and secondary effects of the method used to oxidize the coal can play a role in determining its properties. Such effects arising out of chemical and gaseous oxidation and their role in determining the flotation properties of coal samples is studied in this work.

MATERIALS AND METHODS

High volatile bituminous coal with an ash content of 16.8% obtained from St. Joe Minerals Corp., Penn. was used in this study. The coal was crushed under nitrogen atmosphere using a Quaker city laboratory mill from The Straub Co. The crushed coal was sieved under ambient conditions for 20 minutes and the 150-250 μm fraction was stored under nitrogen until ready for use.

A schematic illustration of the apparatus used for gaseous oxidation of coal is shown in Figure 1. The oxidation chamber consisted of a vertical glass tube with a fritted-glass disk at the bottom through which the gas could flow. Nitrogen or the oxygen-nitrogen mixture was passed through a drying chamber, a flowmeter and preheating tube before being introduced into the chamber. Potassium permanganate solutions (28 mg/l) were used for the chemical oxidation of the coal. Flotation was conducted in a modified 250 ml Buchner funnel. Flotation conditions used are given in Table 1.



1. Nitrogen (or Oxygen) Supply
2. Drierite
3. Oxygen Removal Device (Used when nitrogen gas only is supplied)
4. Flowmeter
5. Low Temperature Oven
6. Preheating Tube
7. Fritted Disk
8. Coal Sample
9. Oxidation Chamber
10. Thermometer
11. Exit to the atmosphere

Fig. Schematic illustration of the apparatus used for gaseous oxidation

TABLE 1 Flotation conditions

Particle size	150-250 μm
Pulp density	1 percent by weight
Frother (MIBC)	112.5 mg/l
Gas flow rate (nitrogen)	42.5 cc/min.
Conditioning time	20 minutes
Flotation time	2 minutes
pH	natural (6.9)

RESULTS AND DISCUSSION

Gaseous Oxidation

Results obtained for flotation of coal which has been exposed to different environments for various periods are shown in Figure 2. Nitrogen is used as an inert gas to determine the direct effects of the heating process. There appears to be no difference in the flotation of coal within the first eight hours of exposure of the coal to nitrogen at ambient temperature (27°C) and 90°C. However, upon prolonged treatment the coal becomes slightly more floatable which is probably due to the removal of surface moisture. The exposure of coal to air at ambient conditions did not show any effect on the floatability of coal even though the coal exposed to nitrogen at ambient conditions showed higher floatability than that exposed to air. Treatment with air at 90°C produced a drastic decrease in floatability following an initial increase. The initial increase is again attributed to the removal of surface moisture rendering the coal surface more hydrophobic. Other researchers have also noted an increase in coal floatability when using air as an oxidizing agent at 150°C [11] and at 70°C [12]. The decrease in floatability upon prolonged heating is the result of oxidation effects owing to the formation of hydrophilic groups on the coal surface [13-15].

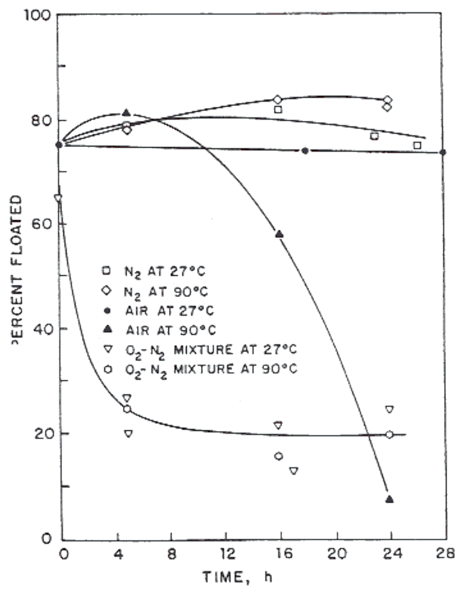


Fig. 2 Diagram showing the effect of exposure of coal to various gaseous environments

When the coal samples were exposed at 27°C and 90°C to an oxygen-nitrogen mixture (21% oxygen, 79% nitrogen) similar to that found in air, a marked decrease in flotation was observed within eight hours. The absence of any moisture in the $N_2.O_2$ mixture is possibly responsible for the enhanced oxidation effect.

Flotation results obtained for coal exposed to various gases at different temperatures showed, as expected, that as coal becomes more oxidized, the hydrophobicity decreases. However, zeta potential of coal after exposure to various gases for five hours as a function of pH (Figure 3) shows that the isoelectric point of nitrogen treated samples occurs at pH 4, whereas those of the samples treated with pure oxygen, oxygen-nitrogen mixture, and air at room temperature occur at pH 5.1, 4.8 and 4.5 respectively. These results clearly show that the surface of the oxygen treated samples is more positively charged than those of the samples treated with nitrogen, and is contrary to expectations, since oxygen groups generated are usually anionic.

Chemical Oxidation

Chemical oxidation was conducted by treating the coal with potassium permanganate ($KMnO_4$) solution followed by washing the samples to remove any dissolved products formed during the chemical treatment. Figure 4 shows flotation results obtained with $KMnO_4$ treated and untreated coals. A significant decrease in the floatability is caused by the permanganate treatment which can be attributed to the oxidation of the coal surface with concomitant formation of polar groups. The effect of washing was examined by conducting flotation experiments with untreated coal which has been washed and comparing the results with those for samples which were not washed. No measurable difference between flotation of the washed and unwashed samples was observed.

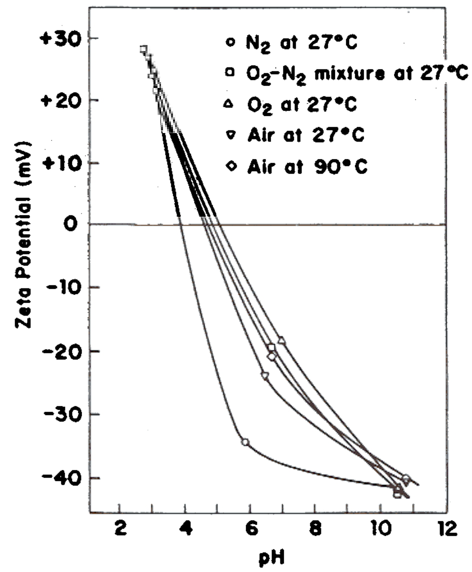


Fig.3 Zeta potential of coal after exposure to various gases for five hours, as a function of pH

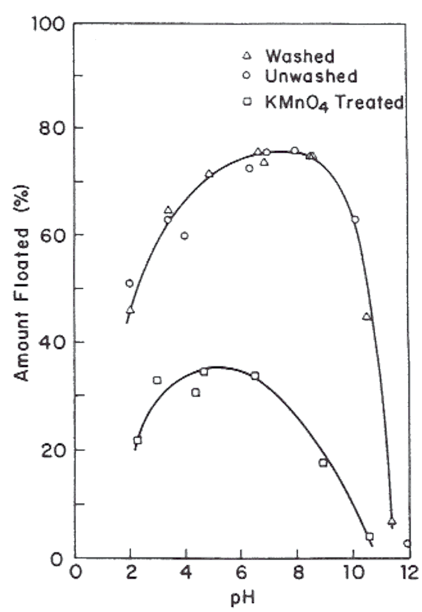


Fig.4 Diagram showing the effect of $KMnO_4$ treatment of coal as a function of pH

Figure 5 shows the results of flotation experiments conducted with untreated coal sample in the supernatant obtained during the washing of the $KMnO_4$ treated coal. The supernatant will contain dissolved species which could have formed during the treatment with $KMnO_4$ as well as any soluble components from the coal. It is clear that by-products produced during chemical oxidation have a significant effect on flotation in the low pH region. In the neutral and basic pH region no effect is observed. The decrease in flotation recovery at low pH regions could be due to precipitation of metal hydroxides [16].

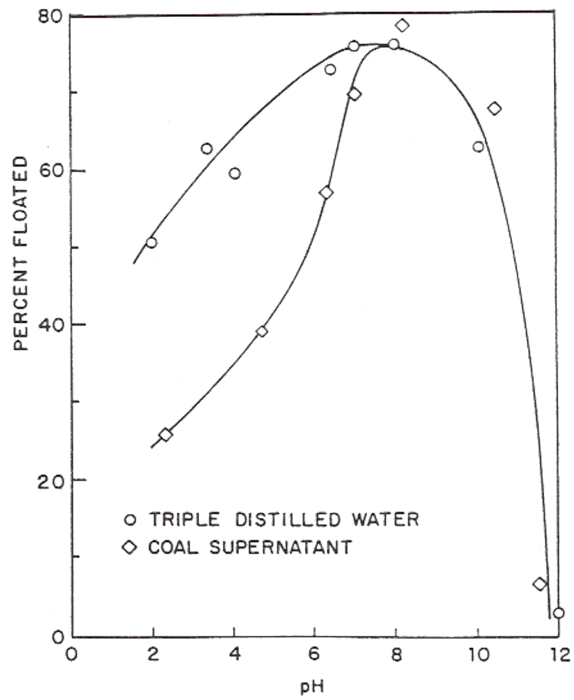


Fig.5 Flotation of untreated coal in triple distilled water and in the supernatant obtained from the washing of the $KMnO_4$ treated coal sample

Zeta potential results given in Figure 6 showed an isoelectric point of pH 4.3 for untreated coal and no observed isoelectric point for the $KMnO_4$ treated coal. The more negative zeta potential of the $KMnO_4$ treated coal over the entire pH region of 2 to 10 suggests the formation of acidic oxygen containing surface functional groups.

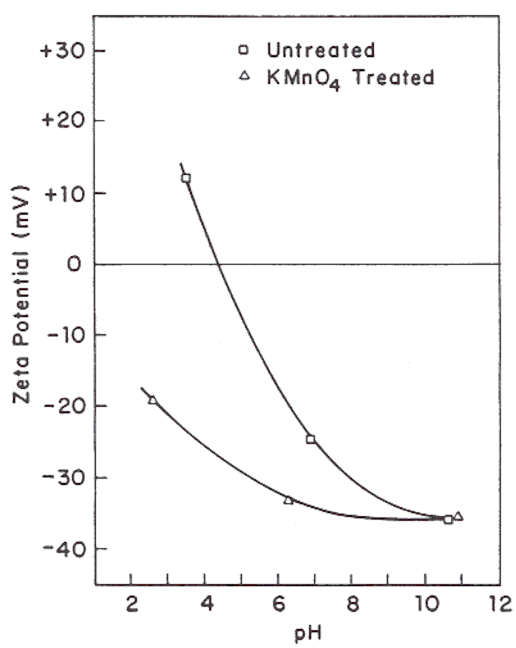


Fig.6 Zeta potential of untreated, and $KMnO_4$ treated coal as a function of pH

CONCLUSIONS

The above study shows that when coal is exposed to a non-oxidizing gaseous environment thermal effects prevail leading to an increase in floatability. In the case of coal exposed to air the temperature of the environment and the time of exposure determines the floatability. Even though at ambient temperature the oxidation of coal is slight, at 90°C initially thermal effects predominate and subsequently a marked reduction in flotation results. In an oxidizing environment thermal effects are negligible and oxidation proceeds rapidly. In the present study correlation between zeta potential and flotation is obtained only for the chemically treated coal and no correlation is obtained for the gas treated coal which suggests further useful studies of this phenomenon. The role of atmospheric moisture is possibly an important factor in determining the surface properties of oxidized coal. In the case of chemical oxidation marked decrease in floatability is observed in the entire pH region, due to the formation of hydrophilic groups on the coal surface in basic solutions and precipitation of the by-products of chemical oxidation such as metal hydroxides in acidic solutions.

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