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Dust in Mineral Processing

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Abstract

The generation of airborne dust is a significant problem for the mineral industry. Previous studies in the literature concluded that surfactants were the most effective dust suppressant agents since they enhance the wetting characteristics of the material. However, personnel in the iron ore industry have reported that these agents were not effective. Why is it that surfactants are effective for materials like coal but not iron ore? If surfactants can not control dust levels, what other reagents should be considered?

A fundamental problem in addressing these questions is that there was no standard method for evaluating the effectiveness of dust suppressants. Although it was possible to conduct experiments at an industrial site, it was difficult to have consistent, controlled conditions. There are various factors such as throughput, wind conditions, temperature, humidity, and access limitations which make it very difficult to conduct controlled experiments. To get around these difficulties, a novel dust tower method was developed. The method exposed the treated material to the types of conditions which were expected to occur at a processing facility, namely multiple impacts and sufficient drop height. Using these systematic studies, the suppressants were evaluated based upon reductions in measured dust levels.

Even though surfactants improved the wetting rate of the iron ore as much as 96%, surfactants were no more effective than water in suppressing dust levels in the dust tower. Hygroscopic agents were 79% more effective than water, even though these reagents actually reduced the wetting rate by approximately 99%. This means that effective wetting was not the concern with iron ore dust. This is why surfactants were ineffective for the iron ore industry. Reagents which reduced moisture loss were the most effective in suppressing iron ore dust.

INTRODUCTION

Release of particulate matter (PM) is receiving more attention as their adverse health effects are better understood. The U.S. Environmental Protection Agency (US EPA) has placed strict limits on the amounts of PM which can be released. This was the result of studies which have concluded that PM represents a significant concern for public health. The US EPA currently regulates PM through PM_{10} and $PM_{2.5}$ standards (EPA, 2005). PM_{10} material signifies airborne particles 10 micrometers in diameter and smaller and $PM_{2.5}$ particulates being 2.5 micrometers in diameter and smaller (EPA, 2005). $PM_{2.5}$ material is of special concern as it easily imbeds into lung tissue causing significant health concerns (EPA, 2005; NIH, 2005). For an industrial operation to survive, it is essential that it has effective dust control methods in place to address these concerns and standards.

Previous dust suppression studies have worked with materials like coal. Coal dust is a naturally hydrophobic material which is difficult to suppress since it does not wet easily. Surfactants have therefore been suggested as an effective reagent since they enhance the wettability of the fine coal particles (Chander et al., 1986; Mohal, 1988; Kim, 1995). In practice, surfactants are effective in reducing coal dust levels. Recently, an iron ore plant in the US was experiencing significant problems with airborne dust. Considering that surfactants have shown a benefit in the past, and are popular commercial dust suppressants, they were used at this facility. Unfortunately, these reagents were not effective in reducing ambient dust levels from the iron ore facility.

The effects of various suppressants on the wetting rate of iron ore were relatively unknown. Previous studies found that acetyletic glycol surfactants were extremely effective for iron ore (Copeland & Kawatra, 2005). However, the effects of hygroscopic agents on the wetting rate of iron ore were still unknown. In previous studies, the Walker Sink Test has been used to examine the wetting characteristics for coal (Mohal, 1988; Kim, 1995) and copper sulfides (Cristovici, 1991). This experiment measures the amount of time required for a given sample to be completely engulfed by the suppressant. Using this method, the ability of various suppressants to wet the iron ore could be explored.

A significant gap in the literature involves the correlation of suppressant addition to reduced dust levels. Previously, there was no standard method for evaluating the ability of a suppressant to reduce ambient dust levels under controlled conditions. Therefore, a novel dust tower was developed which, for the first time, measured how effective suppressants were in reducing PM_{10} and $PM_{2.5}$. For this analysis, the treated material was dropped through an enclosed tower at a height over 8 feet (2.4m). The ambient dust concentrations (PM_{10} and $PM_{2.5}$) were measured using an isokinetic nozzle. Since this method was measuring dust levels, the impact of suppressants on dust production was evaluated directly. This allowed for a fair comparison of each reagent, and resulted in a better understanding of which factors were the most important in controlling ambient dust levels.

LABORATORY STUDIES

Wetting Rate of Fine Particles: Procedure

A Walker Sink Test method was used to evaluate the ability of the suppressant to engulf fine particles. For these experiments 40 milligrams of fines were dropped a fixed height onto the surface of the suppressant. The particles then wetted at the surface and settled onto an ultra-sensitive balance pan. The wetting time was the amount of time required for the entire sample to completely settle onto the balance pan. A short wetting time meant that the material had a rapid wetting rate. A diagram of this experiment is given in Figure 1.

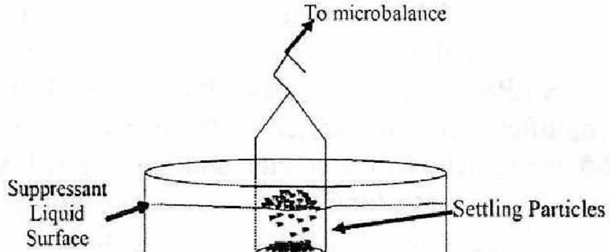

Fig. 1: Walker Sink Test Apparatus

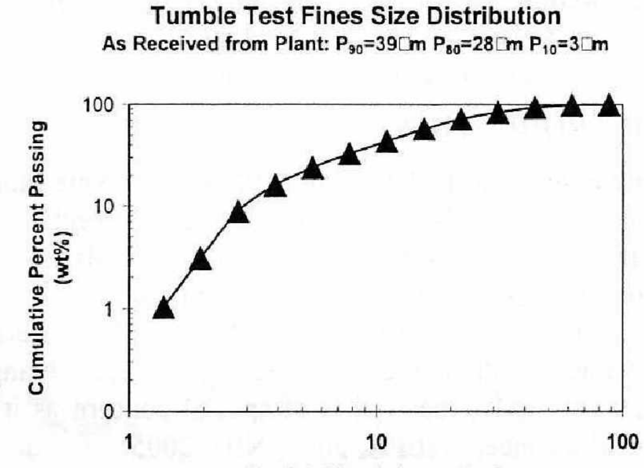

Fig. 2: Size Distribution of Tumble Test Fines Received From Plant. This Material was Used in the Walker Sink Test Experiments

For these experiments, tumble test fines obtained from a mineral plant in the US were used. Chemical analysis using total dissolvable iron titration and magnetic analysis showed that this material was 80%

hematite (Fe_2O_3), 10% magnetite (Fe_3O_4), and a balance of silica plus other. Particle size distribution analysis was performed using a Microtrac analyzer. The results of this analysis are given in Figure 2.

Wetting Rate of Fine Particles: Results

Two different types of suppressants were tested on their ability to engulf iron ore particles: surfactants, and hygroscopic salts. These reagents were tested at various concentrations based upon dosages which were reported by the manufacturers as being effective for dust control. The first reagent was an acetyletic glycol surfactant. This chemical reagent has been shown to be extremely effective in enhancing the wetting rate of iron ore particles (Copeland & Kawatra, 2005).

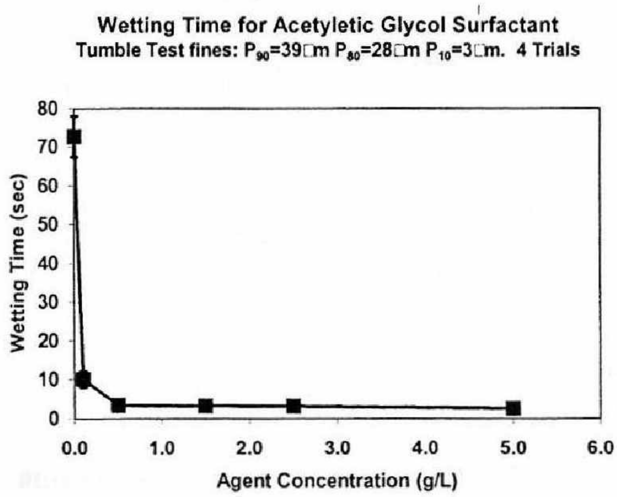

Fig. 3: Effects of Acetyletic Glycol Surfactant on the Wetting Time of a 40mg Sample of Tumble Test Fines. This was the Total Amount of Time Required for the Entire Sample to Settle. Error Bars are +/- 1σ

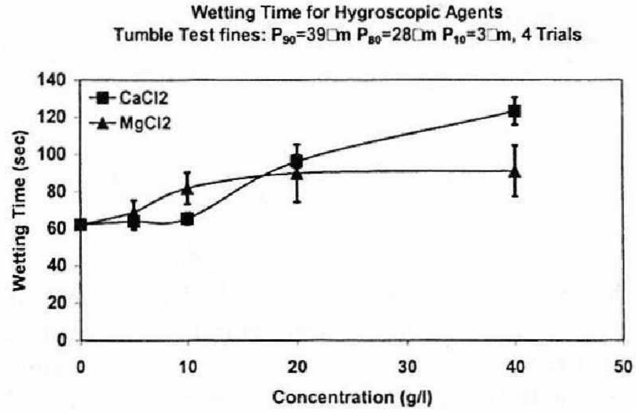

Fig. 4: Effects of Hygroscopic Agents on the Wetting Time of a 40mg Sample of Tumble Test Fines. This was the Total Amount of Time Required for the Entire Sample to Settle. Error Bars are +/- 1σ

The acetyletic glycol surfactant reduced the wetting time from about 75 seconds to less than 5 seconds. This is shown in Figure 3. It was clear that the acetyletic glycol surfactant significantly enhanced the wetting rate of the material. In contrast, calcium chloride and magnesium chloride (hygroscopic dust suppressants) increased the wetting time, as shown in Figure 4. The tumble test fines used in Figure 3, and 4 were from different sources.

Pilot Plant Studies

Dust Tower Studies: Procedure

A novel method was developed to study the effects of various dust suppressants on the generation of PM_{10} and $PM_{2.5}$ from iron ore. A mixture of iron ore pellets (1 Kilogram) and fines (10.000 grams) were treated with a given suppressant, allowed to cure in open container in ambient conditions, and then were passed through the tower. For treatment, the pellets and fines were tumbled in a container as the suppressant was applied. This ensured an even application. Suppressants consisted of solutions of the active ingredient in distilled water. Concentrations of the active ingredients were 2.5 wt% for the surfactant, and 4.0wt% for the hygroscopic salts. The suppressants were added at a rate of 4Kg/Tonne of ore.

After treatment and curing, the material was tested in the dust tower. As the material fell through the tower, it struck several flat plates, which produced airborne particulate material (PM). The airborne PM was removed from the tower using a counter current air stream generated from a vacuum source at the top of the tower. The dust laden air was collected in a duct (ID=3" or 7.6cm) where PM measurements were made. An isokinetic nozzle placed in the dust stream was used to measure PM concentrations. This method ensured the measured sample was representative of the dust levels in the tower. The extracted air stream was diluted in an aerosol diluter (Figure 5) and PM concentrations were determined using a Dust Trak device. This device was fitted with a size selective nozzle which allowed for PM_{10} and $PM_{2.5}$ measurements to be made. A diagram of this apparatus is given in Fig. 6.

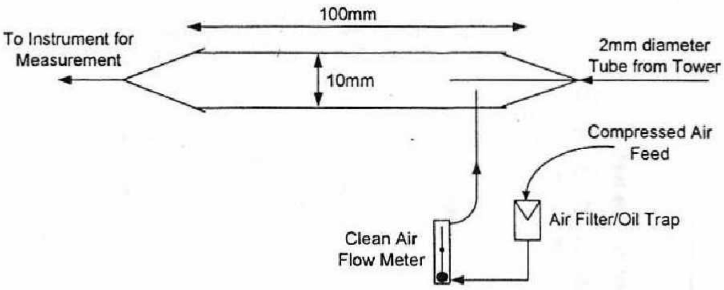

Fig. 5: Aerosol Diluter Schematic. Dust Laden Air From Tower Entered on the Right Hand Side. Clean Air (No Dust) was Injected (Right Side, Bottom) and Allowed to Mix with Dust Laden Air. Diluted Aerosol Exited Mixing Chamber (Left Hand Side) to the Dust Trak Instrument

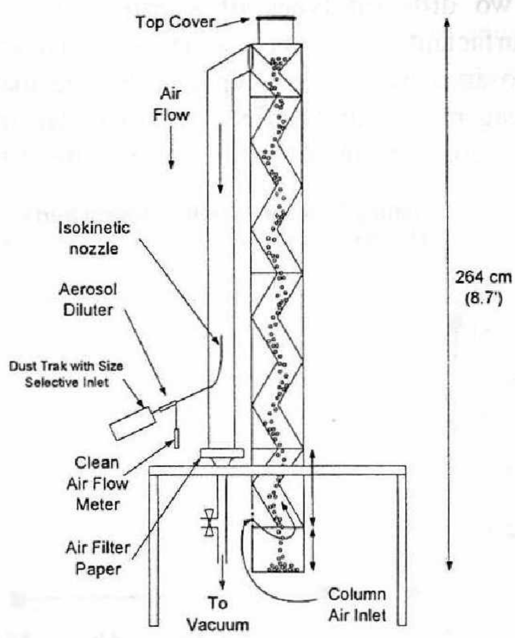

Fig. 6: MTU Dust Tower Apparatus with PM Concentration Measurement

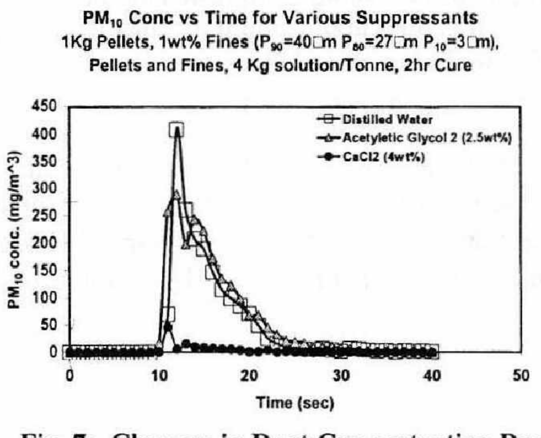

Fig. 7: Changes in Dust Concentration During a Drop Test, with Water, Acetyletic Glycol, a Surfactant, and Calcium Chloride, a Hygroscopic Material

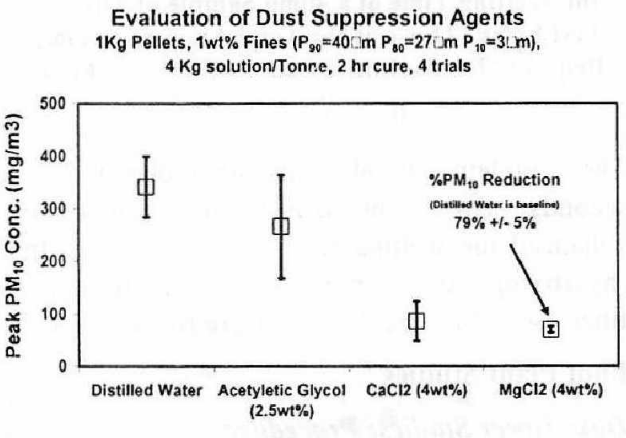

Fig. 8: Effects of Various Dust Suppressants on the Peak PM_{10} Concentration. Magnesium Chloride was 79% (+/- 5%) More Effective Than Water in Suppressing PM_{10}. Error Bars are +/- 1σ

Dust Tower Studies: Results

Each suppressant was tested on its ability to suppress PM_{10} and $PM_{2.5}$ using the dust tower apparatus. Four suppressants were examined in these experiments: water, acetyletic glycol (2.5wt%), calcium chloride (4wt%), and magnesium chloride (4wt%). For an agent to show any value, it must be more effective than water. Experiments were performed four times each for reproducibility. Experiments were conducted which measured PM_{10} and $PM_{2.5}$ separately. Figure 7 shows how the concentration of dust changed during an experiment. A TSI Dust Trak air monitor was used to measure PM_{10} and $PM_{2.5}$ quantities. The Dust Trak started collecting data at time equal to zero. At ten seconds, the treated material was dropped. Within 2 seconds after the material was dropped, the dust concentration reached a maximum ("peak concentration") value. As the air circulated through the tower, the concentration decreased until all of the dust was removed. The suppression of dust by water, a surfactant, acetyletic glycol, and a hygroscopic material calcium chloride are shown in Figure 7. The hygroscopic material was found to be more effective than water and the acetyletic glycol suppressants.

The effects of surfactants and hygroscopic materials on the generation of PM_{10} and $PM_{2.5}$ are shown in Figure 8 and Figure 9 respectively. The calcium chloride and magnesium chloride suppressants significantly reduced PM_{10} and $PM_{2.5}$. This means that moisture retention, not enhanced wetting rate, was the most effective dust control method for this material. The acetyletic glycol suppressant was far less effective than calcium chloride or magnesium chloride in suppressing PM_{10} or $PM_{2.5}$. This again indicated that the wetting rate was not the primary concern in suppressing dust from this material.

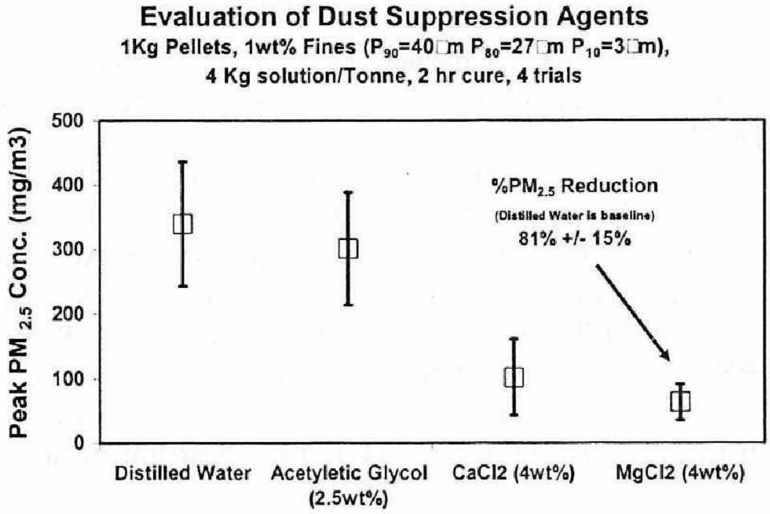

Fig. 9: Effects of Various Dust Suppressants on the Peak $PM_{2.5}$ Concentration. Magnesium Chloride was 81% (+/- 15%) More Effective Than Water in Suppressing $PM_{2.5}$. Error Bars are +/- 1σ

CONCLUSIONS

Effective suppression of airborne particulates is in the best interest of the minerals industries. Not only does this material represent a problem from a regulatory standpoint, it also represents a significant problem to public health. A wide range of suppressants are commercially available to address the problems of fugitive dusts. Previous works and industrial projects have focused on the use of surfactants. These agents have been effective for materials like coal in improving the wetting characteristics of the material. It is therefore commonly believed that this is the case for all materials. However, in the iron ore industry, this approach was unsuccessful in reducing ambient dust levels.

Systematic dust studies carried out using a novel dust tower showed that the hygroscopic agents were far superior to the surfactant as dust suppressants. These reagents were as much as 80% more effective than water in reducing both PM_{10} and $PM_{2.5}$ levels. The acetyletic glycol and water suppressants were much less effective than calcium and magnesium chloride, in spite of the fact that wettability experiments showed that the surfactant greatly increased the wetting rate of the dust. From these results, it was concluded that once a material is sufficiently wettable by a dust suppressant, further increase in wettability give no additional benefit. For wettable materials, suppressants that prevent water evaporation are of much more value than wetting aids.

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LITERATURE CITED

[1] Chander, S., Mohal, B.R., Aplan, F.f., 1986. "Wetting characteristics of particles and their significance in dust abatement." Presented at the International Symposium on Respirable Dust in the Mineral Industries. The Pennsylvania State University, University Park, Pennsylvania. Oct. 14-16.

[2] Cristovici, M.A., 1991. "Investigation to control mine dust using surfactants and a new approach for eliminating their negative effect on flotation." Minerals & Metallurgical Processing. Vol 8. No 1. Feb. pp. 38-42

[3] Copeland, C.R., Kawatra, S.K., 2005. "Dust suppression in iron ore processing plants." Minerals & Metallurgical Processing. Vol 22. No 4. Nov. pp 177-191

[4] EPA (2005); www.epa.gov. Date of Access: 10-20-2005. Search PM10 and PM2.5

[5] Kim, J., 1995. "Respirable Coal Dust Control Using Surfactants—With Special Emphasis on a Liquid Spray System." PhD. Thesis. University of Missouri—Rolla. Rolla, Missouri.

[6] Mohal, B.R., 1988. "Enhancement of the Wettability of Coal Powders Using Surfactants." Ph.D. Thesis. The Pennsylvania State University. University Park, Pennsylvania.

[7] NIH (2005); www.nih.gov. Date of Access: 11-1-2005. Search Particulate Matter