Haul Road Dust Control

Fugitive dust characteristics from surface mine haul roads and methods of control

BY W.R. REED AND J.A. ORGANISCAK

Characterizing fugitive dust emissions from haul trucks will help mine operators understand the effects of exposure.

Surface mining operations use large off-road haul trucks extensively to move material at mining properties. Past research, using the United States Environmental Protection Agency's (EPA) emissions factors for unpaved haul roads, has shown that haul trucks generate the majority of dust emissions from surface mining sites, accounting for approximately 78%-97% of total dust emissions.

Observations of dust emissions from haul trucks show that if the dust emissions are uncontrolled, they can be a safety hazard by impairing the operator's visibility. This increases the probability for haul truck accidents (See photos above). However, the greatest long-term health hazard of dust generated from hauling operations is due to inhalation of the respirable dust [median diameter <4 micrometers (µm)] and thoracic dust, which is equivalent to the EPA's definition of PM10 [particulate matter with a median diameter <10 µm]. Exposure to respirable dust has long been considered a health hazard at surface mining operations, especially if silica dust is present.

There are two legislative acts that regulate the air quality for mining operations: the Federal Coal Mine Health and Safety Act of 1969 and the Clean Air Act of 1970. The Federal Coal Mine Health and Safety Act of 1969 established the limits for dust in the work place for health and safety purposes. The Clean Air Act of 1970 regulates air emissions from facilities from an environmental perspective.

The Federal Coal Mine Health and Safety Act of 1969 established a limit for coal respirable dust of 2 mg/m^3 for coal mine workers. The U.S. Mine Safety and Health Administration (MSHA) enacts and enforces mine worker safety and health standards to mitigate mine worker injuries and occupational diseases. If silica is encountered during the sampling process then the applicable respirable dust standard is reduced to the quotient of 10 divided by the percentage of quartz in the dust. For non-coal mine workers, the applicable standard is the respirable dust standard of 10 divided by the total of the quartz percentage plus 2. Both of these dust standards are designed to limit worker respirable crystalline silica (quartz) exposure to 0.1 mg/m^3 or less for the shift. Compliance with these dust standards is expected to reduce a worker's risk of occupational lung disease over an average life expectancy. Additionally, MSHA's nuisance dust limit (total dust) for non-coal miners is 10 mg/m^3.

Mine worker overexposure to the reduced dust standard due to quartz remains an ongoing problem at mining operations in the United States. An evaluation of a recent MSHA database of respirable dust samples containing silica from 1996 through 2000 shows that overexposure rates for truck drivers and road grader operators at surface mines ranged from 5% to 10% and 3% to 29%, respectively.

The Clean Air Amendment of 1990 regulates emissions from any facility into the air and addresses toxic substances. The national ambient air quality standards (NAAQS) have been in effect for PM10 since before 1987. As dictated by the standards, facilities are not allowed to emit levels of PM10 at a rate that exceeds a 150 µg/m^3, 24-hour average concentration. The NAAQS regulations for PM10 are the maximum emission levels allowable in ambient air; however, states have the right to create stricter regulations. For example, in California the 24-hr average for PM10 is 50 µg/m^3, with an annual average of 20 µg/m^3. However, the NAAQS regulations pertain to ambient air, which is defined as air that is accessible to the general public. Therefore, the NAAQS would not apply within the boundaries of areas that are enclosed by a fence, for instance.

Although the health and safety concerns for dust overexposure focus on respirable dust, PM10 has also been shown to represent a broader health hazard. Many epidemiologic studies have been completed that show that PM10, by itself, causes harm to humans. In one EPA study, a 50-microgram/cubic meter (µg/m^3) increase in the 24-hour average PM10 concentration was statistically significant in increasing mortality rates by 2.5%-8.5%. Long-term effects from PM10 are dependent upon the exposure to PM10 over the life of the worker.

In light of the health and safety issues outlined above, of particular concern is the use of haul trucks outside of the mining industry. There are many off-road haul trucks that are used in the construction industry. Highway construction sites use some of the same heavy equipment as surface mining operations. This equipment may be operated in close proximity to laborers, equipment operators, and to the general public. There may be a high probability for potential exposure of respirable dust to these personnel at these locations. However, data to substantiate this supposition is almost non-existent. The goal in this study is to use data from two mining operations to characterize the fugitive dust emissions from haul trucks at surface mine sites. This will help both mine operators and construction operators to understand the effects of dust generated from haul trucks.

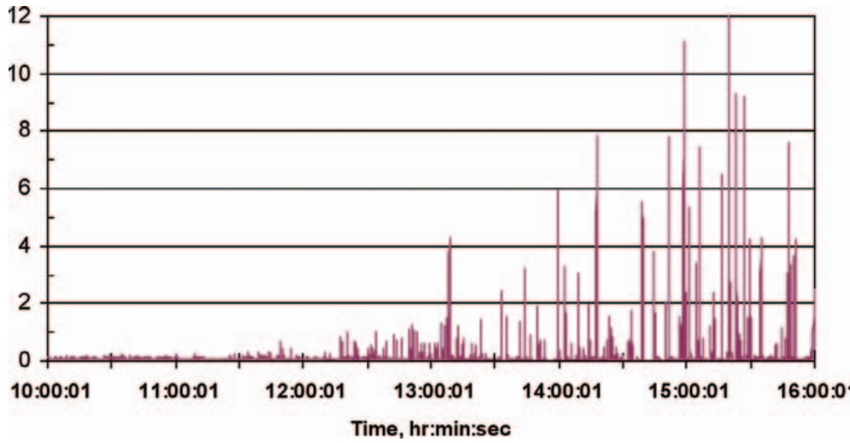

Figure 1—Instantaneous dust concentrations from haul trucks on test section of road as it is initially wetted and allowed to dry.

Characterization of Fugitive Dust

Fugitive dust generated along unpaved haulage roads from truck traffic can encompass larger regions of the mine, possibly exposing other workers or neighboring residences to airborne dust when downwind of the haulage roads. Due to a lack of data characterizing airborne dust generated from haul trucks, a field study was conducted that measured dust from haul trucks at several sites—a limestone quarry (LQ) and a coal preparation plant waste hauling operation (CP). This study used sampling stations located at varying distances from the haul road. The locations used in this study were labelled as A, B, C, and D. Location A was placed upwind and adjacent to the haul road, with location B adjacent to the road, location C 50 ft from the road, and location D 100 ft from the road and placed downwind. (It should be noted that the planned upwind-downwind configurations did not occur several times during testing due to changing wind directions.) The test section of the haul road was a straight un-watered section of road approximately 100 ft in length and relatively flat.

During one of the tests at the LQ, the haul road test section was watered at the beginning of the test and allowed to dry throughout the day with no more water applications occurring. Dust measurements were obtained adjacent to the haul road, which show how this road wetting effected the dust emissions from the road throughout the day. Figure 1 shows how the dust concentrations became greater as the haul road dried out.

Weather data consisting of temperature, both dry and wet bulb, and barometric pressure were recorded hourly. A wind speed and direction station was placed nearby and recorded wind speeds and directions every 30 seconds. Respirable, thoracic, and total dust measurements were collected for approximately six to seven hours per day. Samples were collected on 37-mm filters. Respirable dust was measured using Escort ELF personal sampling pumps, operating at 1.7 liters/minute (L/min), with 10-mm Dorr-Oliver cyclones. Additionally, MIE personal data RAMs, fitted with 10-mm Dorr-Oliver cyclones and operated at 1.7 L/min, were used to collect instantaneous respirable dust concentrations, recording dust concentrations every 2 seconds. Thoracic dust was measured using Escort ELF personal sampling pumps, operating at 1.6 L/min, with BGI GK2.69 cyclones. Total dust concentrations were measured by attaching 37-mm filters directly to the Escort ELF personal sampling pumps, set to operate at 1.7 L/min. The particle size distribution of airborne dust was measured using Cascade Impactors that contained 6 stages connected to Escort ELF personal sampling pumps operating at 2 L/min.

A time study was also conducted of the haul trucks using the test haul road throughout the entire time period of the study. The haul truck time entering and exiting the test section of the road, type of haul truck, and speed and direction of travel were recorded. The haul trucks operating at the LQ were mostly various tandem-axle over-the-road trucks, with some trailer trucks, capable of carrying 20-ton payloads. Additionally, some 50-ton off-road haul trucks were included in this study. Their average speed during the study was 15.6 mph. The CP operated 50-60-ton off-road trucks (Cat, Terex, and Payhauler) that traveled at an average speed of 15.9 mph. The road conditions were similar at both sites with average road surface material specific gravity, moisture content, and silt content being 2.86, 0.16%, and 22.3%, respectively, for the LQ and 2.48, 0.62%, and 21.9%, respectively for the CP.

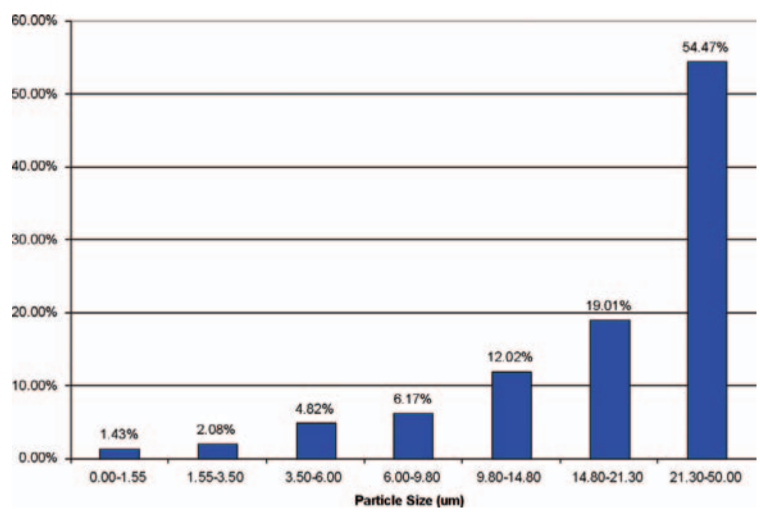

Figure 2—Average size distribution for airborne dust generated by haul trucks for the entire sampling period.

Results

Average particle size distributions of dust generated from haul trucks were calculated using cascade impactor sampler data from both sites. The cascade impactor sampler locations were adjacent to the haul road. The average particle size distribution of the dust generated by haul trucks during this study is shown in Figure 2. On average, 14.5% of the airborne dust generated from haul trucks consists of material <10 µm, and 3.5% is material <3.5 µm (Figure 3). The majority (85.5%) of the airborne dust consists of larger particles that do not pose a respirable threat to the truck operator, but may be a visibility hazard.

The average gravimetric respirable, thoracic (which is similar to PM10), and total dust concentrations from the sampling completed during the LQ and CP study are shown in Figures 3 and 4, respectively. For reference, locations of sampling stations A and B were on opposite sides of but adjacent to the haul road, with station A being generally on the upwind side. The results show that the dust concentrations drop off rapidly at 50 ft away from the haul road, and at 100 ft away from the road the concentrations were at or below background levels, which were approximately 0.05 and 0.04 mg/m^3 for respirable dust for the LQ and CP, respectively, as measured in these studies. Surprisingly, the time-weighted average concentrations were not that high during the six- to seven-hour measurement time periods.

An evaluation of the average instantaneous respirable dust data revealed the variability of the dust concentrations. Figure 5 shows the average of all instantaneous respirable dust concentrations for all the haul trucks passing by one of the sampling stations at the CP. The time period measured was a three-minute time interval recording one minute prior to the truck arriving at the sampling station and two minutes after passing. The negative time intervals represent the time before the haul truck arrived at the sampling station, and the positive time intervals represent the time after the haul truck passed the sampling station. The curve on the graph represents an average of the concentrations, which peaked at approximately 2.30 mg/m^3 and were quite variable. This variability was due to the continually shifting wind directions that were recorded during testing. During testing, wind directions came from a predominant direction with individual recorded wind directions originating from all 360˚.

To show this variability, percentile plots were created from this data. These plots present the statistics for the median and for the 25th, 75th, and 90th percentiles of the instantaneous respirable dust concentrations of all the haul truck passes at the CP during the study period (See Figure 6). This graph shows that half of the peak respirable dust concentrations were above 1.70 mg/m^3, while 25% were above 3.55 mg/m^3. This analysis could not be conducted on the LQ data due to the high traffic volume, which precluded the creation of instantaneous respirable dust concentration curves for each individual truck due to interferences from other trucks.

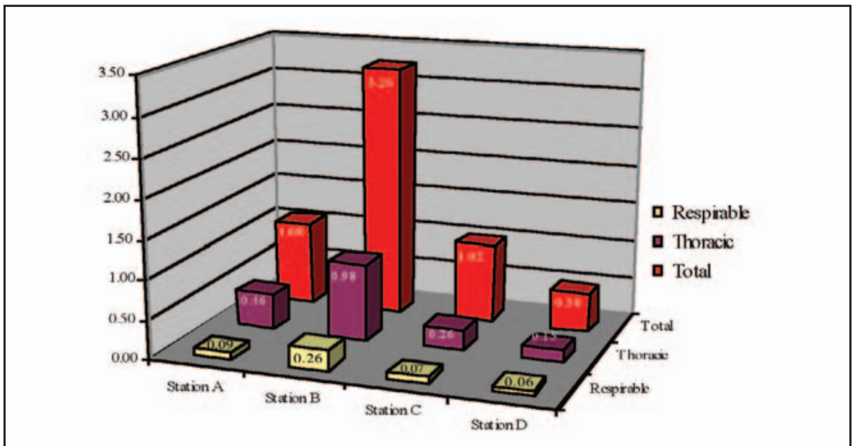

Figure 3—Average gravimetric respirable, thoracic, and total dust concentrations at each sampling station during the limestone quarry hauling study.

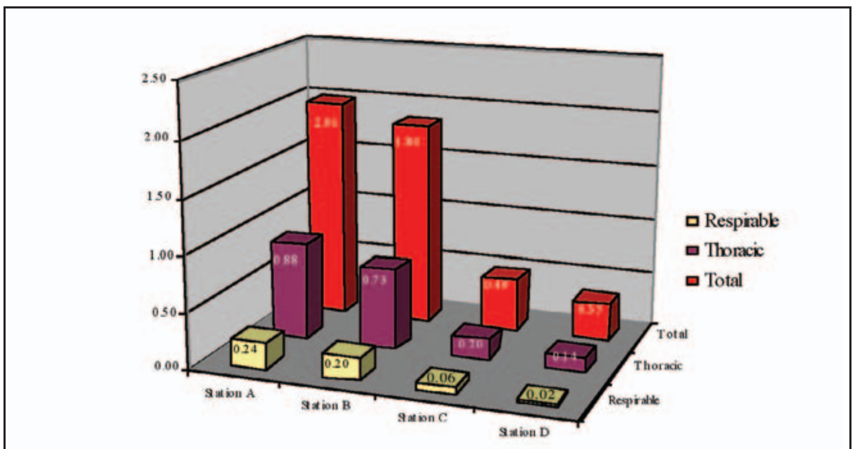

Figure 4—Average gravimetric respirable, thoracic, and total dust concentrations at each sampling station during the coal preparation plant waste hauling study.

Conclusions

This truck haulage dust study showed that primarily wind, distance, and road treatment conditions notably affected the dust concentrations at locations next to, 50 ft from, and 100 ft away from the unpaved haulage road. Airborne dust measured along the unpaved haul road showed that high concentrations of fugitive dust can be generated with these concentrations rapidly decreasing to nearly background levels within 100 ft of the road.

Instantaneous respirable dust measurements illustrated that the trucks generate a real-time dust cloud that has a peak concentration with a time-related decay rate as the dust moves past the sampling locations. The respirable dust concentrations and peak levels were notably diminished as the dust cloud was transported, diluted, and diffused by the wind over the 100 ft distance from the road. Individual truck concentrations and peak levels measured next to the dry road surface test section were quite variable and dependent on wind conditions, particularly wind direction, with respect to reaching the sampling location. The vast majority of the fugitive airborne dust generated from

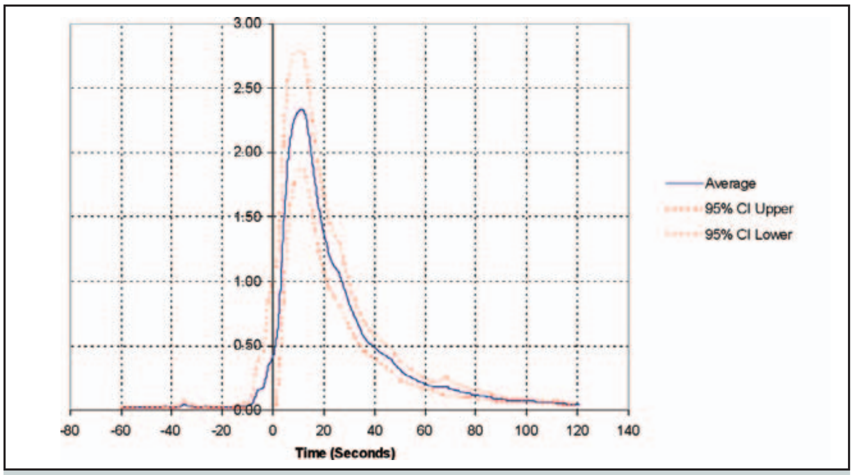

Figure 5—Average instantaneous respirable dust concentrations for Station B—downwind and adjacent to the haul road of the coal preparation plant waste hauling study.

unpaved and untreated haulage roads was non-respirable. At least 85% of the airborne dust sampled by impactors was larger than 10 µm (aerodynamic diameter size).

Since the truck-generated dust appears to dilute and diffuse rapidly away from the road, the most susceptible persons for exposure are the truck workers themselves. Exposure is not as likely from their own truck, but from dust plumes of opposing truck traffic and when following behind trucks in the same direction. Other occupations that can be exposed to fugitive truck dust are the operators of shovels and front-end loaders that fill the trucks, and bulldozer and crusher operators who may be working in the close proximity to the dump, processing, and storage facilities.

As surface mine facilities are dynamic operations exposed to changing weather conditions, day-to-day dust levels can be highly variable. However, there are many dust control practices for haul trucks available which can assist with maintaining worker exposures below mandated standards. These practices include reducing haul truck speed and maintaining safe following distances, watering haul roads, treating haul roads, and maintaining equipment cabs.

Reducing the haul truck speed is the simplest control method. The reduction in dust is attributable to the lower amount of disturbance to the haul road at lower speeds. The results of the field study completed at the LQ and CP showed that the critical time period of maximum dust exposure when following a truck is from 0 to 20 seconds. Implementing a policy to ensure that trucks do not follow within 20 seconds of another truck can result in a 41%-52% reduction in airborne respirable dust exposure to the following truck.

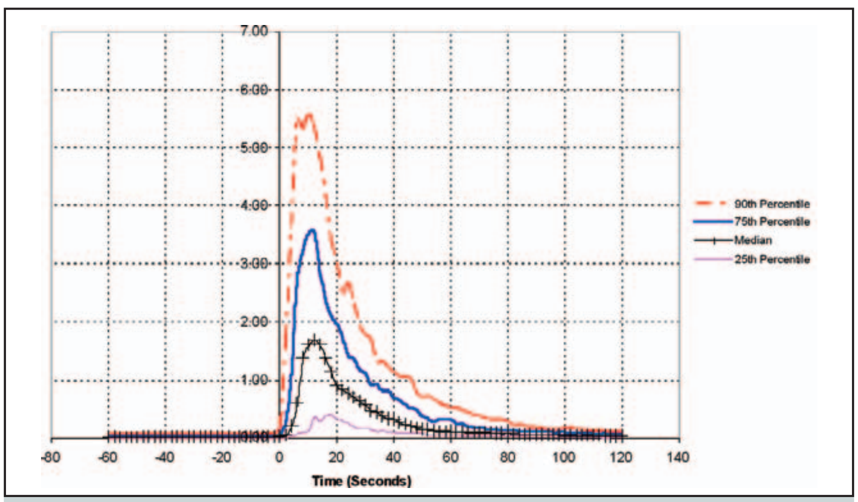

Figure 6—Percentile graph of airborne respirable dust concentrations generated from haul trucks for Station B—downwind and adjacent to the haul road of the coal preparation plant waste hauling study.

The use of water on haul roads is the most common dust control method used. As seen in Figure 1, watering the haul road on the test section in this study allowed instantaneous dust concentrations to remain below 2 mg/m^3 for over three hours. Past research has shown that watering haul roads with a water truck once an hour has been shown to have a control efficiency of 40% for total suspended particulates (TSP). If watering is increased to once every half hour, the control efficiency for TSP increases to 55%. The control efficiency was defined as a comparison of the controlled (watered) emission rate to the uncontrolled emission rate. The EPA reported several test results of watering haul roads. The results ranged from a control efficiency of 74% for TSP for the three to four hours following the application of water at a rate of 2.08 L/m^2 (0.46 gallons/yd^2) to a control efficiency of 95% for TSP for 0.5 hours after the application of 0.59 L/m^2 (0.13 gallons/yd^2).

Treating haul roads is generally completed through the application of chemicals, and requires a significant amount of road maintenance. In one study, control efficiencies were shown to be 95% for magnesium chloride and 70% for a petroleum derivative for controlling haul truck generated dust.

Maintaining equipment cabs in good operating condition also reduces operator exposure to respirable dust. A study conducted on dozers and drills demonstrated that properly maintained cabs can attain dust reductions of 90% for drills and between 44% and 100% for dozers. The variations of the dust reductions for dozers were attributed to re-entrainment of internal cab dust. An additional study completed on haul trucks, which involved the retrofitting of a cab with a filtration/pressure air conditioning system to produce positive pressure in the cab, showed that properly maintained cabs can produce a potential 52% reduction of respirable dust.

Characterizing the fugitive dust emissions from haul trucks at surface mine sites will help operators understand the effects of dust generated by haul trucks. This knowledge will also help in the understanding of dust exposure for equipment operators and mine personnel, which will provide mine operators additional insight as to how to effectively reduce dust.

Reed and Organiscak are mining engineers with NIOSH-PRL, located in Pittsburg, Pa. Reed can be reached at E-mail: rreed@cdc.gov or Tel: 412-386-5205. A set of references are availible by request.