

# Dealing with DPM

Using Real-Time Diesel Particulate Matter Measurements to Optimize the Implementation of Administrative Controls.

By James Noll, Larry Patts and Roy Grau



Figure 1: Airtec being worn by miner.

Many underground aggregates operations use enclosed cabs as their mainstay control technology to protect workers from diesel particulate matter (DPM). However, some workers, such as blasters, do not always work inside a cab and can potentially be exposed to elevated concentrations of DPM. Such exposure is a health concern for miners because DPM is classified as carcinogenic to humans by the International Agency for Research on Cancer.

To reduce exposures of its blasters, one stone mine increased ventilation, installed a diesel particulate filter on

the blasters' truck, and used 20 percent biodiesel. When these improvements failed to reduce the DPM to the desired levels, the mine instituted administrative controls, which included operating some of the highest DPM-emitting vehicles (loaders and trucks) during a different shift than the blasters and, when possible, operating other vehicles such as drills and scalers downstream of the blasters. When correctly applied, these controls proved to be effective in bringing the blasters into compliance. Further, when these administrative controls were not strictly followed, real-time measurements could help prevent

an overexposure by providing an early warning, allowing corrective actions to be implemented quickly. This paper describes the administrative controls, their effectiveness, and the use of real-time monitoring to manage them.

## Background

Since underground miners work alongside diesel equipment in a confined environment, they can be correspondingly exposed to some of the highest levels of DPM of any workers in the country. To protect miners from this health hazard, the Mine Safety and Health Administration (MSHA) promulgated a rule to limit exposures of metal/nonmetal underground miners to DPM to an eight-hour time-weighted average (TWA) of 160  $\mu\text{g}/\text{m}^3$  total carbon (TC).

One method for reducing miners' exposures to DPM is to utilize enclosed cabs with effective filtration and pressurization systems on mobile mining equipment. These enclosed cabs create a microenvironment that can protect workers from mine aerosol contaminants. In a properly functioning cab, a fan induces positive pressure and blows outside air through a filtration system where particles are collected, resulting in clean air entering the compartment where the miner is located. Due to the high protection factor and compatibility with most equipment in underground aggregates operations, enclosed cabs are the primary control technology used by many of these types of mines.

Despite the above option, some mine workers, such as blasters, spend a large portion of their workday outside

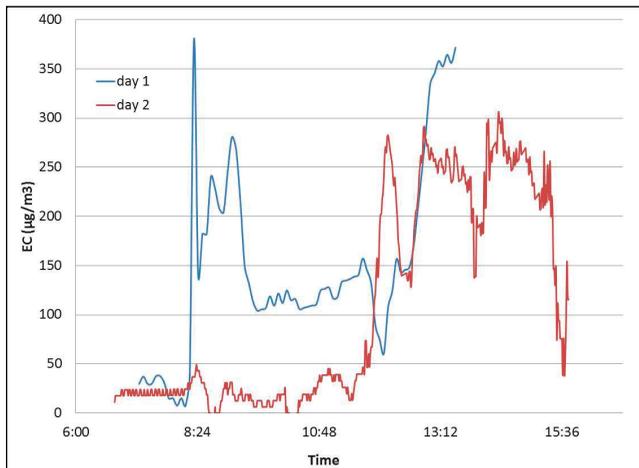
of a cab, thus being potentially exposed to elevated concentrations of DPM. To investigate methods to reduce the exposures of these miners, NIOSH partnered with a stone mine whose blasters' DPM exposures were above the permissible exposure limit (PEL).

An integrated approach, which included using a combination of different controls to lower DPM exposures, was implemented at this stone mine. This integrated approach included reviewing and adjusting mine ventilation, the addition of diesel engine particulate filters, and the institution of administrative controls. Mine personnel and NIOSH researchers reviewed the mine ventilation plan and determined that adjustments in the ventilation system were needed in order to bring higher air quantities to the working areas. In order to accomplish this, larger fans were installed to provide the main airflow, auxiliary fans were used to direct and push air, brattice stoppings were added, and existing brattice stoppings were sealed. As a result of these modifications, the fresh airflow quantity into the mine was increased from 100,000 cfm to over 300,000 cfm, and the airflow control was improved resulting in better ventilation at the working faces.

A Huss diesel particulate filter (DPF) was installed on the blasters' truck and B20 biodiesel (20 percent biodiesel, 80 percent ultra-low sulfur fuel) was used to fuel the entire fleet, which reduced the emissions of all of its vehicles. The DPF was installed on the blasters' truck to reduce the DPM contribution generated by the truck in the blasters' working area. The Huss DPF was chosen because it is advertised by the manufacturer to reduce soot particles by 99.9 percent. In addition, it can initiate regeneration (cleaning of the soot on the filter necessary to avoid high backpressure across the filter) while the blasters' truck is operating under normal conditions.

Following implementation of the DPM emission controls, DPM concentrations were reduced but still remained above the PEL. Therefore, the mine implemented several administrative controls to further reduce the DPM exposures. Managing the implementation of these administrative controls, however, proved to be difficult. At times, the drill or loader operated upstream or near the blasters, resulting in elevated concentrations of DPM.

The Airtec, a real-time elemental carbon (EC) monitor, was used to identify breakdowns in the administrative controls and could be used to manage the implementations of these controls to address problems before an overexposure occurs. The Airtec (Figure 1) is a wearable device developed by NIOSH to measure real-time EC concentrations. It is compact and simple in design and weighs approximately 1.5 lb. and can be worn comfortably by a worker or easily positioned for area sampling. A diaphragm pump draws ambient air at a set flow rate that enables a pre-selector to make about a 1- $\mu\text{m}$



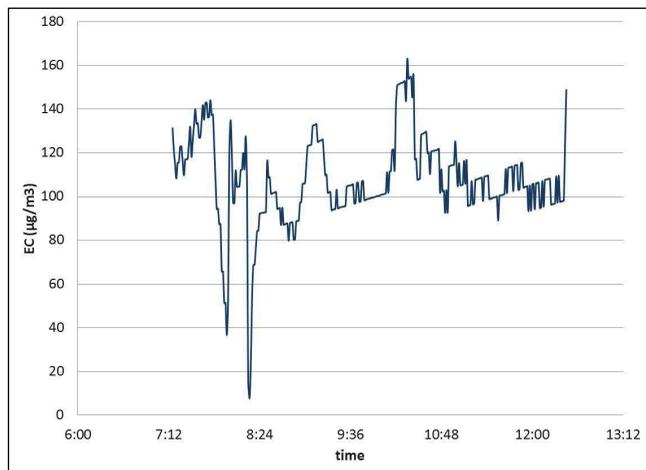
*Figure 2: Real-time DPM graphs before administrative controls were implemented. When determining the concentration of DPM in the mine where and when the blasters were working, it is important to note that the blasters' truck was not in the mine when the concentration of EC was around 0; hence the DPM samplers, which were attached to the truck, were collecting in fresh air at this time.*

size cut. Conductive tubing allows EC to reach the Teflon filter without sticking to the tubing walls. The Teflon filter is housed in a specially designed cassette that has a defined volume chamber as well as a carefully constructed flow path to achieve uniform distribution of EC on the Teflon filter.

A laser penetrates through the sample while collecting DPM, and the absorption of the laser's energy is measured and converted to  $\mu\text{g}$  of EC collected on the filter using a calibration curve. EC was chosen as the analyte because it makes up a major portion of DPM, is not prone to interferences, and is one of the surrogates used by MSHA for compliance sampling. Filter-based laser extinction was determined to be a feasible method because EC concentrations are proportional to laser absorption and because this simple technique can be adapted into a small instrument.

## Baseline Testing

Before the administrative controls were implemented but after the DPM emission controls, DPM concentrations were measured in the area where the blasters were working by attaching NIOSH method 5040 samplers and an Airtec to the blasters' truck. The surrogates used by MSHA for DPM compliance (EC and TC) were measured. NIOSH method 5040 samplers provided the average EC and TC concentrations for the entire shift, and Airtec instruments provided the average and real-time EC data. One reason why TC is used as a surrogate is because DPM is usually over 80 percent TC, and EC is used because it is selective to DPM and typically the TC/EC ratio is around 1.3 in mining. The PEL is a TC concentration ( $160 \mu\text{g}/\text{m}^3$ ).



**Figure 3:** An example of a real-time DPM graph after administrative controls were implemented. The concentration of DPM was less than 150 µg/m<sup>3</sup> EC most of the time. When determining the concentration of DPM in the mine where and when the blasters were working, it is important to note that the blasters' truck was not in the mine when the concentration of EC was around 0; hence the DPM samplers, which were attached to the truck, were collecting in fresh air at this time.

Two consecutive days of baseline testing verified that the blasters could be exposed to concentrations of DPM over the PEL. The average concentration of TC in the area where the blasters were working was 227 µg/m<sup>3</sup> TC on day 1 and 273 µg/m<sup>3</sup> TC on day 2 according to NIOSH method 5040 samples. As seen in Figure 2, the real-time data shows concentrations consistently above 200 µg/m<sup>3</sup> EC (which would correspond to about 260 µg/m<sup>3</sup> TC) in the area of the mine where the blasters were located for the two days of baseline testing.

## Administrative Controls

In an attempt to reduce DPM concentrations, administrative controls were employed at the mine. These administrative controls included operating high-DPM-emitting vehicles away from the blasters. First, the main contributors of DPM in the area of the blasters were identified by performing tail-pipe analysis via Bacharach smoke dot test on vehicles operating at the same level of the mine as the blasters. The Bacharach smoke dot test entails passing a known volume of diesel engine exhaust through a strip of filter paper, which forms an exhaust deposit spot. Based upon its shade of darkness, a number is then assigned to the spot by comparison with the standard smoke spot scale. The assigned number ranges from zero to nine; zero represents the least amount of DPM emitted, and nine represents the highest DPM.

This mine was a split level mine. The diesel equipment routinely operating at the same level as the blasters was two jumbo drills, a scaler, a blasters' truck, a loader and two haul

trucks. According to smoke dot test, the blasters' truck generated minimal emissions due to the Huss DPF (smoke dot number of 0). Each of the other types of vehicles contributed to the DPM emissions (smoke dot number of 2.5-3) with one of the haul trucks (smoke dot number of 7) and jumbo drills (smoke dot number of 8) being higher emitters.

An administrative control instituted was a second shift where the haul trucks, some loaders and utility trucks would operate, thus limiting the number of vehicles generating emissions during the shift when the blasters worked. In addition, the drills and scalers, which can be high DPM emitters, were operated in entries that would not be occupied by blasters for at least several hours (or an entire shift when possible). This time lapse allowed the DPM to clear out of the areas before the blasters entered. Finally, the drill and scaler ran downstream of blasters as much as possible.

## Post-Analysis

After the administrative controls were implemented, NIOSH method 5040 samplers and an Airtec were placed on the blasters' truck for eight different shifts. When the administrative controls were adhered to, the average concentration of DPM was 163±27 µg/m<sup>3</sup> TC, and five out of six samples would have been in compliance if personal samples would have been obtained. As seen in Figure 3, the real-time data shows that the EC was below 150 µg/m<sup>3</sup> most of the time compared to being over 200 µg/m<sup>3</sup> during the baseline testing. Taking into account the average concentrations of the baseline vs. post-analysis, approximately a 35 percent reduction in DPM was observed when the administrative controls were followed.

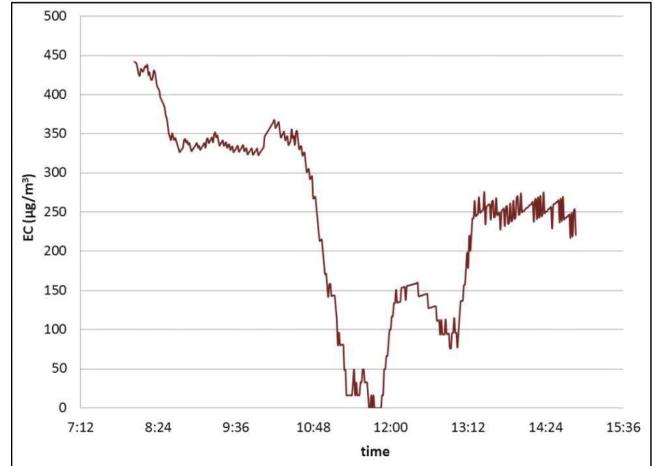
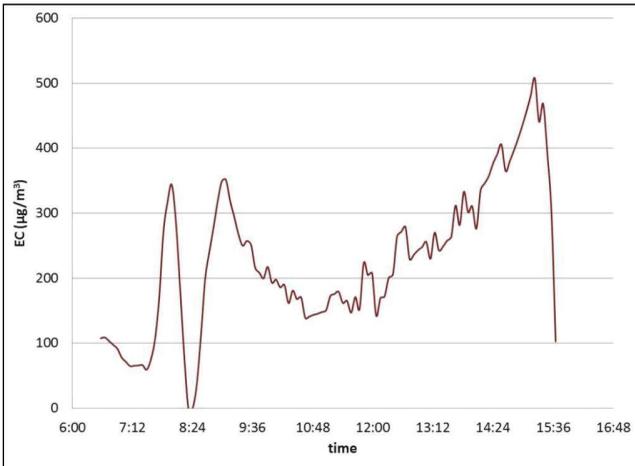
In two days of post-analysis, it was realized that not all of the administrative controls were being strictly kept. On one day a loader and truck were operating upstream of the blasters and on the other day multiple vehicles including the drill (high DPM emitter) were operating upstream of the blasters. This resulted in the average concentration of DPM being over the PEL (235 µg/m<sup>3</sup> TC on day 1 and 240 µg/m<sup>3</sup> TC on day 2).

## Administrative Controls With Real-Time Monitoring

Real-time graphs, as seen in Figures 3 and 4, identified when the blasters were experiencing higher DPM exposures. The real-time data collected when vehicles were operating near the blasters showed higher concentrations of DPM than the data collected when the administrative controls were followed. This shows that by using a real-time monitor, blasters can be warned that elevated concentrations of DPM are in their work area before an overexposure occurs.

The blasters could wear or have in their proximity an Airtec which provides a warning when the DPM concentration is too high. Another way of using the Airtec is to have mine man-

“ By using a real-time monitor, blasters can be warned that elevated concentrations of DPM are in their work area before an overexposure occurs. ”



agement take readings in areas before the blasters enter to ensure that elevated levels of DPM are not present. These measurements would allow corrective actions to be applied quickly or allow the blasters to avoid areas of elevated concentrations of DPM. Since this study occurred, the management at the study mine has improved the implementation of administrative controls, and the blasters have been in compliance. ▲

Figure 4: Real-time DPM graphs on two days when there was a breakdown in the administrative controls. When determining the concentration of DPM in the mine where and when the blasters were working, it is important to note that the blasters' truck was not in the mine when the concentration of EC was around 0; hence the DPM samplers, which were attached to the truck, were collecting in fresh air at this time.

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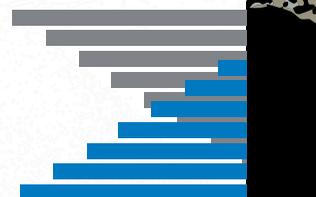
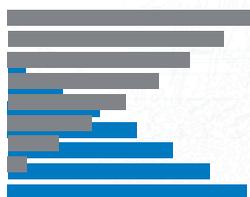
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## Rock Products Celebrates Young Leaders

**R**ock Products has its eyes on the future of the aggregates industry, which will be, without question, in the hands of its Young Leaders.

To that end, we will be sponsoring the National Stone, Sand and Gravel Association's Mark S. Walsh Annual Leadership Award – presented each year at the Young Leaders annual convention – to an individual who exemplifies the leadership traits of professionalism, enthusiasm and commitment, and whose efforts in improving and developing the image and programs of the Young Leaders are in keeping with the example set forth by the honoree of this award.

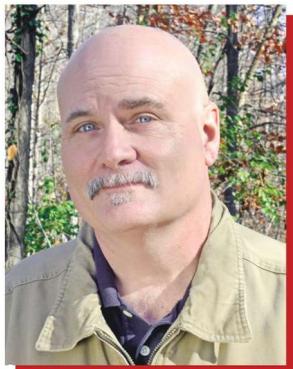
At AGG1, *Rock Products* is also sponsoring the first annual Young Leaders Luncheon. Dave Turin of Discovery Channel's "Gold Rush" television series will be the keynote speaker at the event, and his presence is thanks to the generous sponsorship of Superior Industries. Turin will discuss the importance of attracting and retaining talented young leaders for the aggregates and mining industries.

While many people are aware of his involvement in the gold mining industry, not as many know that his background is squarely in aggregates.

A former high school and college football star, Turin earned a Civil Engineering degree before joining the family aggregates business, Mt. Hood Rock. Turin has managed the asphalt production and rock quarry company with his father and three brothers for more than two decades. In 2010, hometown friends brought him in as an outside consultant at their Porcupine Creek, Alaska, gold prospecting claim. He helped the rookie miners get their operation running and was inspired by their dream of mining for gold. Turin was offered the chance to join the team full time and has regularly appeared on "Gold Rush" since its second season.

You can read an exclusive interview with Dave on page 22 of this issue.

The complimentary luncheon is open to all registered AGG1 attendees, 40 years of age and younger. This event will require attendees to pre-register, and attendance will be capped at 200.



We look forward to seeing you there, and to celebrating the critical contributions of the aggregates industry's Young Leaders.

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