Diesel Particulate Matter

Where does it come from? How is it present in mining?
Diesel emissions are a complicated mixture of chemicals and particulates. They can be broadly categorized into a particulate phase and a gas/vapor phase, where each contains both organic and inorganic components. The particulate phase of diesel exhaust includes clusters of respirable particles (i.e., sizes that can be inhaled into the lungs) composed mainly of carbon and are termed "diesel particulate matter" (DPM). A variety of chemicals are contained within or adsorbed onto the diesel particulate matter, which has the potential to affect the toxicity of the particulate. The major constituents of the gas/vapor phase include carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), aldehydes and many polycyclic aromatic hydrocarbons (PAHs). The gas phase is composed of many of the urban hazardous air pollutants, such as acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde and polycyclic aromatic hydrocarbons.

Diesel particulate matter also has many different types of particles that can be classified by size or composition. The size of diesel particulates that are of greatest health concern are those that are in the categories of fine, and ultra fine particles which can get deep into the lung when inhaled. The composition of these fine and ultra fine particles may be composed of elemental carbon with adsorbed compounds such as organic compounds, sulfate, nitrate, metals and other trace elements. In mining, the most common exposures to diesel particulate matter occur underground with the use of diesel-powered equipment (e.g., mucking equipment, locomotives, etc.).

What are the primary health effects from exposure to Diesel Particulate Matter?
Short term exposure to high concentrations of diesel exhaust can cause irritation to the eyes, nose, throat and lungs and some neurological effects such as lightheadedness. High levels over a short period of time can also cause coughing and/or nausea. Diesel exhaust can make asthma worsen and cause allergies. Long term exposure in experimental animal studies showed a range of dose dependent lung inflammation and lung cell changes. Based upon human and laboratory studies, there is evidence that diesel exhaust is a carcinogen.

What are the occupational exposure limits for Diesel Particulate Matter?
30 CFR Part 57.5060 provides current guidance on the Mine Safety and Health Administration standard for diesel particulate matter. Effective May 20, 2008, a miner's exposure to diesel particulate matter (DPM) in an underground mine must not exceed an average eight-hour equivalent full shift airborne concentration of 160 micrograms of total carbon per cubic meter of air (160 ug/m^3 as total carbon).

How often shall I complete exposure measurements for Diesel Particulate Matter?
If your mine operates diesel equipment, particularly underground, you are required to complete diesel particulate matter air sampling. 30 CFR Part 57.5060 requires that exposure surveys be conducted *as frequently as necessary* to determine the adequacy of control measures. It is standard practice to sample initially (called a baseline evaluation) to determine potential exposure concentrations. Routine or periodic monitoring (usually annually) is also recommended. Sampling may need to be done more often if the tasks change, if engineering controls change, or if sampling results are above the "action limit" which, for most chemicals, is defined as 50% (or half) of the TLV.

How do I measure potential exposure to Diesel Particulate Matter?
NIOSH Method 5040 is used to estimate diesel particulate matter exposures in terms of total carbon (total carbon = elemental + organic carbon). This method uses either a 37-millimeter heat-treated quartz fiber filter or a precision-jeweled impactor that allows for collection of <0.1 micron particle sizes of diesel particulate matter to intentionally exclude extraneous dusts, coal dusts and other elemental carbon interferences. A GS-1 cyclone can be added to the precision-jeweled impactor for environments where larger particles are likely to clog the jeweled impactor.

The flow rate of the air sampling pump is set at 1.7 liters per minute (metal/non-metal mines) and 2.0 liters of air per minute (coal mines). The acceptable volume for each quartz filter or jeweled impactor is 142 – 19,000 liters of air. Analysis is performed by evolved gas (EGA) by a certified laboratory. Calibration of the jeweled impactor with the GS-1 cyclone requires a specialized calibration jar. Blank samples should be sent to the laboratory with the exposure samples. Blank samples should be handled the same way as the exposure samples without collecting any volume of air onto the filter media.

Once the laboratory provides you with the mass of diesel particulate matter in milligrams measured on the filter and in the solution, you can calculate the air concentration as:

$$C = \frac{M}{Q \times T}$$

where C is the concentration of diesel particulate matter in mg/m^3, M is the mass of diesel particulate matter measured on the filter in mg, Q is the pump flow rate in liters per minute and T is the total time of sampling in minutes. Note that many laboratories will do this calculation for you if you provide the flow rate and total sample time or the sample volume on your chain of custody. Many laboratories will also loan you the necessary equipment to obtain the samples and provide you with the filter media.

Certified laboratories that can assist with measuring Diesel Particulate Matter:
Galson http://www.galsonlabs.com/
Analytics Corporation http://www.analyticscorp.com/

How do I control exposures to Diesel Particulate Matter?
30 CFR Part 57.5060 requires the mine operator to install, use, and maintain feasible engineering and administrative controls to reduce a miner's exposure to or below the DPM limit. When engineering and administrative controls do not reduce a miner's DPM exposure below the current standard, controls are infeasible, or controls do not produce significant reductions in DPM exposures, respiratory protection must be used.

While respirators should not be exclusively used to control DPM exposures, a half or full-face negative pressure, tight-fitting respirator with high-efficiency particulate cartridges (at least N95) combined with an organic vapor chemical cartridge or multi-chemical cartridge can be used to help reduce exposures.

It is important to note that mine operators have a variety of tools available to control diesel particulate matter exposures. It is most feasible and common for a combination of exposure controls (i.e., ventilation, environmental cabs and administrative controls) and exhaust reduction strategies (i.e., diesel engine design, maintenance, biodiesel use, and after-treatments) to be applied to achieve compliance with the current regulation.

References:
Metz EA. *Diesel Particulate Matter – So What's the Big Deal.* SME Annual Meeting – Denver. February 2001. He C, Ge Y, Tan J, You K, Han X, Wang J, You Q, Shah An. *Comparison of carbonyl compounds emissions from diesel engine fueled with biodiesel and diesel.* Atmospheric Environment 2009;43(24):3657-3661.
United States Environmental Protection Agency, Air Toxics in New England, www.epa.gov/region1/ecol/diesel, 2011.
United States Department of Labor, Mine Safety and Health Administration, 30 CFR Part 57.5060, "*Limit on Exposure To Diesel Particulate Matter*", 2006.
National Institute for Occupational Safety and Health, Manual of Analytical Methods, Fourth Edition, Method 5040, *Diesel Particulate Matter as Elemental Carbon)*, August 15, 1994.
United States Department of Labor, Mine Safety and Health Administration, "*Diesel Particulate Matter Control Strategies*", www.msha.gov/01-995/2009Docs/DPMControlStratgies.pdf. October, 2010.