Dust Management – Thinking Outside the Square

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ABSTRACT

Dust emissions from mining, material processing and ship loading operations (fugitive dust sources) are an environmental issue of increasing concern to both government regulators and the community. The main concerns relate to potential amenity, health and environmental impacts from the emissions. Therefore it is imperative that mining/ processing operations, as part of their overall environmental management, reduce fugitive particulate emissions to as low a level as is practicably possible.

This technical paper outlines the mechanisms that lead to fugitive particulate emissions, the importance of understanding the exact cause of fugitive emissions, monitoring methods that can be used to quantify the emissions from specific sources, the use of atmospheric dispersion modelling in dust management and innovative dust management strategies including predictive meteorology and proactive management.

INTRODUCTION

Dust emissions from mining, material processing and ship loading operations are an environmental issue of increasing concern to both government regulators and the community. The main concerns relate to potential amenity, health and environmental impacts from the emissions. If fugitive particulate emissions are perceived to be significant then a facility may face increased regulatory requirements, more stringent environmental licence conditions and poor community relationships, which may potentially impact on the continuing operation of the facility. Therefore it is imperative that mining operations, as part of their overall environmental management, reduce fugitive particulate emissions to as low a level as is practicably possible.

Currently, a variety of methods are used to reduce particulate emissions. These range from engineering solutions such as enclosing the source, installing wet or dry scrubbers and conveyor belt washing, to traditional methods of dust suppression using water cannons and water trucks. However, it is becoming increasingly apparent that the dust reduction methods being utilised are insufficient to reduce particulate emissions down to a level that is acceptable to either the community or the regulators.

This technical paper outlines the mechanisms that lead to fugitive particulate emissions, the importance of understanding the exact cause of such emissions, and monitoring methods that can be used to quantify these emissions from specific sources. The use of atmospheric dispersion modelling in dust management and innovative dust management strategies including predictive meteorology and proactive management will also be discussed.

PARTICLE SIZE DEFINITION

Typically, particulate matter is characterised by its size as measured by collection devices specified by regulatory agencies. The particulate size ranges routinely specified in ambient air criteria are total suspended particulate (TSP), particulate matter below ten microns (PM_{10}) and particulate matter below 2.5 microns ($PM_{2.5}$).

TSP refers to particulate that can remain suspended in the air or can be measured though a TSP sampler. This particle size does not correspond to a fixed physical size, but varies, as the size of particle that can remain suspended in the air is a function of air turbulence. Under strong winds and over rough surfaces, particles with aerodynamic diameters up to 100 microns can remain suspended, while under lighter wind conditions these particles will typically fall out within several minutes.

The aerodynamic diameter is the diameter of a sphere of density 1 gm/cm^3 that has the same settling velocity as the particle of concern. Aerodynamic diameters are used to standardise particle sizes because particle settling velocity, and the ability to penetrate into the respiratory tract (or be separated by a sampling head), are dependent on the size, shape and density of the particle. For example, an iron ore particle of physical size of 4.5 microns with density 5.2 g/cm^3 will behave as an aerodynamic particle of approximately ten microns.

PM_{10} and $PM_{2.5}$ particles are those that are sampled with PM_{10} and $PM_{2.5}$ samplers, which have a 50 per cent cut point at ten and 2.5 microns respectively. An illustration of the size of a particle of ten and 2.5 microns diameter in relation to a human hair is presented in Figure 1.

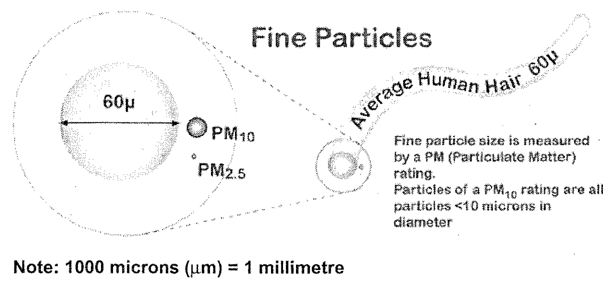

FIG 1 - Example of particle sizes (Queensland Environmental Protection Agency (EPA), 2009).

DUST GENERATION OVERVIEW

Ore mining, handling, processing and transport activities generate dust through either wind action or the physical movement of ore through mechanical processes.

Wind generated dust occurs when the wind speed exceeds a 'threshold' velocity (nominally in the five to 10 m/s range) for erosion of the underlying surface. Under these conditions, particles greater than 100 microns in diameter that protrude above the surface are dislodged by shear forces and bounce and creep across the surface. These particles (through their bouncing or skipping motion) can dislodge smaller particles, which then remain suspended in the air. The amount of particulate matter generated is highly dependent upon the wind speed: below the wind speed threshold, no particulate matter is generated, while above the threshold, particulate matter generation tends to increase with the cube of the wind speed.

The amount of particulate matter generated by wind is also dependent on the material's surface properties. This includes whether the material is crusted, the amount of non-erodible particles present (particles greater than several millimetres that tend to protect the smaller particles) and the size distribution of the material (Sinclair Knight Merz (SKM), 2005).

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Mechanical processes that generate and potentially release particulate matter include comminution (crushing, screening and grinding), material movement (transfer points, stacking, reclaiming and ship loading), blasting and vehicular movement over unsealed or dust laden surfaces. The amount of particulate matter generated from these processes is less dependent on wind speed in comparison to wind erosion, but is more dependent on the moisture properties of the material being transferred, the particle size distribution of the material, drop heights and the dust management measures and emission controls in place for the sources (SKM, 2005).

A range of methods are available to measure and characterise the 'dustiness' or dust generation tendencies of various ores during handling processes.

EMISSION CHARACTERISATION

Emission characterisation is one of the critical steps in dust management as you cannot manage what you do not know. It is essential for any facility that is trying to reduce dust emissions and related impact to fully understand the processes that lead to emissions.

The potential emission characteristics of an ore can be determined before mining and processing by using well established laboratory tests. Ideally the results of the tests are used collectively to determine the potential for both mechanical and wind generated emissions. For a facility already in operation it is advisable that field measurements be used to complement the laboratory testing to fully understand the sources and causes of emissions.

The preferred laboratory tests and the methodology to conduct the field measurements are outlined in the sections that follow.

Laboratory testing

Laboratory testing can be used to determine the emission characteristics of ore. The first two processes outlined below are used to determine the relationship between dust emissions, moisture content and flow characteristics and result in understanding the optimal moisture range for a specific product. The third and fourth processes described are used to determine the wind erosion potential of the ore. These tests can assist in determining potential emissions before material handling commences, therefore allowing for appropriate dust reduction strategies to be incorporated during the initial design phase, and reducing the need to retrofit dust reduction equipment.

Rotating drum test

One of the first laboratory tests that can be conducted is a rotating drum test to determine the dust extinction moisture (DEM) of each ore type. This test determines the dust/moisture relationship for the ore. This relationship can then be applied to understanding the potential emissions from each ore type during material handling processes across a range of moisture contents. This test was originally designed to determine the dust/moisture relationship for coal and has now been successfully used for iron ore (Standards Australia, 2000).

Durham cone test

In addition to the rotating drum test it is recommended that a Durham Cone test is conducted. This test assists in determining the moisture concentration in which flow handling issues becomes apparent and will define the upper limit of the moisture band (Standards Australia, 2002). An example of how the optimal moisture range is determined using these two tests is presented in Figure 2. From this figure it can seen that the DEM for this product occurs at approximately six per cent moisture

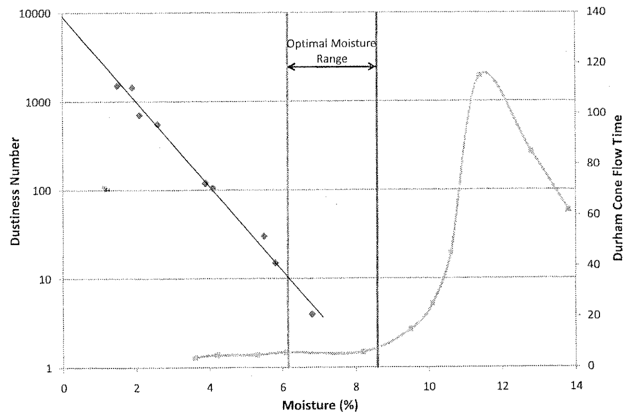

FIG 2 - Example of how the optimal moisture range of a product is determined.

while material handling issues start to be encountered above a moisture content of 8.5 per cent. Therefore the optimal moisture range for this product is from six per cent to 8.5 per cent.

Wind tunnel testing

To assist in understanding the wind erosion potential of various products it is advisable to conduct wind tunnel testing. This testing will determine the minimum wind speed at which various ores will begin to become an issue and allow for various management strategies to be incorporated to reduce or eliminate this type of emission.

Particle sizing

A further test that can be conducted to help assess the dust potential of an ore product is particle sizing. This is test involves sieving the product and determining the percentage of material that is classified as 'ultra fine' or below approximately 15 microns. Particles below this size have two issues:

1. increased surface area creating issues in achieving the correct moisture concentration; and
2. susceptibility to wind erosion, especially during stacking and shiploading.

FIELD MEASUREMENT

One of the methods available to characterise the emissions from a facility is site specific monitoring. This technique involves sampling a dust plume downwind of the source to generate dust profiles. These dust profiles along with measurements of the wind speed, distance down wind and atmospheric stability can then be used to estimate the dust emission rate for that particular source.

To obtain a comprehensive understanding of the emissions from each source, transects of the dust plume are conducted over a range of wind speeds and, if applicable, product types. An example of how the emission rate from a transfer station changes with wind speed is presented in Figure 3 for different products. The figure shows that the emission rate for product two (upper curve), increases with increasing wind speed at a greater rate, than that for product one (lower curve). An empirical equation that represents the line of best fit (as derived from the site testing) is determined and used to represent the emissions for each product from the transfer station.

If the emission rate is found to vary with the moisture content of the ore, there is the capacity for this to be incorporated into the equation.

When all the sources at a facility have been characterised, the equations derived can be used to determine the emission rate for

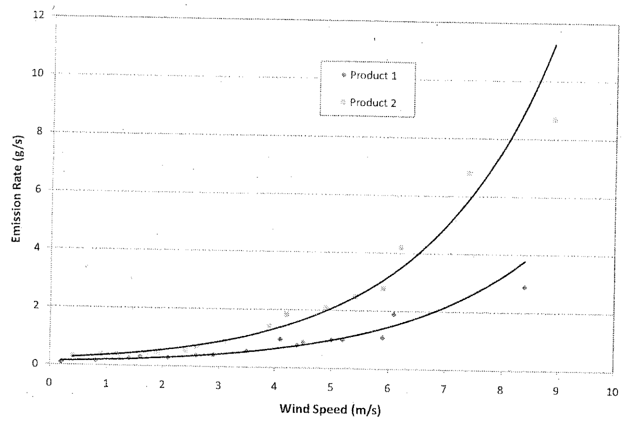

FIG 3 - Example of how the emission rate from a transfer station changes with wind speed.

each source for every hour of the year. Sources from a facility may include, but are not be limited to, the following:

- car dumpers,
- conveyors,
- transfer stations,
- crushing/screening,
- stacking/reclaiming,
- ship loading operations,
- wind blown dust from exposed areas and stockpiles, and
- wheel generated dust from roadways.

ATMOSPHERIC DISPERSION MODELLING

Atmospheric dispersion models, if applied correctly, have the potential to be extremely valuable tools in assisting to reduce dust emissions. Essentially there are three different ways that modelling can be applied. These three methods are outlined in the sections that follow.

Emission reduction

To effectively use a dispersion model for emission reduction, the information obtained from both the field and laboratory testing needs to be integrated. This ensures that the dispersion model accurately reflects the emission sources from a given facility. From here, the most appropriate and cost-effective reduction strategies targeted at the largest emission sources can be identified and then implemented.

There are a number of dispersion models that can be used to predict the ground level concentrations that result from a facility and its operation. The choice of model can be dependent on the complexity of the terrain around the facility, the availability of meteorological data and the type of sources within the facility. For a site surrounded by relatively flat terrain, regardless of the availability of meteorological data, the Victorian Environmental Protection Agency (EPA) Gaussian plume model AUSPLUME is suitable. For a site located within complex terrain then the United States Environmental Protection Agency (USEPA) model CALPUFF may be more applicable (Department of Environment and Conservation (DoE), 2006).

Regardless of the type of model that is used, the basic methodology remains constant. The model is run using the calculated emission rates for all sources within the facility and the predicted ground level concentrations are determined for applicable receptors, such as a residence or site of significance. Ideally the model is validated against monitoring data to determine the accuracy of predicted concentrations. This validation process requires a minimum of one year of monitoring data and it is preferable that the monitoring data is from at least two monitoring locations. Ideally, the first monitor should be located at a sensitive receptor while the second should be a background monitor situated well away from the facility. Such a site is essential in determining the background dust concentration within the area and will assist in determining the dust concentration attributable to the facility.

Once the model has been validated and there is sufficient confidence that the calculated emission rates accurately reflect what is occurring at the facility, the next stage of the modelling process can commence. This stage involves determining the contribution of each individual emission source to dust concentrations at the sensitive receptor. An example of this process is presented as a pareto graph in Figure 4. The results in this figure are ranked by the 99th percentile ground level concentration. When interrogating the modelling results it is important to concentrate on the lower statistical values, as opposed to the maximum value, as these represent a greater frequency of occurrence.

In the conceptual case presented in Figure 4 it is noticeable that although the wind erosion source has the highest predicted maximum concentration, it has lower predicted concentrations at the 99th, 95th, 90th and 70th percentiles as well as the annual average when compared to emissions from the crusher. When the lower statistics are compared it is also apparent that vehicle activity on the ROM pad also has a greater impact on the receptor than the wind erosion source.

Having identified the significant dust generation contributors at the receptors of interest, the next step is to focus on targeted control measures. This is accomplished by using an analysis such as presented in Figure 4 and determining why each of these sources is dusty when considering dust reduction strategies. Examining the reasons for the dustiness of identified sources is imperative to ensure the most relevant reduction mechanisms are implemented. An example of this would be a facility installing a wet scrubber to reduce dust emissions, when the major source of dust is inspection hatches that have been left open. Where a facility has multiple sources impacting a receptor it may be preferable to concentrate on the top ten to fifteen impactors to simplify the process.

When examining the reduction strategy for each source, it is imperative to determine the cost of implementing that strategy to ensure that the facility receives the most effective reduction. For example, if strategy A was to reduce dust from the crusher by 40 per cent and would cost 20 million dollars, while strategy B was going to reduce dust from the same source by 30 per cent but would only cost one million dollars, it would be preferable to implement strategy B and utilise the remaining budget to implement reduction strategies for other sources.

REAL-TIME MODELLING

Using the validated dispersion model developed in the previous section together with operational process information and real-time meteorological data there is the potential for a facility to monitor their emissions and determine their impact in real-time. By using real-time modelling a facility can monitor the emission rate from multiple sources thereby determining which process is resulting in the highest emissions and taking corrective action before it becomes an issue. To work effectively, the modelling program should be commissioned to send an alarm to site personnel if the emission rate and wind direction indicate that a receptor may be adversely impacted.

PREDICTIVE MODELLING

Although real-time modelling can be incorporated into the dust reduction strategy for a facility it is still a reactive method. These methods will always require the prompt attention of personnel to initiate the chosen controls and as the alarms are only activated

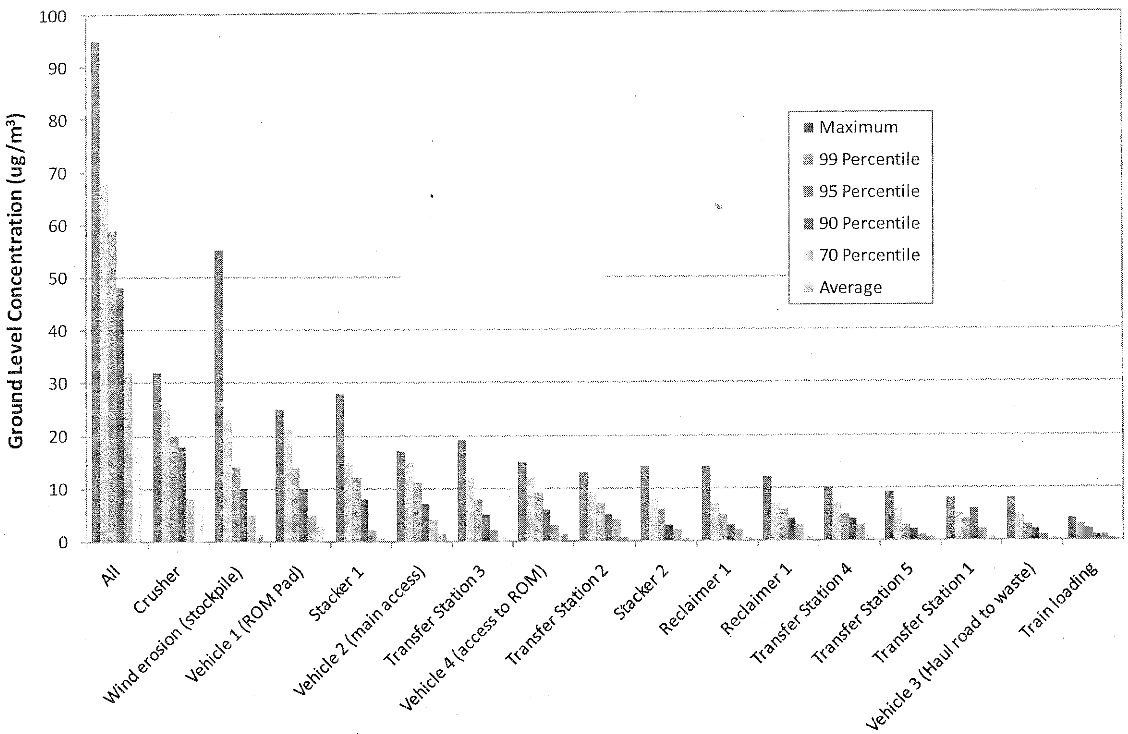

FIG 4 - An example of the impact at a receptor from individual dust sources.

once certain conditions are met it is possible that the reduction strategies initiated may be too little too late. As such it is preferable to know 24 to 48 hours in advance if the expected meteorological and operating conditions are conducive to a facility having an issue at a receptor.

To use this forecasting capability to its full potential, the results of the model should be analysed by another program that references the facility's dust management plan. This ensures that not only are the results of the model interpreted with respect to the various reduction strategies that a facility has, but that the appropriate personnel are notified. The notification includes what action is required to be completed by what time to prevent high emissions from occurring. This is a cost-effective approach to dust management that is supportive of sustainability concepts.

CONCLUSION

The first critical step towards reducing dust emissions for any facility or operation is emission characterisation you cannot manage what you do not know. This can be achieved through both laboratory testing and field measurements. To optimise understanding and support decision making, laboratory testing should include rotating drum and Durham Cone testing to determine a product's optimal moisture range and particle size analysis and wind tunnel testing to assist in determining the wind erosion potential. The field measurements ensure that a comprehensive picture of the emissions from each source is determined by wind speed, product type and moisture.

Incorporating the laboratory results and field measurements in an atmospheric dispersion model assists in determining which sources from a facility are impacting various sensitive receptors. From here the most appropriate and cost-effective reduction strategies targeted at the largest emitters can be identified and implemented.

The atmospheric dispersion models should also be used as part of a facility's ongoing dust management plan. These models can be used in either a real-time mode to monitor for high emissions and adverse meteorological conditions so that corrective action can be implemented, or in a predictive mode which allows a facility to determine their potential impact 24 to 48 hours in advance. Predictive modelling has the potential to greatly assist facilities in reducing their dust emissions to an acceptable level.

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