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Peter Wypych

*University of Wollongong*, [wypych@uow.edu.au](mailto:wypych@uow.edu.au)

Leong Mar

*DuPont Australia Ltd.*

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### Abstract

The mining industry, minerals processing, transport and export infrastructure sectors are facing increasingly difficult challenges in the near future, such as sustainable development and operation (e.g. environmental emissions, social/ cultural impacts, economics). This paper describes some of the new technologies that are being researched, developed and employed to minimise dust emissions by addressing dustability and dust generation mechanisms. It also presents some results from the research being undertaken on the measurement of the dustiness of bulk materials.

### Keywords

bulk, dustiness, into, investigations, materials

### Disciplines

Engineering | Science and Technology Studies

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# Investigations into the dustiness of bulk materials

By Peter Wypych, Faculty of Engineering, University of Wollongong and Leong Mar, DuPont Australia Ltd., Sydney

## Abstract

The mining industry, minerals processing, transport and export infrastructure sectors are facing increasingly difficult challenges in the near future, such as sustainable development and operation (e.g. environmental emissions, social/cultural impacts, economics). This paper describes some of the new technologies that are being researched, developed and employed to minimise dust emissions by addressing dustability and dust generation mechanisms. It also presents some results from the research being undertaken on the measurement of the dustiness of bulk materials.

## Introduction

Fugitive dust emissions from the mining, processing, storage, handling, transportation and loading/unloading of bulk materials are creating an increasing number of problems for industry, the community and the government. For example:

- Loss of valuable material and export income.
- Increasing workplace dust emissions (e.g. mine sites, loading, receipt, ports, bulk berths).
- Increasing direct costs to industry: dust monitoring/testing; control, maintenance and housekeeping; premature failure of components; shutdown of process/plant; fines and prevention notices; project rejections (e.g. new mine applications).
- Deteriorating ambient air quality and human health for workers and nearby communities.
- Residential complaints (e.g. dust fallout onto the community and its properties).
- Build-up of dust layers and further dust lift-off along road/rail routes, underneath conveyors, etc.
- Tighter air quality objectives being set by the regulators for protection of both health and amenity, requiring more sophisticated control and monitoring methods.
- Increasing integration of bulk transport/export infrastructure with residential communities.
- Increasing number of government authorities, legislation and legal actions to deal with the above issues (e.g. new departments, acts, regulations).

The above problems are exacerbated as larger quantities of bulk material are mined, processed and handled, and especially as the product becomes finer and more difficult to handle. The common (traditional) ways to control dust emissions include:

1. General ventilation (i.e. dilution of dust concentration) is considered as a last resort control option.
2. Containment (usually with integral filtration).
3. 'Push-pull' systems (using the 'air-knife' concept).
4. Dust suppression veneer treatment (via water, chemicals, additives and/or foam): sealing exposed product surfaces on rail wagons trucks, stockpiles, etc.
5. Water spray or misting systems trying to suppress airborne dust particles on stockpiles, conveyor transfers, train loading/unloading).
6. Dust agglomeration (via ionisation or ultrasonics).
7. Local exhaust ventilation (LEV), also known as dust extraction, with dust filtration (e.g. baghouse and fan).
8. Wind barriers or diffusers (e.g. tress, mesh, walls, mesh).
9. Vegetation (e.g. grass, shrubs) to help capture/trap and minimise the dispersion of airborne dust over large flat areas.

Most of these dust control measures really only treat the symptoms of dust generation and are considered as protection methods (i.e. they do not deal with the root cause/s of the problem). They also have been found to be relatively inefficient in terms of controlling fugitive dust emissions. For example:

- LEV requires suction/vacuum flows, which are relatively inefficient in capturing airborne dust;
- Traditional water spray/misting nozzles are inefficient in dealing with fine dust, associated air flows and external disturbances, such as cross winds;
- Dust suppression veneers need to be re-applied whenever the treated product surface is broken or disturbed (e.g. after loading and unloading trucks and rail wagons, stacking and reclaiming stockpiles).

The following areas have been identified to be some of the main causes or 'offenders' of fugitive dust emissions:

- ROM hoppers in open-cut and underground mines, where product is dumped over relatively large heights and dust emissions are affected significantly by cross-winds.
- Dump hoppers in road/rail receipt stations (due to relatively large drop heights and subsequent air gusts).
- Stacker/reclaimers on stockpiles, where the product is dropped over great distances and cross-winds can affect dust emissions significantly.
- Conveyor transfers and chutes, which generally are poorly designed, especially in relation to dust control.
- Haul roads in open cut mines, where trucks continuously generate/agitate fine dust, which is then easily dispersed by cross-winds.

To achieve a step-change improvement in solving fugitive dust emission problems for the mining industry, more fundamental research needs to be done to address the application areas listed above. The following new technologies are being researched and developed for this purpose at the University of Wollongong.

1. New types of high-energy water mist/fogging systems that can be designed and optimised to suit different applications (e.g. ROM and dump hoppers, stacker/reclaimers). Mist curtain efficiency and energy need to be matched to suit product flow rates, process driven air flows and external cross-winds.
2. New calibrated and validated Discrete Element (DE) simulation modelling [1-2] of product flows to ensure a 'complete' or 'total solutions' approach to conveyor transfer and chute design/operation, so that not only product flows, but also air/dust flows, are modelled properly to help minimise dust generation at the source (i.e. target the root cause/s of the problem). With this new approach to modelling and design, it is possible to design new and modify existing conveyor transfers to achieve minimal dust operation (e.g. where the dust-laden air flows are contained inside the transfer/chute enclosure, particle impacts are minimised, etc). The size and cost of any subsequent control measures to deal with the residual air/dust are also minimised.



Figure 1: BMEA Rotating Drum Dustiness Testers: AS4156.6 [3] (left); I.S. EN15051 [4] (right).

3. Research and development of new cost-effective and sustainable dust suppression technologies for ‘total particle’ treatment, where the aim is to treat the mined product once at the mine site and retain its efficacy so that no further downstream dust suppression or control is needed. This research is being pursued in collaboration with DuPont Australia. Calibrated/validated DE simulation technology [1-2] is also being employed to ensure optimal application of the new dust suppression solution. The potential advantages of this new radical and high-tech approach are significant, where the product can be handled, conveyed and shipped with minimal dust generation. The potential beneficiaries of this new technology include:

- the mining companies (e.g. being able to sell ‘zero’ or low dust product);
- the road and rail transport network owners and operators (where dust-lift off and deposition can be a serious problem);
- the ports, terminals and shipping companies, where the ore can be handled, conveyed and loaded safely;

| Parameter                                     | AS4156.6 (2000)   | I.S. EN15051 (2006)   |
|---|---|---|
| Bulk sample size                              | 1 kg (coal) – or equiv. bulk volume (1litre)                  | 35 cm <sup>3</sup> (35 ml or 0.035 l)                                       |
| Max. particle size                            | 6.3 mm  | Not specified   |
| Ambient conditions                            | 20 deg C, 63% humidity  | 21 deg C, 50% humidity  |
| Drum diameter                                 | 300 mm  | 300 mm  |
| “Blades” inside drum                          | 7 mm wide × 6 mm high (8 off)                                 | 25 mm high (8 off)  |
| Drum speed                                    | 29 rpm  | 4 rpm   |
| Test duration                                 | 10 min  | 1 min   |
| Drum air inlet dia.                           | 40 mm   | 150 mm  |
| Suction air flow                              | 170 litres/min  | 38 litres/min   |
| Drum inlet air velocity                       | 2.25 m/s  | 0.036 m/s   |
| Superficial air velocity inside rotating drum | 0.04 m/s  | 0.009 m/s   |
| Dustiness                                     | Dust No. = Dust (g) / Sample (g) × 105 (DEM = Dust No. of 10) | Workplace Emissions: Inhalable, Thoracic, Respirable Mass Fractions (mg/kg) |

Table 1: Comparison of Existing Rotating Drum Specifications.

- the end users who do not need to worry about fugitive dust emission problems.
- A unified and science-based approach is needed for the research, development and performance quantification

of ‘total particle’ dust suppression technology for a given bulk material and application. The issues being addressed holistically by DuPont Australia and the University of Wollongong are summarised on the following page.

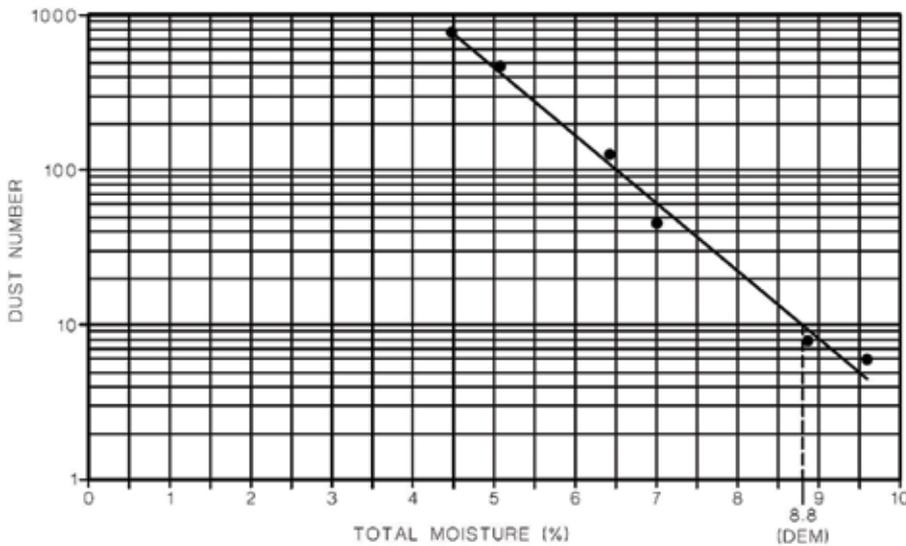


Figure 2: Dust/Moisture Curve for Coal, showing DEM = 8.8% [3].



Figure 4: Dustiness Test on Ore at 8.1% wb (DEM = 11% wb)

- Dustiness 'performance' characteristics, such as wettability, Dust Extinction Moisture (DEM), moisture retention capability of suppressants and agglomeration/adhesion properties;
- Improved dustiness testing and numerical modelling (with the aim to overcome the problems and limitations of existing standards and develop a more effective and practical methodology);
- Flowability or handleability implications (e.g. flow properties, flowability index);
- Application compatibility and health, safety and environment requirements.

Two standards that can be used to quantify the dustiness of bulk materials are: AS4156.6 [3], which was originally developed for coal; and I.S. EN15051 [4], which was developed for a wider range

of bulk materials. Figure 1 shows the two different rotating drum dustiness testers based on these standards at Bulk Materials Engineering Australia (BMEA) at the University of Wollongong and some typical materials being tested, dry sand in the AS4156.6 [3] tester on the left and dry iron ore in the I.S. EN15051 [4] tester on the right.

Examination of these two standards have identified some key differences that can influence the accuracy and validity of the results from the two rotating drum tests. The key differences are summarised in Table 1.

The amount of material required in each tester is quite different (e.g. 1000 versus 35 ml) as can be seen in Figure 1. This will affect the amount of dust collected. The differences in test duration, rotational speed and air flow also will affect the amount of dust generated/collected.



Figure 5: Dustiness Test on Concentrate at 1.6% wb

There are also some fundamental differences in the overall aim or focus of each standard. AS4156.6 [3] mainly deals with the dust/moisture relationship and how the DEM is determined for a particular bulk material. Equation (1) is used to determine the dust number (dustiness) at a particular moisture content in the experiment. The dust numbers at different moisture contents are plotted on a log/linear graph as shown in Figure 2. AS4156.6 [3] describes how an exponential trendline is fitted to the data and used to determine the DEM for the material. The DEM is defined as the moisture content at which the Dust Number is 10.

$$\text{Dust Number} = \frac{M_b - M_a}{M_s} \times 10^5$$

where  $M_b$  = Mass of filter bag and dust;  $M_a$  = Mass of filter bag; and  $M_s$  = Mass of sample placed in drum.

I.S. EN15051 [4] focusses on measuring and classifying the dustiness or dustability of a particular powder sample for workplace emissions, based on the inhalable, thoracic and respirable dust mass fractions. If the inhalable dust mass fraction is found to be > 5000

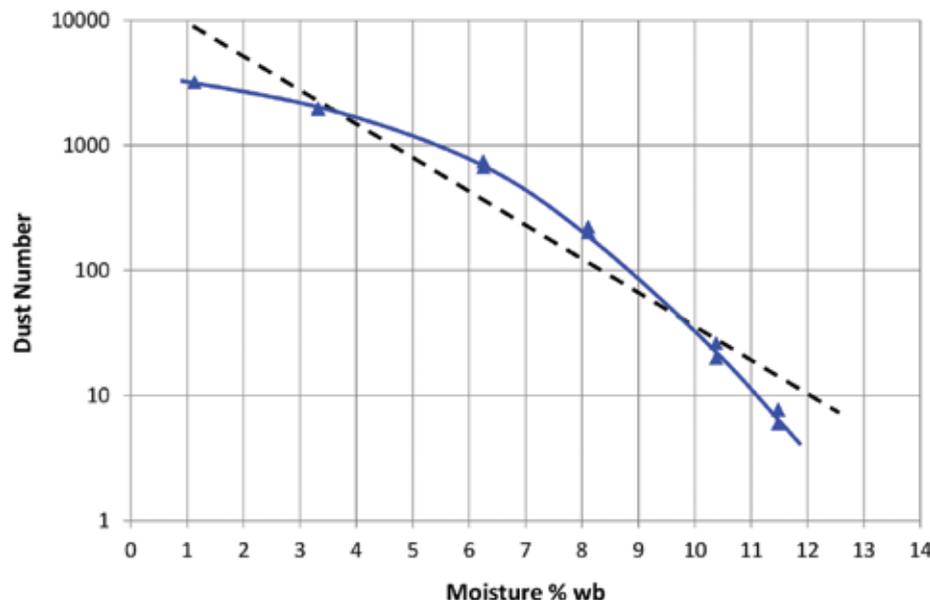
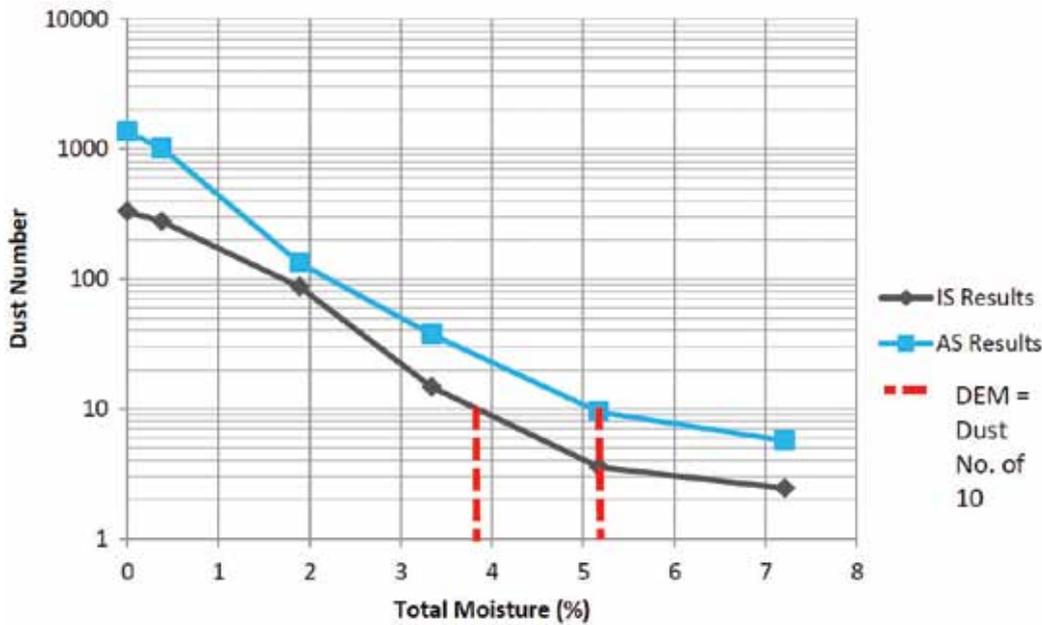


Figure 3: Dustiness and DEM of Ore based on different Curve Fitting Methods: Exponential Curve based on AS4156.6 [3] (dashed curve) and Smooth Trendline (solid curve)



mg kg<sup>-1</sup>, then the dustiness of the powder sample is classified as high [4]. Although not described in I.S. EN15051 [4], it is possible to determine a dust/moisture relationship for a particular powder by simply repeating the test for different moisture contents. Equation (2) can then be used to calculate equivalence between the two standards.

(2) Inhalable Dustiness Mass Fraction [4] = 10 x Dust Number [3]

Based on research conducted at BMEA to date, some other issues have been identified as possible limitations and/or errors sources of the two current rotating drum tests. Two potentially significant issues are summarised below.

- The exponential dust/moisture curve stipulated by AS4156.6 [3] does not necessarily occur for all bulk materials and can provide misleading results as indicated in Figure 3. The DEM for this material was determined to be 12% based on the method used in AS4156.6 [3]. However the DEM was found to be 11% based on a smoothed trendline. Based on such results, the latter approach appears more accurate and representative of bulk materials in general (i.e. as a better indicator of the actual DEM).
- At moistures approaching DEM, some adhesion of product is noticed on the inside of both rotating drums (e.g. see Figure 4, which shows a dustiness test on the same ore shown in Figure 3). Such adhesion is expected to have an appreciable effect on the results. An example of significant adhesion is shown in Figure 5.

To investigate possible differences between the two standards, side-by-side experiments have also been performed. Figure 6 provides an example of some typical results obtained on iron ore. The resulting difference in the DEM shown in Figure 6 (viz. DEM = 5.2% AS4156.6 [3] and 3.8% I.S. EN15051 [4]) indicates a significant difference in the moisture that would be required for dust control.

Some possible key improvements to dustiness testing are being investigated, such as: collecting the entire dust sample and then determining its Particle Size Distribution (PSD), so that inhalable, thoracic and respirable dustiness mass fractions can be determined; re-designing the dust chambers and transfer pipes/tubes to avoid dust deposition; investigating possible system effects via coupled DE-CFD simulation modelling of the product-air flows inside each rotating drum. Such improvements are being pursued with the overall aim of developing a reliable and practical dustiness tester that is representative of the bulk material sample and does not contain any system effects or operator dependencies.

## Conclusions

Fugitive dust emissions from the mining, processing, storage, handling, transportation and loading/unloading of bulk materials are creating an increasing number of problems for industry, the community and the government. Most of the existing dust control measures only treat the 'symptoms' of dust generation and can be considered as 'protection' technologies

New technologies are being researched and developed to achieve a

step-change improvement in solving fugitive dust emission problems for industry: new water mist/fogging system that can be optimised to suit different applications; calibrated/validated simulation modelling of product flows and also air/dust flows to quantify and target the root cause/s of the problem; sustainable dust suppression technologies for 'total particle' treatment via a unified and science-based approach.

Quantifying and knowing the dustiness of bulk materials is a key requirement for dust control. However, there are significant differences between the two current dustiness standards: AS4156.6 [3] and I.S. EN15051 [4]. Also, how the DEM is determined by AS4156.6 [3] using exponential trendlines can result in misleading results. Another potential source of inaccuracy and error occurs when adhesive bulk materials are tested in a rotating drum test, even at moistures well below DEM. Further research is being pursued for the development of a reliable and practical dustiness tester that is representative of the bulk material sample and does not contain any system effects or operator dependencies.

The unified science based approach being pursued collaboratively by DuPont Australia and the University of Wollongong is developing solutions to address the root cause(s) of dust problems. This approach is more sustainable and has greater potential for long-term success.

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