1. INTRODUCTION

While the Aide Memoir on Environmental Management Plans [1] is holistic in its approach, encompassing water, air, biological etc impacts, it contains no specific reference on how atmospheric dust impacts are to be incorporated in the planning process, or to be controlled in practice. Guideline values on air quality issued by the Chief Air Pollution Control Officer have been accepted by the Department of Mineral and Energy affairs as appropriate air quality objectives. Although current practice allows these guidelines to be applied in a flexible manner to cater for the widely differing circumstances in which mines may operate (e.g. urban versus remote desert), there is still a need in the planning phase to be able to link specific activities and processes to likely emissions and impacts.

In this contribution I will examine the potential impacts of airborne emissions, typical of mining activities. A framework will be developed for the preparation of dust control plans, which will meet the Department of Mineral and Energy Affairs requirements for Environmental Management Planning. Incorporation of air quality issues into the mine planning process will be done within the guidelines of the BATNEEC concept (Best Available Technology Not Entailing Excessive Cost).
2. BACKGROUND ON NON-TRADITIONAL DUST SOURCES

In the past decade, a number of major studies have been conducted in the USA to determine the sources of atmospheric air pollution. Generally, these studies have been initiated in response to requirements of the US Clean Air Act, when the city or region has failed to meet the National Ambient Air Quality Standards (NAAQS). In this context, it must be remembered that this failure to meet the NAAQS has persisted even after the clean up of visible emissions from the traditional smoke stack industries, using Reasonably Available Control Technology (RACM) (the USA equivalent of South Africa’s Best Practicable Means - BPM policy), or even Best Available Control Technology (BACM).

The findings of most of these studies are that 'non-traditional sources' contribute more than half of the atmospheric particulate burden. In this context, the slightly misleading term 'non-traditional' refers to any emission that is not emitted through a ducted stack (the 'traditional' control point). Included are fugitive emissions from industrial processes, wind blown dust from stockpiles and material transfer points, emissions from industrial and unpaved roadways, traffic generated dust including tailpipe emissions and road dust, area sources including domestic burning and agriculture, and natural regional background.

In such circumstances, imposition of further stringent controls on stack emissions might not only be grossly unjust, but patently ineffective, if the desired aim was to improve ambient air quality.

A way out of this conundrum is have available inventories of ALL sources of atmospheric particulate emissions, ducted and non-ducted, and not only from scheduled industries. The inventories should include for each source, among several other details, a quantitative estimate of the
emissions in terms of grams per second of particulate and gaseous pollutants. With such an inventory as a starting point, dispersion and receptor models can be applied to estimate the impacts of various sources or source categories on the environment. Rational control plans may then be devised for individual facilities in the context of their fractional contribution to the overall atmospheric burden, whether local or regional, natural or man made.

3. RELEVANCE TO THE MINING INDUSTRY

In the light of the above, it becomes essential to have quantitative estimates of the air pollution emissions from all sources, including surface mines and works.

Current good engineering practice on mines includes many facets of dust control. However, these aspects are seldom coordinated in an overall environmental control plan. A major reason for this is that methods for estimating both emission factors and effectiveness of control methods have not been readily available. Resources and standardized procedures for direct measurement of non-ducted emissions are also not readily available.

Despite these shortcomings, it is in the interests of mining companies, and a requirement of the new reality in the era of EMP, to devise dust control plans. Firstly, a rational dust control plan will allow cost-effective allocation of resources within the atmospheric pollution budget of the operation. It will assist in allocating resources to the atmospheric budget in relation to other sections of the environmental control plan. It will provide factual data in motivations to the board for capital expenditure. It will provide a rational basis for
interactions with the control authorities and surrounding communities. It will provide a credible base for environmental auditing.

4. ELEMENTS OF DUST CONTROL PLANS

Research into fugitive dust has not been a glamorous or well funded field anywhere in the world. However, a consistent long term programme has taken place at a few institutes, including the Midwestern Research Institute, Kansas City, Missouri, and Batelle Northwestern Research Institute (mainly in relation to uranium mine tailings). The recent studies mentioned above have led to a renewed interest in the field. This has led to revisions and expansion of the technical manuals of fugitive dust emission factors, dispersion models and control measures by the US Environmental Protection Agency. The following comments are based on EPA guideline documents and practices. [2,3]

5. EMISSION FACTOR ESTIMATES

The input to all dispersion models requires emission factors, to quantify the mass of material entering the atmosphere. The complexity of the physical processes involved in most fugitive dust emissions (e.g. dust generated by a vehicle wheel rolling over an unpaved surface) has prevented the development of simple mathematical physical descriptions. An alternative approach has been based on a series of empirical measurements and parameterisation of dependence on causative factors. For example, the following empirical formula has been developed for emissions of a vehicle travelling on unpaved roadways:

\[ E = 1.7 \times k \left( \frac{s}{12} \right) \left( \frac{S}{48} \right) \left( \frac{W}{2.7} \right)^{0.7} \left( \frac{w}{4} \right)^{0.5} \left( \frac{365-p}{365} \right) \] (kg/VKT)

where \( E \) = emission factor in kg per vehicle kilometer travelled (kg/VKT)
Planning inputs to use this equation would require the lengths of road segments for different uses, specification of vehicle types, traffic density and speed on each segment. These figures would in any case be needed to calculate production and for specifying vehicle purchases. The only additional parameters specifically related to environment in this formula are the number of rainfall days, and silt determinations for each road segment.

As a further example of how dust emissions may be quantified, consider materials handling. Adding aggregate material to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with front end loader are examples of batch drop operations. Adding material to a pile by a conveyor stacker is an example of a continuous drop operation. The following equation is used to estimate emissions from both batch and continuous operations.

\[
E = k \frac{(0.0016)}{(M/2)^{1.4}} \quad \text{(kg/Mg)}
\]

where
- \( E \) = emission factor kg per metric ton transferred (kg/Mg)
- \( k \) = particle size multiplier (dimensionless)
- \( U \) = mean wind speed, (m/s)
- \( M \) = material moisture content, (percent)
The particle size multiplier $k$ varies with aerodynamic diameter. 

**Aerodynamic particle size multiplier, $k$**

<table>
<thead>
<tr>
<th>Total suspended particles</th>
<th>$&lt;30$ um</th>
<th>$&lt;15$ um</th>
<th>$&lt;10$ um</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>0.74</td>
<td>0.48</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Again, production planning or actual production figures will provide the total tons handled, while moisture content is often determined for other reasons. The mean wind speed can be obtained from the climatic records for the region, thus justifying the need for this data as part of the EMP report.

Similar formulae exist for wind blown dust from paved roads, stockpiles (intermittent disturbance) and for construction and demolition activity. Emissions from blasting and from wind erosion of flat open fields (including slimes tailing dams) are less well parameterised. Erosion rates for agricultural fields and tailings dams, generally worked out on an annual basis, give an indication of material loss but are not equivalent to emission factors, as a large fraction of eroded material may be deposited within the source area. This is an aspect requiring further work, specifically within the South African mining context.

In addition to these formulae, there are published factors giving the effectiveness of various control factors, such as spraying of roadways with water or chemicals, wind breaks etc.

### 6. DISPERSION MODELS AND DUST CONTROL PLANS

Using these formulae, together with details from the proposed or existing facility, it becomes possible to quantify dust emissions. Once emission factors are available, readily available dispersion models may be used to predict the distribution of dust to the receiving environment, either as fallout (settleable) dust ($\text{mg/d/m}^2$) of airborne concentrations ($\text{mg/m}^3$).
Until recently, available models, such as the ISCST (Industrial Source Complex, Short Term) model were not able to handle settleable dust satisfactorily. The recent release of a Fugitive Dust Model (FDM), and updates (1992) to the ISCST model have filled this gap. Environmental distribution of the dust emissions can then be modelled under various scenarios, and impact or risk assessment carried out.

In addition to modelling estimates for uncontrolled sources, the impact of various control measures can be tested, taking into account control effectiveness, practicality and cost. In this way, plans can be devised to meet whatever environmental targets are appropriate.

7. DUST IMPACT ASSESSMENT

Impacts at receptor sites depend on multiple parameters which have to be assessed on a site specific basis. Simplistic compliance with a regulatory standard, while necessary, is seldom sufficient in terms of environmental planning. The nature of the material and concentrations arriving at receptor sites has to be evaluated against possible sensitivities of receptor systems, for example:

- acute toxicity to humans, animals or plants;
- chronic toxicity to humans, animals or plants;
- aesthetic nuisance value;
- soiling;
- damage to machinery;
- quality impairment by deposition of fruit and leaf crops;
- soil modification;
- accumulation of dust on pasture;
- smothering of plants;
- visibility impairment in pristine sites;
- significant deterioration of existing air quality.

The relative importance of these factors, including the applicable regulatory standards and the setting of environmental control objectives are important matters which need to be considered. These are dealt with in a companion contribution [4].

8. IMPLEMENTATION OF DUST CONTROL PLANS

Once a suitable dust control plan has been devised and accepted by management in agreement with the authorities, implementation needs to be monitored continuously to ensure compliance. The major part of this monitoring is accurate record keeping, as takes place in the management of all other aspects of a well run mining or industrial operation. Log sheets of actions and checks performed, materials consumption, maintenance and replacement of equipment may be part of such a programme. Incorporation of environmental record keeping into the routine management system of the mine is key to long term viability and success of EMP implementation.

In addition, a network of physical monitoring points, measuring concentrations of relevant pollutants may be established at key sites to demonstrate compliance with cross-boundary ambient air pollution standards. Depending on the sensitivity of the receiving environment, ambient monitoring may be performed by independent consultants to ensure the credibility of the data. Environmental monitoring results have traditionally been regarded as the prime means of demonstrating compliance, for regulatory and environmental auditing purposes. For environmental auditing, internal environmental management records, in
combination with a smaller network of monitoring sites, can provide a cost effective means of demonstrating compliance with the EMP.

9. **DUST IMPACTS AND THE EMP: FACING THE REALITY**

The overall aim of the environmental management planning accepted by the mining industry is to obligate surface mines and works to minimize adverse environmental impacts during the entire mining cycle and to close the operation in a permanently satisfactory way. We suggest that an effective and acceptable way to achieve this aim is for mines to include a *dust control plan* as part of their EMPR. The elements of such a control plan have been sketched above.

In summary:

- A quantitative emission inventory;
- A qualitative assessment, including maps of the locality detailing potentially sensitive impact sites;
- Dispersion modelling (based on the emission inventory) to quantitatively estimate dust concentrations and depositions at receptors;
- Impact assessment, taking account the nature of the dust, dispersion predictions, and characteristics of the receiving environment;
- A dust control strategy, drawn up with reference to the emission inventory, dispersion modelling and impact assessment;
- Pollution monitoring for dust deposition, total suspended particulates, or other specific pollutants, within and beyond the mine boundary, as appropriate;
- A management system for recording above information in a form useful for management decision support and environmental auditing.
The details of how individual mines implement each stage will depend on the specific circumstances and should be left to the management concerned. Certain general objectives will however have to be set. These may include the following:

- Demonstration that the facility has a environmental dust control plan;
- Demonstration that the facility is applying best available technology (BATNEEC);
- Demonstration that the facility is adhering to its control plan, through regular inspection of records and pollution monitoring results.

The reality is that surface mining and surface works of underground mines now have to explicitly plan for controlling impacts of airborne emissions. The palatable side of this reality is that this environmental planning and control can be implemented on the basis of existing technology and in a cost effective manner, compatible with much of our current good business and engineering practice.

REFERENCES


