

# Management, mitigation and monitoring of nuisance dust and PM<sub>10</sub> emissions arising from the extractive industries: an overview



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# Executive Summary

This Overview document forms the second part of the MIRO ProtoDust project undertaken by AEA. The first part of the MIRO ProtoDust project is the “Good Practice Guide: Control and Measurement of Nuisance Dust and PM<sub>10</sub> from the Extractive Industries”.

The objective of the Good Practice Guide is to provide clear, concise and consistent methods for reducing dust from mineral extraction, and measuring dust levels, in the areas around minerals sites. The objectives of dust reduction and measurement are met through the development and application of a site specific Dust Management Plan (DMP). The Good Practice Guide provides step-by-step guidance on the compilation of a Dust Management Plan.

This Overview document provides detailed background information on the management, control and monitoring of nuisance dust and PM<sub>10</sub> arising from the extractive industries. The document complements the information presented in the Good Practice Guide and provides case studies and examples of current best practice aimed at mitigating dust emissions associated with the extractive industries.

The over-arching philosophy of this Overview document, and the accompanying Good Practice Guide, is that dust minimisation is best facilitated through the implication of a site specific DMP, as outlined Chapter 2. The DMP should cover all aspects of dust management for a site where extraction is undertaken including: source identification, control, monitoring, management, reviewing and reporting.

Chapter 3 and 4 outline the regulatory and planning frameworks, respectively, used to control nuisance dust and PM<sub>10</sub> emission from the extractive industries in England. These Chapters outline the legislative and statutory control measures applied within England to control dust arising from the extractive industries and the planning control measures used by Local Authorities to control dust emissions.

Chapter 5 and 6 examine dust dispersion via wind-driven erosion and dust dispersion modelling.

Chapter 7 and 8 provide consideration of dust source identification and control techniques. Source identification is the first step in establishing all possible sources of dust attributable to the site and the contributory factors. Chapter 8 emphasises the role of good process design, i.e., “avoidance”, as the key method of minimising dust emissions from extractive activities.

In instances where nuisance dust and/or PM<sub>10</sub> monitoring is required, for example to provide a measure of background concentrations, current concentrations or for source apportionment purposes, Chapter 9 outlines the process of defining a monitoring strategy and describes current, in-use techniques for the measurement and characterisation of nuisance dust and PM<sub>10</sub>.

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## Abbreviations, Acronyms and Definitions

AAC	Absolute Area Coverage. Dust coverage, irrespective of mass and colour, on 'sticky pad' dust slides. Typically expressed as a percentage.
AQO	Air Quality Objectives
AQMA	Air Quality Management Area
BAT	Best Available Techniques (defined in the EU Directive on Integrated Pollution Prevention and Control 96/61/EC)
BATNEEC	Best Available Techniques Not Entailing Excessive Cost
BPM	Best Practicable Means. BPM places the onus on <b>operators</b> to take all <b>reasonably practicable measures</b> having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications. The means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and structures. BPM takes account of such factors as the availability and cost of relevant measures, operator safety and the benefits of reduced discharges and disposals. BPM is defined in the Environmental Protection Act 1990, c.43, Part III, s.79(9).
$d_a$	Aerodynamic (equivalent) diameter. The aerodynamic diameter of a particle is defined as the equivalent diameter of a particle with a unit density (1 g cm <sup>-3</sup> or 1000 kg m <sup>-3</sup> , the density of water) that has the same settling velocity ( $V_{TS}$ , in air and under gravity) as the particle under consideration.
$d_p$	Physical (equivalent) diameter.
DMP	Dust Management Plan, the overall approach taken by a site operator to ensure that dust emissions are minimised, dust concentrations are measured, and any dust problems are dealt with satisfactorily.
Dust	Dust is a generic term commonly used to describe wind-borne earth, sand or household dirt in the form of a fine powder. More specifically dust is composed of air and surface-borne particulate matter up to 75 µm (BS 6069 – Part 2).
Dust Action Plan	The actions a site operator will take to remedy dust emissions arising during an abnormal event.
Dust deposition	The vertical passage of dust to a surface or the ground.
Dust flux	The horizontal passage of dust, usually driven by the wind, past a point.
EA	Environment Act 1995
EAC	Effective Area Coverage. Dust soiling (or obscuration), irrespective of mass, on 'sticky pad' dust slide, usually expressed as a percentage.
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EPA	Environmental Protection Act 1990
EPR	Environmental Permitting Regulations 2010 (as amended)
ES	Environmental Statement
FDMS	Thermo Scientific Series 2500 Filter Dynamics Measurement System
Fugitive dust	Particles suspended in the air due to man-made and natural activities such as the movement of soil, vehicles, equipment, blasting, and wind.

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Grit	Particles ~50 µm to several hundred µm in diameter
LA	Local Authority (Authorities)
LAIPPC	Local Authority Integrated Pollution Prevention and Control, which covers installations known as A2 installations as defined in Pollution Prevention and Control Act 1999, and Environmental Permitting (England and Wales) Regulations 2010 (as amended).
LAPPC	Local Authority Pollution Prevention and Control, which covers installations known as Part B installations Pollution Prevention and Control Act 1999, and Environmental Permitting (England and Wales) Regulations 2010 (as amended).
LAQM	Local Air Quality Management
LAQM.TG	Local Air Quality Management Technical Guidance Note
LPA	Local Planning Authority (Authorities)
Micron (µm or micrometre)	1 µm = 1 millionth (1 x 10 <sup>-6</sup> ) of a metre
MPG	Minerals Planning Guidance
MPS	Minerals Policy Statement
NAEI	National Atmospheric Emissions Inventory
NAQS	National Air Quality Strategy
Nuisance dust	Nuisance dust is the unreasonable or unwarranted intrusion of dust (e.g., through soiling of surfaces) that in some way materially interferes with the right of an individual to enjoy his or her property <sup>1</sup> .
PGN	Process Guidance Note
PM <sub>2.5</sub>	Particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 2.5 µm aerodynamic diameter.
PM <sub>10</sub>	Particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 10 µm aerodynamic diameter.
PPG	Planning Policy Guidance Note <sup>2</sup>
PPS	Planning Policy Statement <sup>2</sup>
Responsible person	The 'responsible person' is someone who has control, or a degree of control, over the site dust management systems. The 'responsible person', must ensure that everyone who works on a site (site staff and contractors) is aware of the site's dust management systems.
SU	Soiling Unit. Dust coverage, irrespective of mass, of an exposed glass microscope slide. Obtained by subtracting the reflectance value from 100.
Source-pathway-receptor	A common expression used to describe the mechanism of dust pollution and other environmental risks. The source-pathway-receptor model can be used to identify what the source may affect (the receptor, e.g., a person, property, animal, plant, eco-system or body of water) and how the source may reach the receptor (the pathway, e.g., the air).
TSP	Total Suspended Particulates. A measure of total airborne particulate matter by total weight.

<sup>1</sup> The construction of "nuisance" under Part III of the Environmental Protection Act 1990 is narrower, necessarily involving some impact on health.

<sup>2</sup> PPSs have gradually replaced PPGs.



## **Part I: Dust management, legislation, prediction and modelling**

# Chapter 1. Dust from the extractive industries

## 1.1 Overview

Dust (defined for the purpose of this document as nuisance dust and PM<sub>10</sub>) is ubiquitous and has a broad range of sources and concentrations. Natural sources of dust include particles derived from (in no particular order): wind-suspended sea salt; combustion; volcanic or geothermal activities; and, natural weathering of minerals and soils. Man-made sources of dust include: agriculture (especially arable farming); industrial activities, e.g., mechanical handling of minerals and allied materials; and road transport. The source strength of dust emissions can vary on a daily, weekly or seasonal basis. For example PM<sub>10</sub> emissions associated with road vehicles tend to be greatest during the daytime. Similar diurnal variations may apply to other sources.

Dust emissions from the extractive industries are generally fugitive<sup>3</sup> and are difficult to accurately quantify compared to emissions from exhaust stacks. There are no UK sector-based dust emission estimates. In order to attempt to quantify dust emissions by industry sector national emission estimates of PM<sub>10</sub> have been used as a surrogate. Dust particle sizes extend up to 75 µm in diameter. Consequently, dust emissions from the extractive industries will be under-represented by the PM<sub>10</sub> emissions estimates presented below, whilst for other sectors involving high-temperature processes (e.g., combustion) the PM<sub>10</sub> size fraction more accurately describes particulate emissions from that sector.

Figure 1.1 shows UK PM<sub>10</sub> emissions by source sector for 2008 taken from the National Atmospheric Emissions Inventory (NAEI)<sup>4</sup>. Figure 1.1 shows that combustion sources, including transport emissions, emissions from solid and liquid fuel combustion for power and heat generation were the largest source of PM<sub>10</sub> emissions in the UK, accounting for 84.1 kilotonnes of PM<sub>10</sub>. The second largest source of PM<sub>10</sub> emissions in the UK was mineral & metal extraction and processing which contributed 22 ktonnes of PM<sub>10</sub>. Just over half (11.9 ktonnes) was estimated to arise from extraction and quarrying activities, including handling and storage. The agriculture sector was estimated to be the third largest emitter in the UK of PM<sub>10</sub> contributing 13.2 ktonnes, of which 2.6 ktonnes of PM<sub>10</sub> were derived from the cultivation of land. PM<sub>10</sub> emissions derived from the cultivation of land tend to be at their highest during the summer months when the land is the driest, therefore more susceptible to wind-driven erosion, and the level of farming activity is high due to harvesting. PM<sub>10</sub> derived from the cultivation of land is an important primary source of PM<sub>10</sub> in rural areas, along with the extractive industries. In rural areas, the number of other PM<sub>10</sub> sources, such as combustion or heavy industry, is limited.

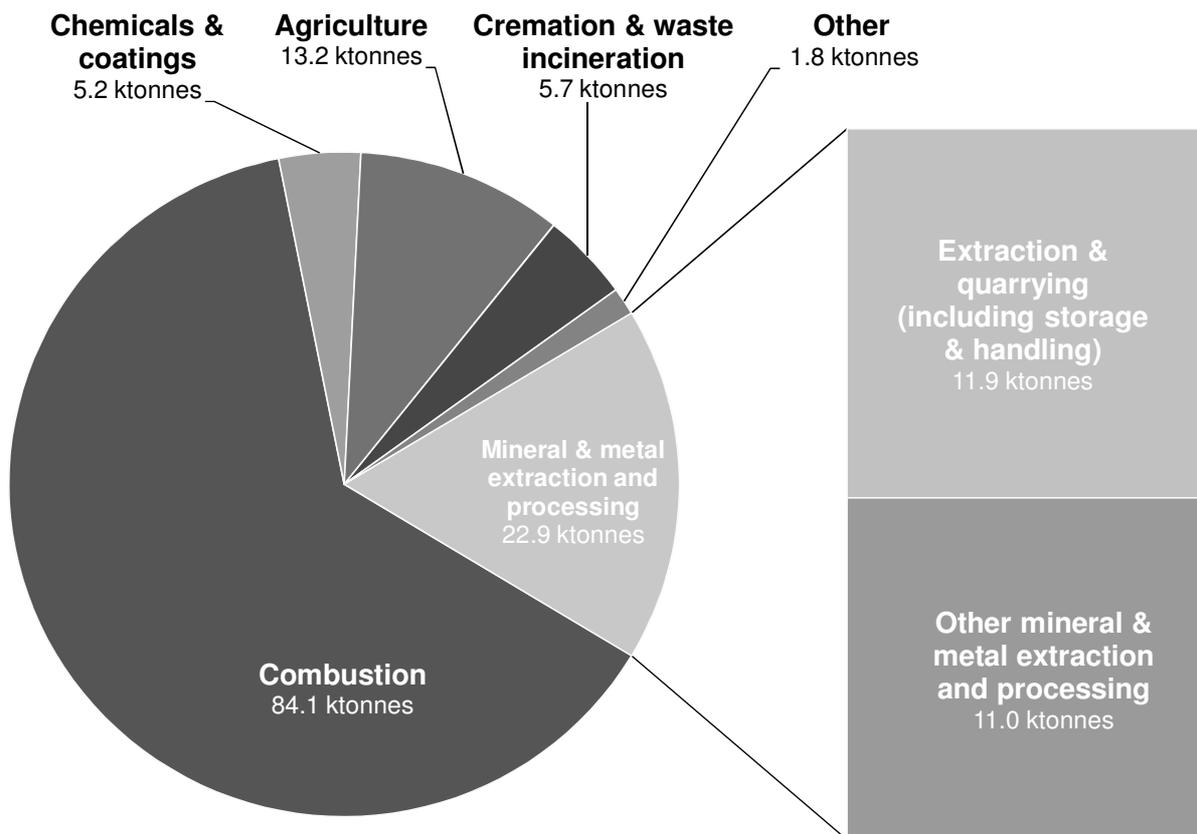
The amount of dust emitted during the extraction and processing of minerals is a reflection of the nature and scale of the task, and the controls applied. As set out in the following chapters, the effect on the environment of the emission of dust arising from the extractive industries can be ameliorated through source identification and legislative, planning and process control.

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<sup>3</sup> Dust generated by the extractive industries is termed "fugitive" because it is not discharged from a point source, i.e., chimney stack or exhaust pipe, to the atmosphere.

<sup>4</sup> The PM<sub>10</sub> emissions within the NAEI are based on European and United States Environmental Protection Agency (US EPA) Compilation of Air Pollution (USEPA-42) emission factors. An emission factor is a representative value that attempts to relate the quantity of a pollutant, e.g., PM<sub>10</sub>, released to the atmosphere with an activity associated with the release of that pollutant. Emission factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of PM<sub>10</sub> emitted per tonne of quarried material) and facilitate estimation of pollutant emissions based on industry activity or production rates. In most cases, these factors are averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average). **Pollutant emission factors are therefore subject to a variable degree of uncertainty and may be based on assumptions which are not appropriate for individual facilities.**

Figure 1.1 UK PM<sub>10</sub> emissions by source sector for 2008.



## 1.2 Impacts

Dust arising from the extractive industries is additional to background dust concentrations. If not adequately controlled dust emissions from the extractive industries may lead to increases in dust concentrations beyond the site boundary, which may affect local amenity. The effects of dust arising from the extractive industries can be broadly characterised in terms of its:

- Potential impact on local air quality, and
- Potential to present a nuisance.

The control and subsequent impact of dust from new and existing quarries and surface mines falls under four discrete regulatory regimes as discussed in Chapter 3. Dust emissions from the extractive industries are site specific and broadly dependent on:

1. The type and amount of material extracted,
2. Site operations, and
3. Local meteorology and topography.

The impacts of dust arising from quarries and surface mines can fall within four broad categories, as set out below:

### 1.2.1 Surface soiling

Surface soiling by dust includes the visible soiling of clean surfaces, such as car bonnets and roofs, exterior brick/stonework, window ledges and laundry. Dust deposits can extend into buildings. The persistent and pervasive nature of dust is a commonly quoted reason for opposition to quarrying

development. Dust can also affect people's ability to enjoy their leisure time and surroundings, making leisure activities unpleasant and unappealing.

For most people, the main effect of a dust problem is the annoyance caused by the increased requirement for cleaning. This can also involve a financial aspect through the increased use of cleaning materials, water, and possibly paid labour. Dust can potentially affect property values. This is a more difficult and often more emotive subject than soiling. There is no simple method for quantifying loss of amenity, due to the different value placed on each item or activity by each individual. This would need to be assessed on a case-by-case basis.

### **1.2.2 Reduction in visibility**

Increased airborne dust concentrations can lead to a reduction in visibility, due to increased light scattering and absorption by airborne particles. Visibility effects from dust are usually only a concern in the immediate vicinity of a specific source. The effects are largely a matter of individual perception, but visibility is one of the main ways by which people commonly judge air quality.

### **1.2.3 Effect on food crops and vegetation**

Dust deposition on to surfaces can potentially affect plant life, though this occurs only at high dust loadings. The consequences include:

- Reduced photosynthesis resulting from reduced light penetration through the leaves leading to reduced growth rates and plant vigour. It can be especially important for horticultural crops, through reductions in fruit setting, fruit size and sugar levels.
- Increased incidence of plant pests and diseases. Dust deposits can act as a medium for the growth of fungal diseases. Also, pests such as sucking and chewing insects are reportedly unaffected by dust deposits to any great extent, compared to their natural predators.
- Reduced effectiveness of pesticide sprays due to reduced penetration.
- Buyer rejection and downgrading of horticultural crops.

### **1.2.4 Effect on human health**

The health effects of dust inhalation are of topical interest. Personal (including workplace) exposure and the occupational health aspects of respirable particles from mineral extraction activities are not covered by this guide, but advice can be obtained from the UK Health and Safety Executive. The health effects of fine dust particles within an environmental context are associated with the PM<sub>10</sub> fraction of dust.

## **1.3 Aim**

The aim of this overview document is to provide detailed information on the following topics:

- Principles of dust management,
- Legislative and statutory control measures applied within England to control dust arising from the extractive industries,
- Planning control measures used by Local Authorities to control dust emissions,
- Wind-driven dust dispersion: the dependency of dust dispersion on wind speed and dust particle size,
- Dust modelling used to predict the potential impact of sources on receptors in close proximity to quarries and surface mines,
- Source identification,
- Dust management,
- Control measures applied to limit dust emission from the extractive industries, and

- Monitoring methods used to measure dust and PM<sub>10</sub> arising from the extractive industries.

The accompanying Good Practice Guide (Good Practice Guide: Control and Measurement of Nuisance Dust and PM<sub>10</sub> from the Extractive Industries) is a concise guide to **reducing dust from mineral extraction**, and **measuring dust levels** in the areas around minerals sites. It provides step-by-step practical guidance from source identification to the control, monitoring and management of dust.

This overview document is aimed at:

- **Operators:** who must consider the implications of dust arising from their site when making planning applications, and in the site's subsequent operation,
- **Regulators:** who are tasked with reviewing proposed and existing dust control measures. Officers may need to determine their suitability for planning applications, or for compliance with planning conditions. Officers need to consider the appropriateness of controls in the light of process guidance and the principles of Best Available Techniques (BAT). Officers may also need to consider controls in order to fulfil the requirements of Local Air Quality Management (LAQM), particularly for sites located in or near an Air Quality Management Area (AQMA), and
- **Members of the public and other stakeholders:** who can use this guide to assess the suitability of proposed and existing dust management and monitoring methods at minerals sites.

This Overview document may also be applicable to waste management activities associated with the extractive industries, e.g., the construction industry (including recycling of construction waste and secondary aggregate production), landfill and composting.

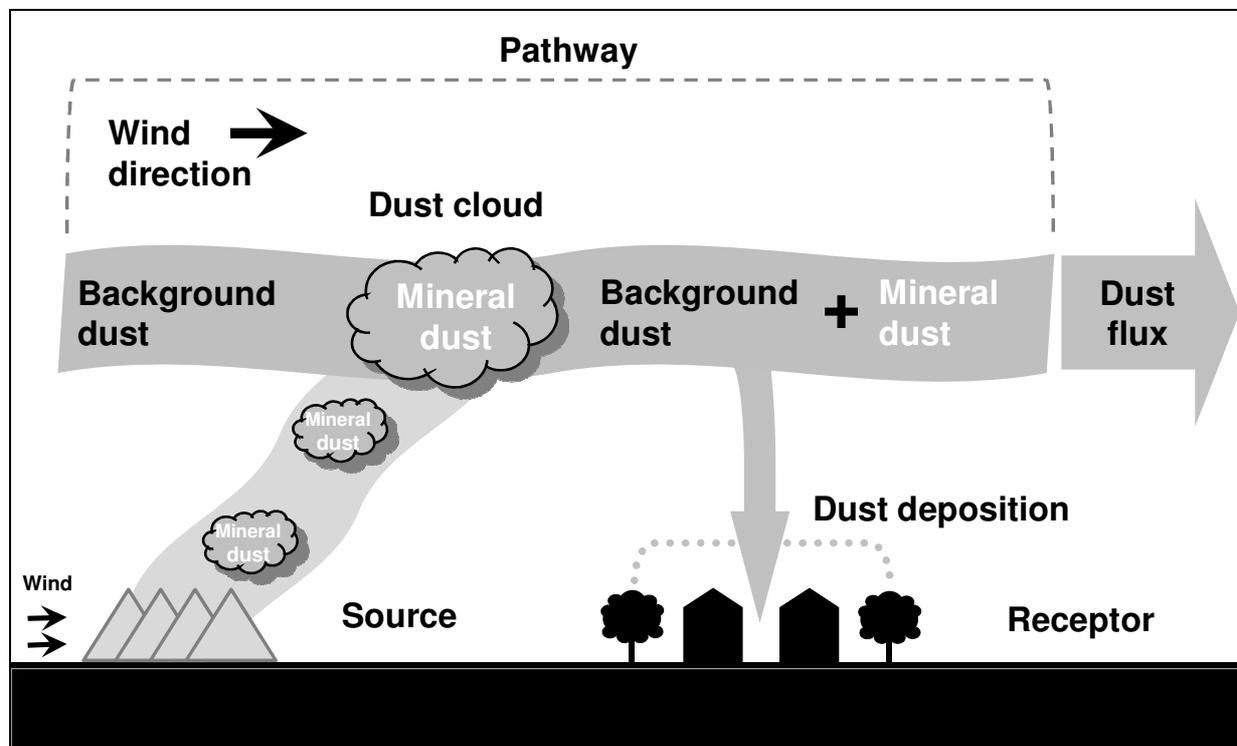
## Chapter 2. Dust Management Plan

### 2.1 Overview

This Chapter describes the concept of dust management, which is encompassed by the site Dust Management Plan (DMP). The DMP outlines the overall approach taken by a site operator to ensure that dust emissions are minimised, dust levels are measured, and any dust problems are satisfactorily dealt with.

The site DMP should cover all aspects of dust management for a site where extraction is undertaken. The aim of the DMP is to interrupt the source-pathway-receptor relationship. Figure 2.1 provides a schematic representation of the source-pathway-receptor relationship. The DMP should contain a description of foreseeable events which may reasonably lead to elevated airborne emissions and the potential impact at sensitive locations. The DMP should identify what actions are to be taken, in each case, to minimise the impact of dust from the extractive industries.

Figure 2.1 Summary of the source-pathway-receptor relationship.



The benefits provided by a standardised DMP approach are five-fold:

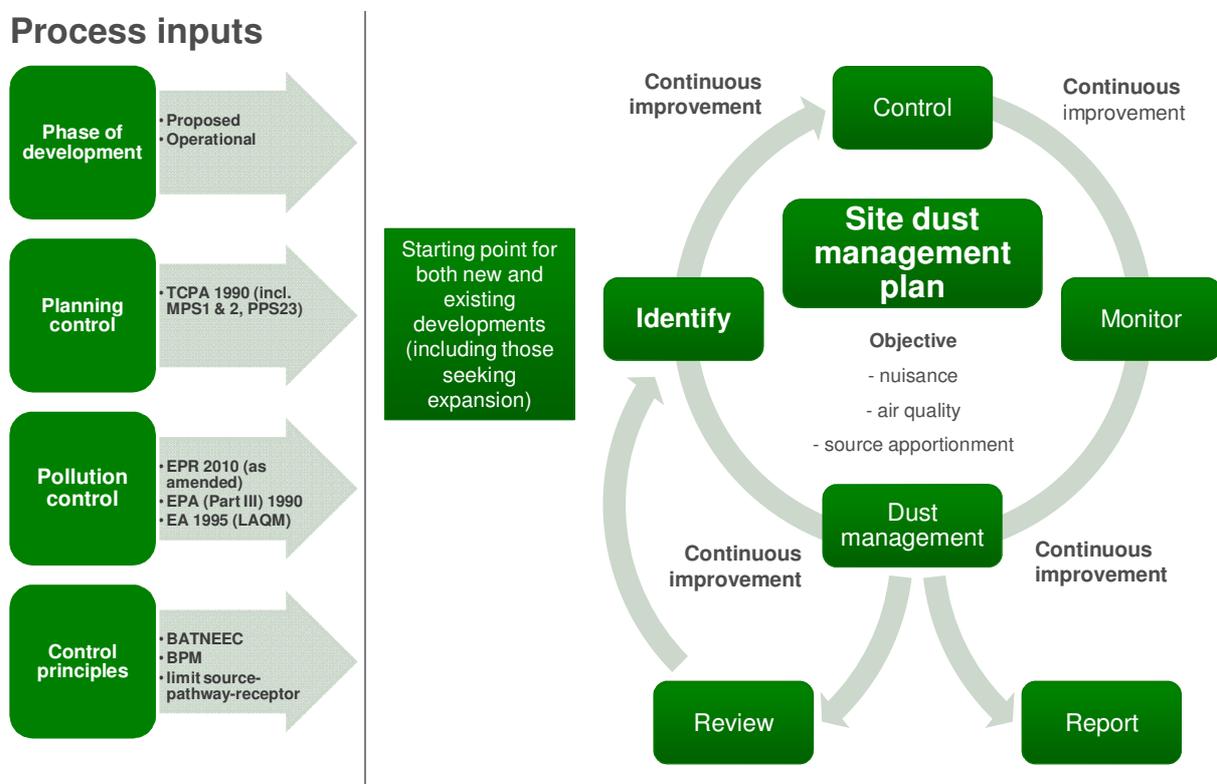
1. Improved performance through a reduction of dust levels on-site and off-site, and a reduction in the number of complaints received.
2. Emission and impact reductions providing an improved reputation with staff and the public.
3. Development of best practice by documenting the processes used to manage dust arising from extractive activities, together with outcome and performance.
4. Documentation of processes which can be integrated across a site or range of sites offering a standardised approach, reducing the duplication of effort across sites within a group.
5. Written procedures for reporting any failures of compliance (i.e., complaint procedure), enabling any issues to be managed, reviewed and audited both internally by the operator, and externally by regulators.

The DMP provides a mechanism to judge the effectiveness of any in-use dust control techniques and therefore it should be reviewed regularly. The DMP should also include a process used to deal with infrequent dust occurrences

The DMP should include the following components, as summarised in Figure 2.2:

- Identify
- Control
- Monitor
- Manage
- Review, and
- Report.

Figure 2.2 Summary of the inter-relationship between the components of the DMP.



Each component requires assessment and evaluation when preparing the DMP, and periodic re-evaluation thereafter.

An effective system of people and record management is essential for ensuring that all aims and objectives of the DMP are recorded and communicated reliably within the company and to stakeholders (regulators and local residents) in order to mitigate the effects of dust arising from the extractive industry. The DMP is intended to be used by operational staff and contractors on a day-to-day basis and should detail the person responsible for initiating the action.

### 2.1.1 Identify

The aim of the dust mitigation measures outlined in the DMP is to ensure that the site operates in accordance with the site's planning permission and/or EPR permit. The site's planning permission and/or EPR permit will have been devised to control the impact of the quarry or surface mine on the surrounding environment and local population. The starting point in the mitigation of dust arising from the extractive industries is source identification. This entails identifying both dust sources and receptors. Dust source identification is discussed in Chapter 7.

## 2.1.2 Control

Once all the dust sources have been identified, they should be controlled through the introduction of appropriate measures. This can be achieved by:

- Ensuring appropriate resources are available to meet the commitments made in the DMP.
- Ensuring good standards of housekeeping, i.e., that dust control equipment is well maintained and operational.
- Compilation of a procedural and maintenance checklist.
- Periodic inspection.
- Implementation of control measures in line with the dust action plan (see Section 2.1.4).

Typical control measures are outlined in Chapter 8.

## 2.1.3 Manage

Training site staff is an essential component of raising awareness of the issues associated with the mitigation of dust arising from the extractive industries. Critical event planning should be undertaken in order to develop a protocol for dealing with short-term, transient events which might lead to an increase in nuisance dust or PM<sub>10</sub>.

### Training

Staff training should seek to:

- Communicate the contents of the DMP to all personnel.
- Describe the potential amenity problems and set out the benefits of good practice in this area for the site's neighbours, and for the minerals business and employees
- Ensure personnel are aware of their obligations under the site's planning permission and/or EPR permit conditions.
- Provide resources to ensure employees are trained in the minimisation of dust, and the correct use of dust control equipment.
- Ensure employees involved with monitoring are trained in the correct use of dust monitoring equipment.
- Facilitate the flow of ideas and information to and from all employees to maintain and improve their ability to manage dust in all aspects of the operations.
- Undertake and record staff induction and training.

One method of raising awareness amongst site staff is through short five to ten minute talks on a specific topic. These are known as "toolbox talks". Each toolbox talk is designed to form a module of the site staff's complete training package. The frequency at which talks are given will depend upon individual requirements and approaches, and also on the site conditions. Whilst there is no set frequency or method, it is recommended that companies aim to give a toolbox talk to every employee and contractor once a week covering a different topic. Ideally, where practicable, this should be implemented as a set routine, i.e., every week at the same time.

Appendix 2 contains a simple presentation that can be used to raise awareness of the issues associated with the mitigation of nuisance dust and PM<sub>10</sub> arising from the extractive industries. The slides presented in Appendix 2 are meant to provide an example of the information that could be presented as part of a toolbox talk to raise awareness of this issue. Further information can be added to the presentation, as required, from the material presented in this document or to inform staff of site-specific issues.

## 2.1.4 Dust Action Plan

A Dust Action Plan (DAP) is a protocol within the DMP for the control and reporting of the effects of specific dust events, e.g., wind-blown dust during times of strong winds and/or dry conditions, or receipt of dust complaints. The aim is to break the source-pathway-receptor linkage under these circumstances. In the event of high dust concentration or the receipt of more than a specified number of complaints, the responsible person should implement the DAP to reduce dust levels. The responsible person should respond in as timely fashion as practicably achievable. Once normal conditions have been restored, the responsible person can stop implementation of the DAP and take any steps necessary to minimise the risk of recurrence. The DAP should identify:

- The nominated individual responsible for implementing the DAP,
- Trigger for implementing the DAP (e.g., threshold dust or PM<sub>10</sub> level, number of complaints or observed/forecast weather patterns),
- Clear description of reporting procedures (including complaints),
- Site parameters to be recorded, e.g., date, time, source, duration, wind speed & direction, number & type of any complaints received,
- The reason for the incident, e.g., haulage trucks travelling along site access roads during period of extended dry weather, and
- Any actions taken to mitigate the incident, and/or prevent its recurrence

Threshold concentrations could be defined on the basis of levels of dust which could affect local amenity, and/or levels of dust which could affect airborne PM<sub>10</sub> concentrations, particularly at sites in or near an AQMA.

The potential for the initiation of dust propagation based on soil type and wind speed is given in Table 5.1 and Table 5.2.

The information recorded should be reported in the DMP and should be used to identify new or currently inadequately controlled dust sources.

Site staff should be informed of the content of the DAP as part of their on-going staff training. Site operators should check that where the threshold dust or PM<sub>10</sub> level at which the DAP will be implemented is at risk of being exceeded. If "best practice" mitigation techniques are in place this could be used as a defence from prosecution under s.80 of the EPA 1990.

## 2.1.5 Monitor

There can be single or multiple reasons for undertaking dust monitoring:

- Baseline monitoring to establish current concentrations and sources.
- Routine assessment of dust concentrations during day-to-day operation of the site.
- Demonstrate compliance with AQO or planning permission condition.

When undertaking monitoring it is important to:

- Record the justification for the site monitoring strategy (e.g., baseline monitoring, planning permission conditions, proximity to local AQMA) and the assessment criteria.
- Keep clear, standardised records of the measurement methods, monitoring periods and results.
- Maintain the dust monitoring network and associated quality assurance programme.
- Record daily site conditions, including prevailing meteorology, e.g., recent and current rainfall, wind speed wind direction, site operations, site conditions and daily water bowser deployment. For sites involved in the extraction of hard stone, the EPR permit normally requires that a log of the prevailing meteorology is kept.

- Undertake on-/off-site investigations following complaint reporting.
- Record the date and time of specific dust events (exceedence of threshold limits for dust or air quality objective values for PM<sub>10</sub>) in the site log.
- Record the date and time of dust complaints in site log.
- Compile a monitoring checklist.
- Carry-out periodic checklist inspection.
- Provide a traceable audit trail of calibration data, monitoring protocol, measured dust and/or PM<sub>10</sub> concentrations, and data analysis where required.

Chapter 9 discusses nuisance dust and PM<sub>10</sub> monitoring.

## 2.1.6 Reviewing and Reporting

The final component of the DMP is the periodic reviewing and reporting of the effectiveness of the control, management and measurement methods employed to limit and measure dust emissions from extractive activities. This phase allows corrective actions to be identified (if not already done so) and incorporated into the DMP. The review and reporting exercise should be undertaken by the person responsible for the implementation of the DMP, though this will be dependent on company size and structure.

### **Review**

The review process can be divided into two components:

1. System review, and
2. Performance review.

The review process should encompass issues and items identified in the upgrade checklist.

### ***System review***

An annual review of the suitability, adequacy and effectiveness of the DMP should be carried out, considering:

- The extent to which objectives and targets have been met.
- Any dust concerns or complaints from external stakeholders.
- Performance based on monitoring results.
- Periodic internal audit findings of dust management practices.
- Periodic internal technical reviews of dust control trials and investigations.
- Changing circumstances, including any developments in European, national or local statutory and policy requirements.
- Need for an external review of dust management practices and monitoring results.
- Any changes or recommendations for improvement identified are incorporated into the DMP.

### ***Performance review***

An annual review of performance of the current DMP can be carried out. The performance review is intended to:

- Report on the site's performance against specified criteria, national objectives and targets.
- Provide a review and analysis of nuisance dust and PM<sub>10</sub> monitoring results for the reporting year. Monitoring data should be tabulated and plotted graphically to provide an indication of long-term

trends for review purposes. All exceedences should be noted together with date, duration and reason, if known. In instances where statutory limits apply these should be indicated on the plots.

- Analyse trends in nuisance dust and PM<sub>10</sub> monitoring data in order to assess the effectiveness of the DMP.
- Evaluate the monitoring strategy.
- Evaluate the effectiveness of completed improvement plans, and compare data to standards and guidelines where relevant.
- Identify areas for improvement, clearly stating intended control method.
- Summarise complaints relating to dust received from the local community.
- Provide analysis of nuisance dust and PM<sub>10</sub> exceedences against agreed standards.

Any changes or recommendations for improvement identified can be incorporated into the DMP.

## Report

Reporting can range from voluntary internal operator reporting to formal communication to regulators or the public. This can be a review of the performance of the dust management of the site against the aims and objectives of the DMP and this can be part of a wider annual environmental report. This could be incorporated into the EMS for the site. The dust performance report may include as a minimum:

- A summary of any baseline and continuous site monitoring data. The following information should be reported: instrument specification, method, number, location (preferably on a site map), measurement units and contractor or data supplier.
- An assessment of the performance of dust control measures and dust measurements against assessment criteria.
- The outcome of the system and performance review.
- Communicate dust performance to stakeholders: site team members, company management, regulators and the local community.

## 2.2 Compilation of the DMP

For on-going operations the site operator should appoint a person responsible to compile the site DMP. For new sites a dust impact assessment will have been produced by the planning application stage. The dust assessment will dictate the complexity of the associated DMP, if required by planning conditions. The level of detail required will be proportional to the level of potential perceived impact, frequency of occurrence and intensity. This means that every DMP will be site-specific. Table 2.1 provides an example of the components of a DMP. The format shown in Table 2.1 is illustrative and can be amended, as appropriate, to reflect different situations.

The key elements of a DMP described in this Guide may be fulfilled through an existing Environmental Management System (EMS), e.g., ISO 14001. If such information is to be used then the formal DMP should, as a minimum, make reference to the relevant sections of the EMS.

**Table 2.1 Suggested outline for a site DMP.**

Source. Describe how generated	Identify possible failures or abnormal situations. Nature/cause of failure	Potential outcome if failure or an emissions event occurs	What measures have been put into place to prevent or reduce the risk of failure or an emissions event?	What actions have been taken and who is responsible?
Briefly describe the activity or process in which dust is generated. See Chapter 7.	For each source – identify particular difficulties which affect dust generation, abatement.	Identify the local receptors that are likely to be affected and the nature or degree of the impact.	List the relevant control measures and monitoring strategy. See Chapter 8 and 9.	What actions are taken to minimise generation and emission? See Chapter 8. Who (include post) is responsible for authorising the actions described and for recording the event.
Example 1: Jaw and cone crushers. Dust generated through the crushing of rock.	Damaged dust screen on rock crusher.	Increased dust emission from crusher. May lead to elevated boundary dust levels and/or at nearby houses. Occurs infrequently and for short periods until corrective action is taken.	Daily inspection of dust screens.	Cessation of crushing. (Crusher operator, site manager). Repair/ replacement of screens. (Site manager).
Example 2: Site dust. Blown off-site due to the action of wind.	Strong winds following a period of dry weather.	Increased dust levels leading to the receipt of complaints from New Village. Occurs infrequently (once or twice a year).	Regular consultation of 7-day regional weather forecast on Met Office website. Recording of prevailing weather conditions in site log. Review monitoring data.	Increased attention to housekeeping measures under dry conditions. Increased deployment of water bowser. Cessation of site activities under high winds/very dry conditions. (Site manager).

Table 2.2 summarises the supporting information which could be included in a DMP.

**Table 2.2 Supporting information to include in the site DMP.**

<b>Site information</b>
Extent of site including site boundary.
Site operations including current/consented working.
Production (activity) rate.
Mineral type and characteristics (size, moisture content, friability, colour and opacity).
Scale and length of operations, including phasing.
Method of working.
Type of processing activities (frequency of movement and disturbance).
Material handling.
Location of storage areas and stockpiles.
Location and number of access routes and haul roads.
Dust control measures employed on-site, including any dust related planning controls.
Maps showing location of monitoring sites and sensitive receptors (if appropriate).
<b>Background information</b>
Geography & topography (surface features): <i>local topography influences wind speed and direction, hence the extent over which dust is dispersed. For example, hills act to channel and direct winds. Open, exposed sites lacking surface features are susceptible to dust blow. Surface features such as woodland, buildings or other structures influence dust deposition patterns.</i>
List other nearby dust-emitting land uses, e.g., arable farming.
Site hydrology and vegetation, if these contribute to reducing dust emissions.
Describe the character of the area surrounding the site, and list the name, location and type of locally sensitive receptors, e.g., houses, farms, rivers, forest, recreational areas, SSSI, sites of historic importance.
Summarise the local meteorology if data are available, e.g., rainfall, wind speed & direction: <i>rainfall suppresses dust and increases dust 'wash-out', whereas dry conditions contribute to dust generation. Wind dries exposed materials and can initiate the dispersion of dust at wind speeds greater than about 5 m s<sup>-1</sup>. Wind direction influences the range and extent to which dust is dispersed off-site.</i>

In the case of existing sites, the site operator will be aware of the existing sources of dust, based on a combination of observations and anecdotal evidence from staff. For both new quarries and extensions to existing sites the site operator can also rely on personal judgement based on previous experience. The local authority environmental protection department may be able to offer useful advice. The number and strength of on-site dust sources will vary over time due to a combination of non-operational indirect effects (e.g., wind, rain) and operational effects (e.g., output rate, changes in material handling and processing, changes in activity location). These variations underline the need to undertake continuous improvement of the site DMP.

## 2.3 Chapter 2 Summary

The aim of the DMP is to interrupt the source-pathway-receptor relationship. The DMP should contain a description of foreseeable events which may lead to elevated airborne emissions and the potential impact at sensitive locations. The DMP should identify what actions are to be taken, in each case, to minimise the impact of dust under these circumstances.

The key potential sources of dust at a minerals extraction site require assessment and evaluation when preparing the DMP, and periodic re-evaluation thereafter. The level of detail required will be proportional to the level of potential perceived impact, frequency of occurrence and intensity. This means that every DMP will be site-specific.

The key elements of a DMP described in this Guide may be fulfilled through an existing Environmental Management System (EMS), e.g., ISO 14001. If such information is to be used then the formal DMP should, as a minimum, make reference to the relevant sections of the EMS.

The next Chapter examines the regulatory regime used to control of dust impacts from new and existing quarry facilities and related activities.

## Chapter 3. Legislation and Guidance

### 3.1 Overview

It is far more effective to address dust emissions at the design and planning stage of a new quarry than to seek to abate nuisance levels of dust retrospectively. Government guidance encourages operators to consider the potential impacts of their activities and make proposals that are environmentally acceptable from the outset rather than relying on retrospective action. Mineral Planning Authorities (MPAs) should take account of this in their decisions on individual applications. The control of dust impacts from new and existing quarry facilities and related activities falls under three discrete regulatory regimes:

1. Town and Country Planning Act 1990 (TCPA 1990)
2. Environmental Permitting (England and Wales) Regulations 2010 (EPR 2010, as amended), and
3. Environmental Protection Act 1990 (Part III) (EPA 1990).

The assessment, measurement and overall control of ambient PM<sub>10</sub> concentrations are covered under LAQM regulations. These statutory instruments are outlined below.

### 3.2 Town and Country Planning Act (TCPA) 1990

The planning system manages the development and use of land in the public interest. The Town and Country Planning Act 1990 (TCPA 1990) sets out the regulatory framework for land use planning within which quarries and related activities need to operate.

Planning conditions may be applied to control dust from quarries and related activities at the time of determination of a planning application for the establishment of a quarry, its extension, or where an application is made for ancillary quarry activities and these are not controlled under the Environmental Permitting system. Planning conditions may seek to control and mitigate dust arising within both the confines of the quarry boundary as well as to mitigating the potential for fugitive dust impacts on sensitive receptors, i.e., residential properties outside of the quarry boundary. Planning controls are discussed further in Chapter 4.

TCPA 1990 regulates the development and use of land and buildings used for quarry operations. On matters relating to dust and air quality the Minerals Planning Authority will normally consult with the Environmental Health Department and other interested parties<sup>5</sup>.

The Government's policy on planning issues is set out in Planning Policy Guidance Notes (PPGs) or Planning Policy Statements (PPSs). Specific policy guidance on minerals planning is outlined in Minerals Planning Guidance Notes (MPGs) or Mineral Policy Statements (MPSs). Together these provide advice and guidance to MPAs and the minerals industry on policies and the operation of the planning system with regard to minerals.

Minerals Policy Statement 1 (MPS1)<sup>6</sup> is the overarching planning policy document for all minerals extraction activities in England. It provides advice and guidance to planning authorities and the minerals industry, ensuring that the need by society and the economy for minerals is managed in an integrated way against its impact on the environment and communities. MPS1 seeks protection and enhancement by careful planning and design by:

- Minimising environmental impacts during the preparation, working and restoration stages, both on-site and in transportation of quarried materials,
- Incorporating, applying and maintaining good environmental management practices,
- Seeking and maintaining effective consultation and liaison with the local community before submitting planning applications and during operation, restoration and aftercare of sites,

<sup>5</sup> Where the consideration of the impact of dust emissions on sites of historic, ecological or sites of special scientific interest, is required, consultation with special interest groups should be undertaken.

<sup>6</sup> Correct as of October 2010.

- Stating the criteria to be used in assessing mineral proposals and in formulating planning conditions, to ensure that permitted operations do not have unacceptable adverse impacts on the environment or human health<sup>7</sup>, and
- Ensuring that any unavoidable noise, dust and particle emissions and any blasting vibrations caused by mineral extraction are in conformity with national guidance and are controlled, mitigated or removed at source, so as to reduce to an acceptable level any potential adverse impacts on neighbouring land and property.

Minerals Policy Statement 2 (MPS2) provides guidance on the control and mitigation of the environmental effects of mineral extraction in England and highlights the policies and considerations that the Government expects MPAs to follow when preparing development plans and in considering applications for minerals development. Annex 1 of MPS2 specifically considers the control and mitigation of dust arising from mineral workings.

Planning Policy Statement 23 (PPS23): Planning and Pollution Control, issued by the Office of the Deputy Prime Minister (ODPM) in 2004 provides guidance to Local Authorities and site operators with regard to **land use**. PPS23 sets out the pollution control framework applicable to mineral workings and quarries and provides guidance on what information the Minerals Planning Authority should take into consideration for each planning submission where pollution arises, including the:

*“possible impact of potentially polluting development (both direct and indirect) on land use, including effects on health, the natural environment or general amenity;”*

*“need for compliance with any statutory environmental quality standards or objectives including the air quality objectives prescribed by statutory Air Quality Regulations.”*

In assessing nuisance parameters PPS23 states:

*“It is not intended to secure a high level of amenity but is a basic safeguarding standard intended to deal with excessive emissions. Nuisance does not equate to loss of amenity. Significant loss of amenity will often occur at lower levels of emission than would constitute a statutory nuisance. It is therefore important for planning authorities to consider properly, loss of amenity from emissions in the planning process in its wider context and not just from the narrow perspective of statutory nuisance” (Annex 1A, section 1.8).*

This can be interpreted to mean that the criterion for assessing ‘loss of amenity’ is a more stringent criterion than would need to be applied to addressing a statutory nuisance problem. In practice loss of amenity does not necessarily equate either to an absence of dust or even an absence of impact on amenity.

The precautionary principle has been transposed into PPS23, and should be applied where:

*“There is good reason to believe that harmful effects may occur to humans ...”;*

and,

*“The level of scientific uncertainty about the consequences or likelihood of the risk is such that best available scientific advice cannot assess the risk with sufficient confidence to inform decision-making” (Paragraph 6).*

The precautionary principle would be applied in circumstances where:

- The nature and state of the emissions are poorly defined and/or is difficult to represent by using standard assessment techniques (e.g., dispersion modelling as described in Chapter 6), and
- Control of fugitive emissions is solely through process control.

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<sup>7</sup> MPAs should avoid unnecessary conditions or obligations that duplicate the effects of other more specific controls in-line with general guidance in PPS1.

Overall, the planning process provides a clear framework for developers and/or operators when seeking planning permission. Addressing the relevant issues in a detailed and transparent manner should ensure that permission could be granted knowing that the site can operate without unduly affecting local residents.

As of 2010 the national planning framework, including PPS23, is undergoing a period of review. Therefore the national planning framework may change in future years.

### 3.3 Environmental Permitting (England and Wales) Regulations (EPR) 2010 (as amended)

The Environmental Permitting (England and Wales) Regulations 2010 (EPR 2010, as amended) were created to standardise environmental permitting and compliance in England to protect human health and the environment. The 2010 EPRs replaced the 2007 regulations by extending the range of activities that require an environmental permit. Existing licences and authorisations were converted into environmental permits automatically. The regulations affect all regulated facilities that are installations (a full list of installations is available in Schedule 1 of the Regulations. Examples of installations include: mobile plant, waste operations (including mining waste operations), radioactive substances activities, water discharge and groundwater activities. Schedule 1 of the Regulations also provides definitions of what constitute Part A1, A2 and B activities<sup>8</sup>). Broadly speaking:

- Part A1 activities are defined as '*the most polluting activities*' and are regulated for emissions to air, land, water, amongst other environmental considerations by the Environment Agency in England,
- Part A2 activities are defined as '*lesser polluting activities*' and are regulated for emissions to air, land, water, amongst other environmental considerations, whilst
- Part B activities are defined as '*the least polluting activities*' and are regulated for emissions to air only<sup>9</sup>.

The Environment Agency and Local Authority regulated Integrated Pollution Prevention and Control (IPPC) regimes introduced under the Pollution Prevention and Control Act 1999 (PPC 1999) and the PPC Regulations (2000) are operated in parallel. The Environment Agency is responsible for controlling emissions from Part A1 activities, whilst Part A2 and B activities are controlled by Local Authorities. It is the responsibility of the operator to determine the relevant production capacity of their activities and to ensure they hold a permit under the correct regime. For operations which do not constitute Part A1, A2 or B activities under the Regulations, **or**, which do not involve the management of extractive wastes (as discussed overleaf), the control of dust from such facilities would be covered by planning conditions issued by the Minerals Planning Authority or the EPA 1990.

The IPPC system requires that **site-specific issues** be taken into account. Consultation is expected to occur between the Local Planning Authority (LPA) and the relevant pollution control authorities, other interested bodies and members of the public. More weight will generally be needed to be given to consideration of PM<sub>10</sub> where a development would have a significant impact on air quality within, or adjacent to, an Air Quality Management Area (AQMA) defined on the basis of PM<sub>10</sub> levels (as outlined in Section 3.5). Consideration should also be given to assessing the future impact of possible increases in air pollution from a proposed development in situations where an AQMA does not exist, to ensure that future emissions will not lead to the declaration of an AQMA.

The IPPC system makes Local Authorities responsible for regulating emissions (including dust) from Part A2 and B installations:

- Local Authority-Integrated Pollution Prevention and Control (LAIPPC) legislation limits emissions to air, water (including discharges to sewer) and land, plus a range of other activities (odour, waste, noise, energy use, vibrations, accident prevention and site restoration) with a potential environmental impact (Part A2 activities), and

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<sup>8</sup> Part 2 of Environmental Permitting (England and Wales) Regulations 2010 (as amended) provides definitions of the activities covered with each industrial sector, including the mineral industries, and guidance on the interpretation and application of the Regulations.

<sup>9</sup> Examples of other Part B activities include: quarry processes, mineral drying and coating.

- Local Authority-Pollution Prevention and Control (LAPPC) legislation limits emissions to air only (Part B activities).

Sector guidance notes are published for Part A2 activities. Extractive processes are typically Part B activities and therefore prescribed activities under LAPPC, though this may be different if the extractive process is technically connected with a Part A process. Under such circumstances the process would be regulated as a Part A process.

As Part B processes, the control of emissions from the extractive industries is regulated by the Local Authority. The Secretary of State has published a series of process guidance notes that cover Part B activities, including mineral extraction, quarrying and associated activities (see appendix). From 6 April 2008 the PPC Regulations have been incorporated into the framework of EPR 2010 (as amended). The LAIPPC and LAPPC regimes will be identified by the single term "LAPPC" in future Process Guidance Notes (PGNs). Guidance for Local Authorities and site operators can be found on the Defra website.

In applying for a permit the applicant will need to demonstrate that the prescribed process will operate so that:

- *all the appropriate preventive measures are taken against pollution, in particular through application of the best available techniques (not entailing excessive cost)<sup>10</sup>;*
- *no significant pollution<sup>11</sup> is caused<sup>12</sup>.*

Defra has undertaken a phased review of the Environmental Permitting Programme (EPP) as part of the incorporation of the PPC Regulation into EPR 2010 (as amended). The objective of the EPP is to extend the common platform created by the Environmental Permitting Regulations to incorporate other broadly similar regimes whilst maintaining environmental protection standards and reducing bureaucracy and cost as part of the Government's *'Better Regulation Initiative'*, thus providing a single, common, risk-based framework for permitting and compliance.

Drawing these processes under the umbrella of EPR 2010 (as amended) will mean that the same environmental control principles imposed on all prescribed processes will need to be met. Table 3.1 summarises the range of mineral extraction processes for which the Secretary of State has published a PGN under EPR 2010 (as amended) and those which are not prescribed processes. For each prescribed process the PGN is given in brackets.

**PG Notes are reviewed periodically therefore these references may change in time.**

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<sup>10</sup> BATNEEC: best available technique not entailing excessive cost. The application of BATNEEC normally means that the additional costs of avoiding environmental damage are justified by the benefits. Therefore, BATNEEC would not require the reduction of risk from 'low' to 'negligible' if that would require very expensive techniques. Under the Environmental Protection Act 1990, the BATNEEC criterion is applied in integrated pollution control (IPC) and in the management of risks from the release of genetically modified organisms to the environment.

<sup>11</sup> Where 'pollution' is defined as:

*"the direct or indirect introduction as a result of human activity, of substances ...into the air, water or land which may be harmful to human health or the quality of the environment, result in the damage to material property, or impair or interfere with amenities and other legitimate uses of the environment"*.

<sup>12</sup> Article 3 of the Integrated Pollution Prevention and Control (IPPC) Directive [Directive 2008/1/EC of the European Parliament and of the Council - <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:EN:PDF>].

**Table 3.1 Prescribed processes under EPR 2010 (as amended) associated with mineral extraction**

Process	
Prescribed	Not prescribed
Processing and drying of clay (PG 3/02).	Drilling/blasting/extraction of minerals.
General quarry processes associated with the processing of designated minerals including crushing and screening (PG 3/08). Mobile crushing and screening are covered by PG 3/16.	Handling of clay at quarries (unless crushing, grinding or screening is to take place – see PG 3/17).
Manufacturing plaster from gypsum (PG 3/12).	Removal of overburden.
Lime processing, e.g., for slaking (PG 3/14).	Extraction of sand and gravel.
Drying and cooling of sand and minerals (PG 3/15b).	Chalk processing.
China and ball clay processing (PG 3/17).	Cutting and dressing of stone.

As part of second phase of EPP guidance has been issued by Defra and the Environment Agency on the incorporation of Directive 2006/21/EC of the European Parliament on the management of waste from extractive industries (commonly known as the ‘Mining Waste Directive’) into the Environmental Permitting Regulations . The Mining Waste Directive addresses the management of extractive waste generated during the prospecting, extraction and treatment of mineral resources and the working of quarries. The Directive aims to prevent or minimise the negative effects on the environment and risks to human health from the management of waste from the mineral extraction industries by providing a framework within which management must take place.

### 3.4 Environmental Protection Act (Part III) 1990 (EPA 1990)

Where emissions from emitting sources are subject to regulation under the EPR 2010 (as amended), Local Authorities may not institute summary nuisance proceedings with respect to emissions from permitted installations under the 1990 Act without the consent of the Secretary of State.

Nuisance caused by dusts are regulated by the statutory nuisance provisions under Part III of the EPA 1990. s.79(1)(d) EPA 1990 defines this as:

*“Any dust, steam, smell or other effluvia arising on industrial, trade or business premises and being prejudicial to health or a nuisance”.*

Statutory nuisance is not intended to secure a high level of amenity but rather to act as a basic safeguard standard that is intended to deal with excessive emissions. The test for considering whether a process presents a statutory nuisance relies upon considering a range of factors including the character of the locality, the frequency, duration and intensity of the impact. Nuisance does not equate to loss of amenity. Significant loss of amenity can occur at lower levels of emission than would constitute a statutory nuisance.

Officers of the local environmental health department have a duty, wherever practicable, to investigate any complaint about an alleged dust nuisance from a member of the public and to inspect their area for statutory nuisance (under s.79(1) of the EPA 1990). This means that local authorities may become aware of potential statutory nuisance dust either through an Environment Health officers experience while ‘inspecting’ their area, or as a result of complaints. Once an authorised officer has formed the view that a statutory nuisance exists, the Local Authority is under a duty to serve an abatement notice. The standard of proof required at this stage is a civil standard – termed “on the balance of probabilities”, i.e., there is a legal burden on the Local Authority to prove that the nuisance exists, on the balance of probabilities.

The perpetrator of the alleged nuisance has a defence of best practicable means (BPM). BPM provides a way of balancing the interests of industry and residents. BPM can be raised at two stages:

(1) in appealing against an abatement notice, or, (2) as a defence in a prosecution. The BPM criteria are set out in s.79 EPA:

- (a) “ ‘practicable’ means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications;
- (b) the means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and structures;
- (c) the test is to apply only so far as compatible with any duty imposed by law;
- (d) the test is to apply only so far as compatible with safety and safe working conditions, and with the exigencies of any emergency or unforeseeable circumstances.”

Difficulty arises when the polluter has taken all reasonable steps to reduce the dust emissions, but the problem remains constituting a nuisance in the eyes of the Local Authority, since while the operator will have a *prima facie* ground for successful appeal the local authority is still, strictly, obliged to serve an abatement notice.

### 3.5 Environment Act 1995 (EA 1995) and PM<sub>10</sub> Air Quality Objectives

Under Part IV of the Environment Act 1995 (EA 1995) the Government produced a National Air Quality Strategy (NAQS) in 1997. This drew together national and European standards for maintaining and improving air quality in the UK. The Strategy provided objectives and dates for achievement for nine airborne pollutants, including PM<sub>10</sub>. The most recent version of the Strategy was published in 2007. Its primary focus is on protecting the health of the UK population, although it also includes targets for the protection of vegetation, ecosystems and the natural environment. The NAQS provides air quality objectives for airborne PM<sub>10</sub> but not for dust.

Local Authorities have a role under Part IV of the EA 1995 to play in reviewing and assessing ambient air quality in their areas as part of LAQM. In instances where there is a risk of the statutory objectives contained within in the Air Quality Regulations 2007 being exceeded, Local Authorities are required to designate an AQMA and to draw up an Air Quality Action Plan. The Action Plan should consider wide-ranging options for reducing pollutant emissions and describe the measures to be taken in order to realise the necessary improvement in air quality. To this end the planning, transport and air quality control functions of Local Authorities should therefore work closely together in:

- Reviewing and assessing air quality, especially where new development is likely,
- Considering the possible impact of new development in drawing up any air quality action plans and local air quality strategies,
- Considering the results of air quality reviews and assessments in the preparation of development plans, and
- Considering air quality alongside other issues when taking development control decisions which may have a direct or indirect bearing on air quality.

It is also important to bear in mind that air quality within one area may be influenced by pollution from an adjacent area beyond the Local Authority boundary, termed “transboundary pollution”. Likewise developments adjacent to an existing AQMA should also be considered in terms of their potential impact on air quality.

The NAQS contains limit values controlling the mass concentration of airborne PM<sub>10</sub> based on the best available medical and scientific understanding of their effects on health, as well as taking into account relevant developments in Europe. Directive 1999/30/EC provides the basis for the current air quality objectives (AQOs) for PM<sub>10</sub> in England:

- 24-hour mean of 50 µg m<sup>-3</sup> not to be exceeded more than 35 times a year (90<sup>th</sup> percentile), and
- Annual mean of 40 µg m<sup>-3</sup>.

More recently Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe (commonly referred to as the Clean Air for Europe Directive, CAFÉ) has been published. The Directive succeeds Directive 1999/30/EC. The new Directive includes trigger points for the assessment of the limit value for PM<sub>10</sub> in England.

A provisional objective for the control of fine particulate (PM<sub>2.5</sub>) has been proposed. The Directive has yet to be ratified at EU and national level and therefore is not incorporated into the NAQS though this is expected by mid-2011.

### **3.5.1 Criteria for airborne PM<sub>10</sub> monitoring from uncontrolled and fugitive sources**

Local Authorities have statutory duties for LAQM under the EA 1995. They are required to carry out regular Reviews and Assessment studies in order to assess the air quality in their area against standards and objectives prescribed in regulations for the purpose of LAQM. Where any of these objectives are not being achieved, authorities must designate AQMAs and prepare and implement remedial action plans to tackle the problem. The EA 1995 requires that when carrying out their local air quality management functions, Local Authorities shall have regard to guidance issued by the Secretary of State. Further information on the whereabouts and existence of current AQMAs can be found on the Defra website.

LAQM Technical Guidance Note 09 (LAQM.TG(09)) provides technical guidance for Local Authorities on:

- Monitoring,
- Progress reports,
- Undertaking and updating Screening and Detailed Further assessments,
- Supporting information on estimating emissions and modelling, and
- Local Authority responsibilities, many of which are relevant to, though not specific to, quarrying activities.

Table 3.2 outlines the advice given in LAQM.TG(09) on the receptor locations where specific AQOs apply. LAQM.TG(09) also provides a screening checklist for determining the sources of nuisance dust and PM<sub>10</sub>, such as the extractive industries, but also for the purposes of assessing other uncontrolled and fugitive sources (e.g., landfill sites; coal and material stockyards, or materials handling; major construction works; and, waste management sites) that could give rise to elevated concentrations of nuisance dust and PM<sub>10</sub>.

**Table 3.2 Examples of where PM<sub>10</sub> AQOs apply.**

<b>Averaging period</b>	<b>Objectives should apply at...</b>	<b>Objectives should generally not apply at...</b>
Annual mean	All locations where members of the public might be regularly exposed.  Building facades of residential properties, schools, hospitals, libraries etc.	Building facades of offices or other places of work where members of the public do not have regular access.  Gardens of residential properties.  Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
24-hour mean	All locations where the annual mean objective would apply.  Gardens of residential properties.	Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.

### 3.5.2 Screening and Assessment studies for the purposes of LAQM

Screening Assessment studies are undertaken by the local authority to determine the risk of an air quality objective being exceeded. Detailed guidance on undertaking a Screening and Assessment study is contained within LAQM.TG(09). During the Screening and Assessment study the local authority will be required to consult with the site operator.

The proximity of sensitive receptors to the source, such as those given in Table 3.3, will be considered by the local authority when undertaking a Screening and Assessment study. They will consider the distance between the actual source of emission and the receptor, not the distances to the site boundary.

Consideration should be given to the location of on-site sources commonly situated close to site boundaries, e.g., stockpiles and haul roads, as described in Section 7.2.1. Off-site sources are also important and should be considered as potential sources, in particular roads used by vehicles accessing the site as described in Chapter 7. Dust and dirt can be carried-off site by vehicles leaving the site and deposited on the public highway. Material deposited on road surfaces can be re-suspended or generated by attrition, due to the action of vehicle wheels, and vehicle wakes.

Dust concentrations decrease significantly with distance from the source as described in Chapter 5. Screening and Assessment studies are therefore considered to be site specific. In order to quantify the extent of the fugitive dust emissions, monitoring will be required following the principles described in Section 9.1.

**Table 3.3 Examples of dust sensitive facilities.**

<b>High sensitivity</b>	<b>Medium sensitivity</b>	<b>Low sensitivity</b>
Hospitals and clinics	Schools	Farms
Hi-tech industries	Residential areas	Light and heavy industry
Painting and furnishing	Food retailers	Outdoor storage
Food processing	Green houses and nurseries	
	Horticultural land	
	Offices	

Depending on the outcome of the Screening and Assessment study, or if there is any doubt as to the extent of the increase in dust concentrations due to the presence of an extractive process, LAQM.TG(09) advises that Local Authorities should proceed to complete a Detailed Assessment. Box 1 outlines the approach taken during a Screening Assessment Study to determine the need for a Detailed Assessment (as outlined in Section 3.5.3).

### Monitoring Strategy for PM<sub>10</sub> around a quarry

**Scenario: fugitive dust emissions represent a potential problem around a quarry. In order to determine whether a Detailed Assessment is required, a monitoring survey is undertaken.**

- There are relevant receptors (medium or high sensitivity receptors, e.g., schools, hospitals, see Table 3.3) within 400 m of the quarry, so detailed monitoring is necessary.
- A suitable strategy is to set up PM<sub>10</sub> samplers at three to four sites around the quarry source to make indicative measurements. Any type of PM<sub>10</sub> sampler can be used: if power is not available at the sites then battery operated low volume gravimetric samplers or portable automatic monitors could be used. Wind speed and direction are also measured at one site. If manual samplers are used they should be set to operate from midnight to midnight. Samples are collected every other day over a three month period.
- The samplers are located close to the nearest point of public exposure, for example, a house or school. For large quarries the receptor distance should be measured from the area of maximum activity during the survey period. The PM<sub>10</sub> samplers are sited upwind and downwind of the quarry close to the nearest receptors.
- This quarry is active during part of the year only. It is important that the timing of the survey is planned to coincide with a period of quarrying activity.
- A nearby background site such as a national or local network site can be used as a reference, if available. Daily average concentrations are compared to those from the national network site in order to determine the contribution to total PM<sub>10</sub> concentration of background sources.
- In order to further specify the source of the PM<sub>10</sub> filters can be retained for scanning electron microscopic analysis to characterise the collected particles. If no significant exceedences of the objectives are recorded during the three month period, then monitoring can be terminated. Otherwise a detailed monitoring study is undertaken.

### 3.5.3 Detailed Assessments

Guidance on undertaking a Detailed Assessment is contained within LAQM.TG(09). The aim of a Detailed Assessment is to determine, with reasonable certainty, whether there is a likelihood of the PM<sub>10</sub> air quality objectives not being achieved.

## 3.6 “Custom and practice” thresholds for dust

Currently no statutory nuisance dust limit exists in the UK. Discretionary (“custom and practice”) thresholds tend to be imposed on the basis of perceived problem, i.e., as a surrogate for dust nuisance. Consequently planning conditions often use non-specific phrases such as “reduce to a minimum level” pollution by “Best Practicable Means”.

Two basic approaches have been adopted for the determination of dust loading:

- Soiling (obscuration) of a surface based on dust deposition and dust flux measurements, and
- Mass of dust deposited based on dust deposition measurements.

Custom and practice thresholds applied to measure dust deposition and soiling tend to be considered alongside other criteria. Other metrics of annoyance caused by dust include the frequency of occurrence, location and loss of amenity. This is undertaken to provide a balanced and objective view of the level annoyance caused and determination of the existence of a statutory nuisance.

### 3.6.1 Surface soiling

The exposure of a glass (dust) slide or strip or pad of self-adhesive tape horizontally in the field for a week at a height of 1-2 m can provide an indicative measure of surface soiling due to dust. A fuller description of this method is given in Section 9.2.2. The method is designed to replicate the behaviour of dust on outside surfaces which naturally involve dust re-distribution by rainfall and wind. The level of soiling due to dust deposition can be assessed by:

1. Comparative assessment with shading cards, and
2. Measurement of the (loss of) surface reflectance or discolouration with a gloss-meter or similar (such as a 'sticky pad reader') to provide a measure of surface soiling. This can be expressed as Soiling Units (SU) or Effective Area Coverage (EAC%).

The first approach is highly subjective, but provides an instantaneous measure of surface soiling. Custom and practice thresholds apply for the second approach (although it should be noted that measurements obtained using different methods and equipment are not interchangeable). The custom and practice thresholds for surface soiling measured using a glass (dust) slide are 25 SU per week and the upper threshold for EAC is 5.0% EAC per day, the latter is considered the upper threshold for "serious complaints".

### 3.6.2 Dust mass deposition rate

Dust mass deposition measurements are carried out by measuring the rate of mass of dust deposited on a fixed, horizontal surface over the period time, typically one month. Measurements are typically taken at fixed locations (see Section 9.1.9). This can be taken at a fixed location on the site perimeter or at off-site receptors, particularly at sensitive receptors adjacent to a site (as defined in Table 3.3), ideally at multiple sampling points.

Custom and practice thresholds for dust mass deposition are of the order of 80 to 200 mg m<sup>-2</sup> day<sup>-1</sup> averaged over the period of a month. The lower threshold of 80<sup>13</sup> mg m<sup>-2</sup> day<sup>-1</sup> is applicable to darker, high contrast dust, e.g., coal, whilst the higher threshold is applied to lighter-coloured materials which are less apparent to the eye. Such thresholds apply to dust mass deposition measured with a Frisbee dust deposition gauge and no other form of deposition gauge, as different deposition samplers have different dust collection efficiencies.

Figure 3.1 shows the commonly accepted procedure for determining the "likelihood of complaint" level for monthly dust deposit gauge results. Adherence to the procedure outlined in Figure 3.1 requires:

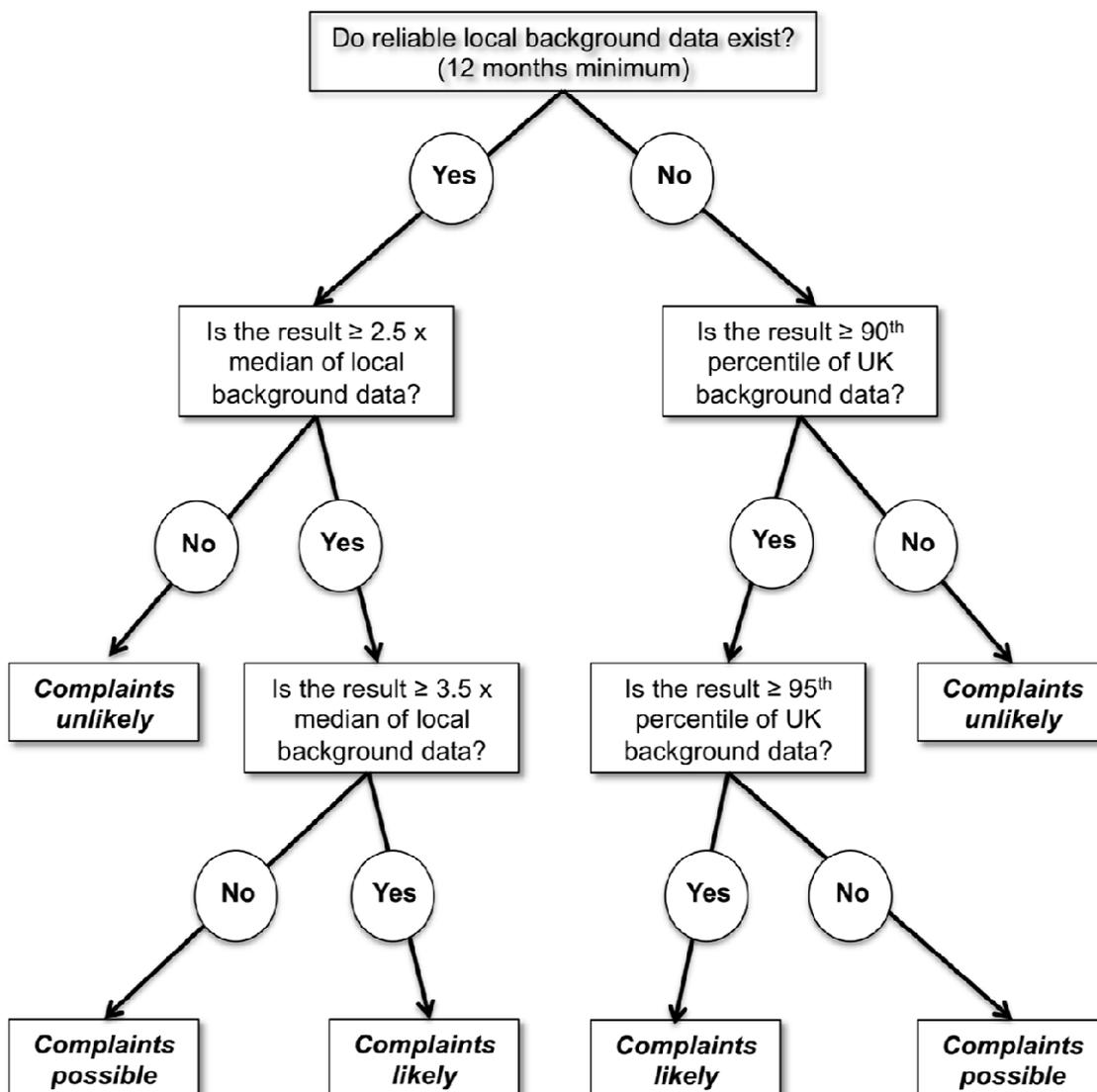
- (a) Knowledge of the background dust deposition rate; and,
- (b) Long-term sampling, to provide comparative data.

In cases where no reliable background data exist, multiples of the percentiles of the background concentration can be used, depending on location. The suggested percentile values for a range of locations are given in Table 3.4.

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<sup>13</sup> Bate and Coppin (1990).

**Figure 3.1** Procedure for determining the “likelihood of complaint” level for a given monthly dust deposit gauge result (Vallack & Shillito, 1995).



**Table 3.4** 5-year means of the annual percentiles of monthly dustfall rates ( $\text{mg m}^{-2} \text{day}^{-1}$  insoluble deposits) determined using a dry Frisbee (foam) gauge<sup>14</sup>.

Location	Median (50 <sup>th</sup> percentile)	90 <sup>th</sup> percentile	95 <sup>th</sup> percentile
Open country	38	103	140
Residential areas and the outskirts of towns	56	146	203
Commercial centres of towns	90	199	261

<sup>14</sup>The values given in the table have been increased by a factor of 1.36 over those stated in Vallack & Shillito (1995) in order to account for the difference in collection efficiency of the Frisbee deposition gauge when compared to the BS1747 Part 1 (British Standard) dust deposit gauge.

### 3.6.3 Dust flux measurements

The dust flux from a site can be assessed in several ways. For dust flux measurements made using a passive directional dust gauge consisting of quadruple dust collectors (also referred to as the BS 1747: Part 5 or CERL-type directional gauge, see p.83) dust flux is assessed by weighing the mass of material collected in each of the four cylindrical holders. The combined mass of dust collected in the four cylinders does not equate to the non-directional (deposited) dust mass. The collected particle distribution, especially for smaller particle sizes, is reported<sup>15</sup> to be significantly different from the ambient distribution, and varies depending on wind speed.

Dust flux measurements can also be made using a sticky sheet or pad mounted on a cylinder which is then exposed to a dust source (see p.85). Dust flux measurements made using this method do not enable a gravimetric measurement of dust flux to be made (by means of measuring the mass of dust collected).

Instead the soiling, or obscuration, caused by dust is measured over an exposure period of typically 1-2 weeks. The dust coverage is often expressed as: **Effective Area Coverage (EAC%)**, a measure of the colour-contrast of the dust calculated by comparing the change in greyscale of the slide where dust is present against the unexposed area, i.e., percentage reduction in reflectance per day, thus taking into account the perceived nuisance effect of darker dusts, or, **Absolute Area Coverage (AAC%)**, a measure of the proportion of an area that has been obscured irrespective of dust colour. Measurements of surface soiling made using a sticky pad can be used to infer dust nuisance. The custom and practice threshold values for surface soiling assessed using a sticky pad range from 0.5% to 5% EAC per day, and are applied on a site-by-site basis as they are dependent on dust colour-contrast.

Table 3.5 is a proposed “dust nuisance risk matrix” that combines AAC and EAC measurements which allow an informal prediction of the potential risk of dust nuisance, as monitored with certain directional sticky pad samplers. By combining the two measures the potential dust nuisance can be inferred as shown in Table 3.5. For less precise assessment, an indicative visual assessment, by comparison to shade or colour charts may be sufficient to provide an approximate idea of dust deposition in an area.

**Table 3.5 Potential nuisance criteria based on AAC and EAC<sup>16</sup>.**

		AAC%: Dust source significance (AAC% value for a 45° wind sector given in brackets)				
		0 (<80%)	1 (80-95%)	2 (95-99%)	3 (99-100%)	4 (100%)
EAC: Dust nuisance potential (EAC% value given in brackets)	0 (<2.5%)	V Low	V Low	V Low	Low	Med
	1 (2.5-5%)	Low	Low	Low	Med	High
	2 (5-15%)	Med	Med	Med	High	High
	3 (15-25%)	High	High	High	High	V High
	4 (>25%)	V High	V High	V High	V High	V High

<sup>15</sup> Bush et al., 1976.

<sup>16</sup> Datson, 2010.

## 3.7 Chapter 3 Summary

The control and subsequent impact of dust from new and existing quarry facilities and related activities falls under four discrete regulatory regimes:

- **Land-use planning** via the TCPA 1990, which established the regulatory framework for land use planning within which quarries and related activities need to operate.
- **Control of industrial air pollution** via the EPR 2010 (as amended) which creates a standardised environmental permitting and compliance mechanism in England.
- **Control of nuisance** via the EPA 1990 (Part III) which provides a definition of statutory nuisance.
- **Control of local air quality** via LAQM regulations invoked by the EA 1990 which sets statutory limits for airborne PM<sub>10</sub> concentrations through the application of daily and annual AQOs.

Table 3.6 summarises the national AQO applied for the assessment of PM<sub>10</sub> concentrations and the custom and practice thresholds used to help predict dust nuisance arising from quarries and surface mines.

**Table 3.6 Nuisance dust and PM<sub>10</sub> assessment criteria.**

Application	Determinand	Limit/threshold value	Type
Environmental protection and air quality management	PM <sub>10</sub>	24-hour average PM <sub>10</sub> concentration not to exceed 50 µg m <sup>-3</sup> more than 35 times per year Annual average PM <sub>10</sub> concentration not to exceed 40 µg m <sup>-3</sup>	AQO
Nuisance	Soiling (slide method)	25 soiling units (SU) week <sup>-1</sup>	Custom and practice (England)
	Deposited dust	80-200 mg m <sup>-2</sup> day <sup>-1</sup> (dependent on dust colour-contrast)	Custom and practice (England)
	Soiling (sticky pad or sheet method)	0.5 to 5% effective area coverage (EAC) day <sup>-1</sup> (dependent on dust colour-contrast)	Custom and practice (England)

Whilst custom and practice thresholds are applied to assess dust deposition and soiling caused by dust arising from the extractive industries, other metrics of annoyance, such as the frequency of occurrence, location, complaints records, and loss of amenity, should be assessed in order to determine the existence of statutory nuisance.

The next Chapter will consider the application of planning controls to limit nuisance dust and PM<sub>10</sub> arising from mineral extraction activities.

# Chapter 4. Spatial planning and development management

## 4.1 Introduction

Understanding the specific impacts of extractive industries is an essential component of the planning application process. In recent years there has been a move away from the traditional prescriptive approach of planning and land use control towards a more progressive, less adversarial regime focused on spatial planning and development management. The new regime places greater emphasis on pre-application discussions in order to enable development which is mutually acceptable to the developer and/or operator and the Minerals Planning Authority.

Spatial planning, and in particular the development management process, provides a mechanism by which the potentially adverse impacts arising from dust may be avoided by design and if this is not possible to ensure that the impacts are suitably minimised or controlled. This may be achieved by changes in site layout and design or by imposition of controlling conditions. Planning conditions relating to the control of dust should not duplicate controls placed on the operator under the relevant pollution control regime. The Government's over-arching policy on pollution control is set out in PPS23. As noted in Section 3.2 the national planning framework is undergoing a period of review and reform.

s.38 of the Planning and Compulsory Purchase Act 2004 requires that planning applications are determined in accordance with the development plan, unless material considerations, e.g., layout, density, access and traffic, indicate otherwise. The significance of one consideration relative to another varies on a site-by-site basis. The development plan includes an adopted Development Plan Document and any saved policies from a Structure Plan or Local Plan.

## 4.2 Pre-application discussions

Minerals Planning Authorities must propose and adopt a Statement of Community Involvement (SCI). The SCI will set out the expectations of the Minerals Planning Authority in relation to engaging the local community in planning discussions. Minerals Planning Authorities will expect developers and/or operators to have engaged with local communities in accordance with the SCI before submitting a planning application. This will:

- (a) Inform the community of the developer's and/or operator's intentions,
- (b) Provide an opportunity for proposals to be amended before they are formally submitted if necessary,
- (c) Allow further information to be provided, where considered necessary, before submission, and
- (d) Allow early engagement with statutory or non-statutory consultees.

The Minerals Planning Authority will also encourage the developer and/or operator to discuss proposals with them before submission. All planning applications need to be validated before being registered. There are national validation requirements which are mandatory and most MPAs will also have adopted local validation lists which will need to be complied with. Pre-application discussions are helpful in identifying the information that will be required in order to validate the application.

PPS23 states that the developer and/or operator should discuss their proposals with both the planning and pollution control authorities and other interested bodies prior to the submission of a planning application. This will provide adequate time for consultation, consideration of the principle of the development, and, minimisation of potential problems through site design. LPAs should consult the pollution control authority at an early stage on proposals for potentially polluting developments to minimise the prospects of conflicting requirements being imposed on the developer and/or operator under the planning and pollution control regimes and undesirable duplication of pollution controls through the planning system.

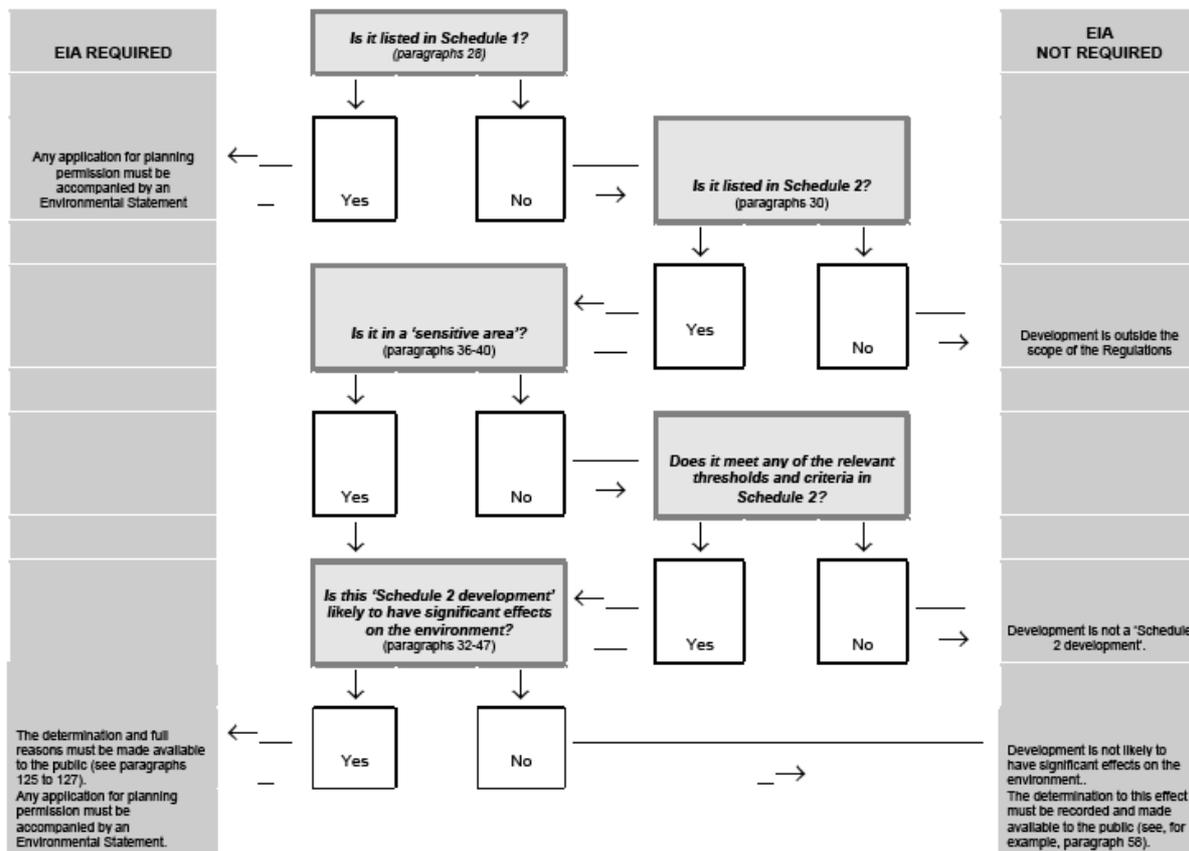
For major developments an informal scoping and mapping stage will be required to allow the LPA, pollution control agencies, other interested parties and the public the opportunity to discuss the development, and moreover the overall decision process. Every opportunity should be taken to streamline the application procedure and promote money saving and time efficiency by avoiding duplication in applications and documentation.

### 4.3 Environmental Impact Assessments (EIA)

The Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (Statutory Instrument 1999 No. 293 (SI 1999 No. 293), as replaced) requires certain developments to be the subject of Environmental Impact Assessment (EIA). The process for showing whether an EIA is required is shown in Figure 4.1. An EIA is mandatory for any proposal falling within the remit of Schedule 1 of the Regulations. An EIA will also be required for development within Schedule 2 where it is considered that the development is likely to have a significant effect on the environment.

**Figure 4.1 Criteria for requirement of an EIA for a proposed development (DETR Circular 2/99).**

Establishing whether a development requires EIA



The likelihood of significant effects will tend to depend on the scale and duration of the extractive operations and the nature of other minerals activities at the site. This will determine the potential consequent impact of dust and other environmental effects. ODPM Circular 02/99 states that for clay, sand and gravel workings an EIA is more likely to be required if they cover more than 15 hectares or involve the extraction of more than 30,000 tonnes of mineral per year. For extractive industries such as quarries and surface mines, Schedules 1 and 2 of SI 1999 No. 293 of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 specifically define the development criteria for which the preparation of an EIA is required.

A **Schedule 1 development** is defined as:

- “Quarries and open-cast mining where the site exceeds 25 hectares...”

The threshold and criteria for the purpose of classifying a development as a **Schedule 2 development** is:

- *“Quarries, open-cast mining... (unless included in Schedule 1) ...except the construction of buildings and other ancillary structures where the new floor space does not exceed 1,000 square metres.”*

DETR circular 2/99 also outlines procedures to be followed when completing an EIA. Where an EIA is required there are three broad stages to the procedure.

- (a) The developer and/or operator must compile detailed information about the likely main environmental effects. To help the developer and/or operator, public authorities must make available any relevant environmental information in their possession. The developer and/or operator can also ask the 'competent authority' for their opinion on what information needs to be included. The information finally compiled by the developer and/or operator is known as an **Environmental Statement (ES)**.
- (b) The ES (and the application to which it relates) must be publicised. Public authorities with relevant environmental responsibilities and the public must be given an opportunity to give their views about the project and ES.
- (c) The ES, together with any other information, comments and representations made on it, must be taken into account by the competent authority in deciding whether or not to give consent for the development. The public must be informed of the decision and the reasoning.

The developer and/or operator may decide for themselves (in the light of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999, the guidance in DETR circular 2/99 and any discussions with the LPA) that an EIA will be required for their proposed development. The developer and/or operator may, therefore, submit a statement with a planning application without having obtained a screening opinion to the effect that one is required.

## 4.4 Applications for planning permission and pollution control permits and licences

For the majority of activities subject to Environmental Permitting, there is no statutory requirement on an operator to obtain planning approval before a pollution control authorisation can be issued or vice versa. In the interest of saving time and money, consideration should be given to submitting applications for planning permission and pollution control permits in parallel. Any conditions imposed under pollution control can then be taken into account in the planning application. The LPA should be able to address any conflict and potential duplication between the pollution control authorisation and planning requirements. This should minimise any delays associated with negotiating separate applications consecutively, and help reduce costs and burdens imposed on the business.

## 4.5 Planning and permitting conditions

PPS23 sets out the Government's core policies and principles on the most important aspects of land use planning. It contains detailed guidance for Local Authorities and developers and/or operators on pollution control through the use of planning control. In cases where the control of pollution from a development is subject to prior approval by another pollution control authority it should not be necessary to use planning conditions. For example, an Environmental Permit issued by the Environment Agency provides strict environmental controls over a development when it is issued. The terms of the EP are to be enforced by the Environment Agency. In cases where a site is exempt from requiring an EP, or similar permit, it may necessary to retain conditions that limit the impact of the development on the surrounding environment, including its affect on local air quality. Planning conditions can be used to control aspects of the development of a quarry or surface mine provided these are not covered by the pollution permit and that a land use planning consideration **can be clearly distinguished**. Appendix A to PPS23 (reproduced in Section A of the accompanying Good Practice Guide) provides a list of issues to be considered in individual planning applications. Planning conditions can be used to control issues such as: hours of operation, transport modes, landscaping, plant and buildings, timescale of operations, non-PPC processes, as well as nuisance dust and PM<sub>10</sub>.

The wording and content of a planning condition should adequately reflect: (a) the development being permitted; and, (b) what is to be achieved by its imposition. With respect to monitoring dust emissions or levels, planning conditions should be **site specific**, stating clearly a set value or range to be achieved, how monitoring is to be carried out, where it is to be undertaken and how it should be logged and/or reported. Planning conditions should avoid duplicating restrictions on site operators imposed by PGNs.

The planning conditions imposed on a site operator would require discussion between the planner and site operator. Some Local Authorities provide specimen planning conditions relating to the control of pollution. Circular 11/95 provides guidance on the use of planning conditions. On a number of occasions the courts have laid down the general criteria for the validity of planning conditions. In addition to satisfying the court's criteria for validity, the Secretaries of State take the view that conditions should not be imposed unless they are both necessary and effective, and do not place unjustifiable burdens on applicants. Conditions should only be imposed where they satisfy all of the tests described in paragraphs 14-42 of Circular 11/95. In brief, Planning Conditions should be:

- Necessary,
- Relevant to planning,
- Relevant to the development to be permitted,
- Enforceable,
- Precise, and
- Reasonable in all other respects.

Planning Conditions may require the site operator to:

- Prepare and implement a DMP, and/or a dust monitoring and mitigation scheme.
- Undertake routine dust monitoring during normal operating conditions when mineral extraction and handling is undertaken (the site operator should note the duration of the monitoring scheme, location of dust monitoring points, type of monitoring equipment, pollutant monitored, and the standard to be monitored against, as outlined in Chapter 9).
- Provide and maintain facilities to enable dust mitigation and control to be undertaken.
- Periodically use dust suppression equipment, wet cleaning methods (water bowsers) or mechanical road sweepers during working hours, especially during dry weather, to limit visible dust emissions.
- Maintain a log of complaints from the public and a record of the measures taken to deal with complaints regarding dust disturbance.

The philosophy of this Overview document and the accompanying Good Practice Guide is that dust management is facilitated through the site specific dust management plan.

## 4.6 Planning obligations

In circumstances where it is not appropriate to use planning conditions to address the impact of a proposed quarry or surface mine, or where a quarry or surface mine is planned in or near to an area of existing sources of pollution, it may be appropriate to enter into a planning obligation under s.106 of the TCPA 1990 (as substituted by the Planning and Compensation Act 1991). Properly used, s.106 Agreements can be used to improve air quality, make other environmental improvements before the development of a quarry or surface mine site goes ahead or to offset the subsequent environmental impact of a proposed extractive process.

Planning obligations should be relevant to planning in land use terms and directly related to the proposed development if they are to influence a decision on a planning application. Measures for which it might be possible to consider for s.106 Agreements include the purchase, installation, operation and maintenance of air quality monitoring equipment or provision of other assistance or support to enable authorities to implement any necessary monitoring or other actions in pursuit of an Air Quality Action Plan.

## 4.7 Planning considerations for PM<sub>10</sub>

The land-use planning system is recognised to play an integral part in improving air quality. This requires close co-operation between planners and environmental health officers. Some local authorities have developed procedures to help ensure that planning applications that might have impacts on air quality are forwarded to the environmental health department for comment. This is considered to be an important first step and authorities are encouraged to ensure that suitable procedures are in place.

Pless-Mulloli et al. (2000) conducted research into the impact of PM<sub>10</sub> derived from opencast coal sites on public health. This work is commonly referred to as the 'Newcastle Study'. PM<sub>10</sub> was measured at ten sites in northern England using TEOMs and Partisol Samplers (these instruments are described in Section 9.2.3). Individual analysis of the PM<sub>10</sub> particles sampled via electron microscopy (described in Section 9.5.2) demonstrated that shale particulates, rather than soot or coal, representative of fugitive emissions from opencast mines, were transported up to 1 km from the site boundary. MPS2 requires consideration of PM<sub>10</sub> monitoring where public habitation is within a distance of 1 km from new mineral extraction sites, and to assess:

- Whether the site is likely to lead to a breach of the AQO for PM<sub>10</sub> (see Section 3.5),
- Whether the impact is significant, and
- If the potential effects on PM<sub>10</sub> levels merit refusal.

When PM<sub>10</sub> impact is found to be significant in planning terms but, on balance, does not merit refusal of an application, procedures to monitor and control PM<sub>10</sub> should be adopted. The Newcastle study recommends an assessment framework for the consideration of impacts from a proposed site. Figure 4.2 shows an amended version of the assessment framework.

Chapter 5 describes the fundamental physical processes that determine of wind-driven erosion and the inter-relationship between wind speed, particle diameter and dispersion distance. Comparison of the observations of Pless-Mulloli et al. (2000) and the derived dispersion distances for PM<sub>10</sub> presented in Chapter 5 provide reasonable agreement.



## Chapter 5. Wind-driven erosion and dispersion

This chapter considers the physical processes by which dust particles from either mineral sites or background sources (e.g., wind-blown soils, rock and mineral weathering) are dispersed. It considers the complex physical processes and site specific factors which affect dust propagation and transport. In general, these factors cannot be accurately determined for large, open diffuse sources, e.g., mineral extraction sites. Chapter 5 considers the application of dispersion modelling techniques to represent these processes. Chapter 6 illustrates some of the difficulties faced when attempting to accurately predict the extent of dust dispersal.

### 5.1 Overview

Wind-driven erosion is the dominant mechanism involved in the transport of dust from extractive processes from source to receptor. The rate of erosion, or “dust mobilisation”, from a surface is dependent on a range of site-specific factors:

- Local climate, e.g., the amount and intensity of precipitation, average temperature, seasonality, wind speed,
- Mineral geology, friability, wetness and grain size or dust particle diameter,
- Surface crusting (crusted soils, whether biologically or physically formed, resist wind erosion, whereas loose or disturbed soils are more readily eroded), and
- Surface roughness (non-erodible cover such as vegetation, which acts to absorb the momentum of the wind, thus reducing wind speeds at the material surface).

The onset of erosion requires the transfer of kinetic energy from the wind to surface bound dust particles. When the surface bound dust particles gain sufficient energy they can overcome the gravitational and cohesive forces binding them to the surface.

### 5.2 Erosion

The extent to which erosion occurs is dependent on the diameter ( $d_p$ ) and density ( $\rho_p$ ) of the dust particle and the threshold friction velocity ( $u_{*t}$ ). The threshold friction velocity ( $u_{*t}$ ) is the minimum friction velocity ( $u_*$ ) at which erosion is initiated. The distance ( $x$ ) over which a particle travels once airborne is dependent on three parameters described later in Equation (5). Particles within the size range of  $10 \leq d_p \leq 30 \mu\text{m}$  can be transported up to 500 m from their source, whereas larger particles  $>30 \mu\text{m}$  may only travel short distances ( $\sim 100$  m) from their source. A series of experimentally derived relationships can be used to calculate the on-set of wind-driven erosion and the distance over which particles will be transported.

In order to calculate  $u_{*t}$  it is necessary to first calculate the Reynolds number ( $Re$ ), a dimensionless number used to indicate the flow regime at the interface of the surface and fluid (air), i.e., whether it is turbulent (well-mixed) or laminar (stratified).

$$Re = ad_p^x + b \quad , \quad \text{Equation (1)}$$

where:  $a$  = 1331  $\text{cm}^{-x}$ ,  
 $d_p$  = particle diameter (cm),  
 $x$  = 1.56, and  
 $b$  = 0.38.

Note: for a  $10 \mu\text{m}$  particle,  $d_p = 1 \times 10^{-3}$  cm, as  $1 \mu\text{m} = 1 \times 10^{-5}$  cm

Determination of  $Re$  dictates the equation used to calculate  $u_{*t}$ .

For  $0.03 < Re \leq 10$ ,

$$u_{*t} = 0.129 \frac{\sqrt{\left(\frac{\rho_a g d_p}{\rho_p}\right) \cdot \sqrt{\left(1 + \frac{0.006}{\rho_p g d_p^{2.5}}\right)}}}{\sqrt{[1.928 \times Re^{0.092}]}} \quad \text{Equation (2)}$$

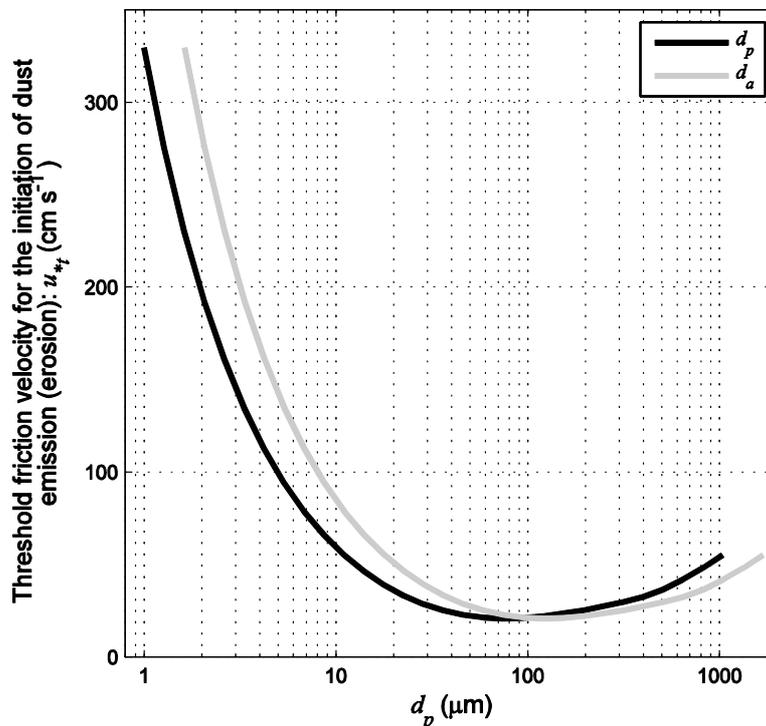
For  $Re > 10$ .

$$u_{*t} = 0.12 \left( \frac{\sqrt{\left(\frac{\rho_a g d_p}{\rho_p}\right) \cdot \sqrt{\left(1 + \frac{0.006}{\rho_p g d_p^{2.5}}\right)}}}{\sqrt{[1.928 \times Re^{0.092}]}} \right) \times \left(1 - 0.0859e^{-0.0617[Re-10]}\right), \quad \text{Equation (3)}$$

where:  $g$  = gravitational constant,  
 =  $9.81 \text{ m s}^{-2}$ ,  
 =  $981 \text{ cm s}^{-2}$ ,  
 $\rho_p$  = particle density,  
 =  $2.65 \text{ g cm}^{-3}$ , and  
 $\rho_a$  = density of air at 20°C and 1 atm (STP),  
 =  $1.23 \times 10^{-3} \text{ g cm}^{-3}$ .

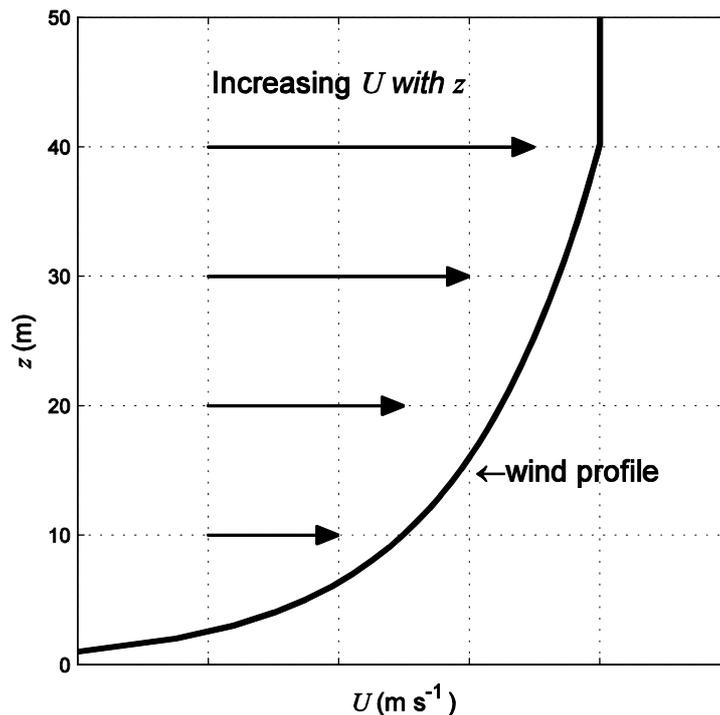
Figure 5.1 shows the relationship of  $u_{*t}$  against  $d_p$  for particles in the size range of 1-1000  $\mu\text{m}$ .

**Figure 5.1 Relationship of  $u_{*t}$  against  $d_p$  for particles in the size range  $1 \leq d_p \leq 1000 \mu\text{m}$ .**



The threshold wind speed for the initiation of dust emission ( $U_t, \text{m s}^{-1}$ ) can be calculated from  $u_{*t}$ , and the logarithmic wind profile in the lower portion of the atmosphere.

**Figure 5.2** Logarithmic profile of wind velocity close to the earth's surface.



The logarithmic wind profile is a semi-empirical relationship used to describe the vertical distribution of horizontal wind speeds above the ground within the atmospheric surface layer. The logarithmic profile of wind speeds is generally limited to the lowest 100 metres of the atmosphere (i.e., the surface layer of the atmospheric boundary layer as shown in Figure 5.2). The wind speed ( $U_z$ ) at a height ( $z$ , metres), and hence the threshold wind speed ( $U_t$ ), above the ground is given by:

$$U_z = \left( \frac{u_{*t}}{\kappa} \right) \ln \left( \frac{z}{z_0} \right), \text{ Equation (4)}$$

where:  $\kappa$  = Karman constant  
 = 0.4 (dimensionless),  
 $z$  = release height (m), and  
 $z_0$  = surface roughness parameter, or roughness length (m)  
 = 0.01 m (for flat, open terrain with limited vegetation).

Figure 5.3 shows the relationship of  $U_t$  against  $d_p$  for particles in the size range of  $1 \leq d_p \leq 1000 \mu\text{m}$ . The horizontal distance over which the particle will be transported can be estimated from  $U_z$  using Equation (5).

As noted in Section 5.1 the onset of erosion requires the transfer of kinetic energy from the wind to surface bound dust particles. The rate of wind-driven erosion from a surface is dependent on a range of site-specific factors:

- Local climate,
- Mineral geology,
- Surface crusting, and
- Surface roughness.

- Wind stress is shared between the erodible and non-erodible surfaces leading to a decrease in the actual friction velocity.
- The clay content of the soil effects the moisture content thereby reducing  $u_{*t}$ . For soils with a clay content >4% by weight,  $u_{*t}$  is reduced appreciably, and more so as the clay content increases.

Therefore the initiation of wind-driven erosion may be observed to occur at higher wind speeds.

Table 5.1 and Table 5.2 summarise the potential for the initiation of dust propagation based on wind speed and soil type. Both tables demonstrate that the initiation of dust propagation for soils and mineral particles occurs at wind speeds in excess of approximately  $3 \text{ m s}^{-1}$ , which is consistent with the minimum  $U_t$  threshold value shown in Figure 5.3.

Figure 5.3 Relationship of  $U_t$  against  $d_p$  for particles in the size range  $1 \leq d_p \leq 1000 \mu\text{m}$ .

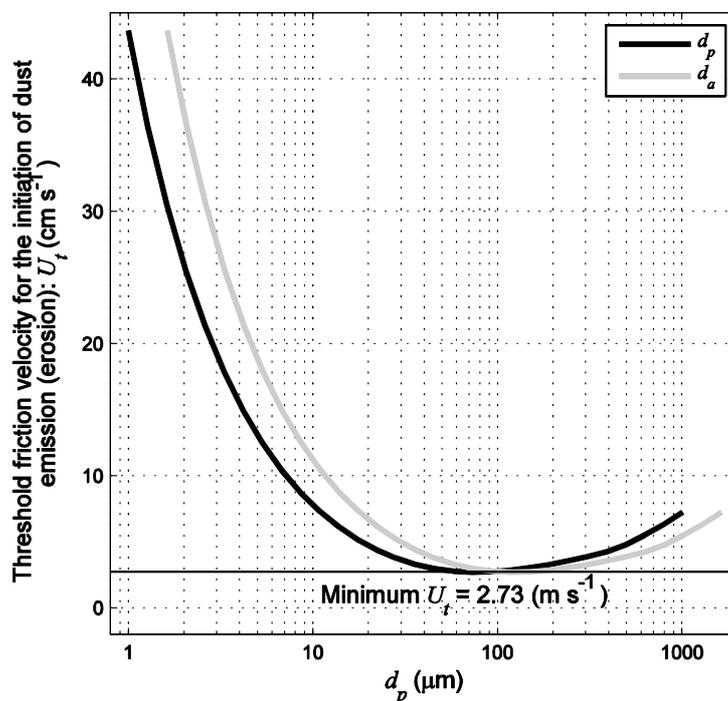


Table 5.1 The potential for the initiation of dust propagation based on wind speed

Wind speed ( $\text{m s}^{-1}$ )	Potential for dust propagation
<0.5	essentially calm, very low potential for dust movement
>0.5	low wind speeds, low potential for dust movement
>2	'average' wind speeds, moderate potential for dust movement
>6	high wind speeds, reasonable potential for dust movement
>10	very high wind speeds, significant potential for dust movement

**Table 5.2 The potential for the initiation of dust propagation based on soil type and wind speed (based on studies of exposed soils).**

Wind speed (m s <sup>-1</sup> )	Soil type
2.9-5.8	Disturbed soils having < 50% clay & < 20% pebble (<1 cm in diameter)
3.6-5.8	Tilled bare solids
5.8-9.4	Disturbed pebbly soils
6.5-10.2	Bare clay soils that have desegregated by natural forces
5.8-21.8	Disturbed soils having a high salt content or more than 50% clay
20.3-29	Undisturbed sandy soils having a crust and soils covered with fine gravel
>21.8	Undisturbed soils having > 50% clay and surface crusts and salt-crusted soils
>26.1	Soils covered by coarse (> 50 mm pebbles)

### 5.3 Dispersion

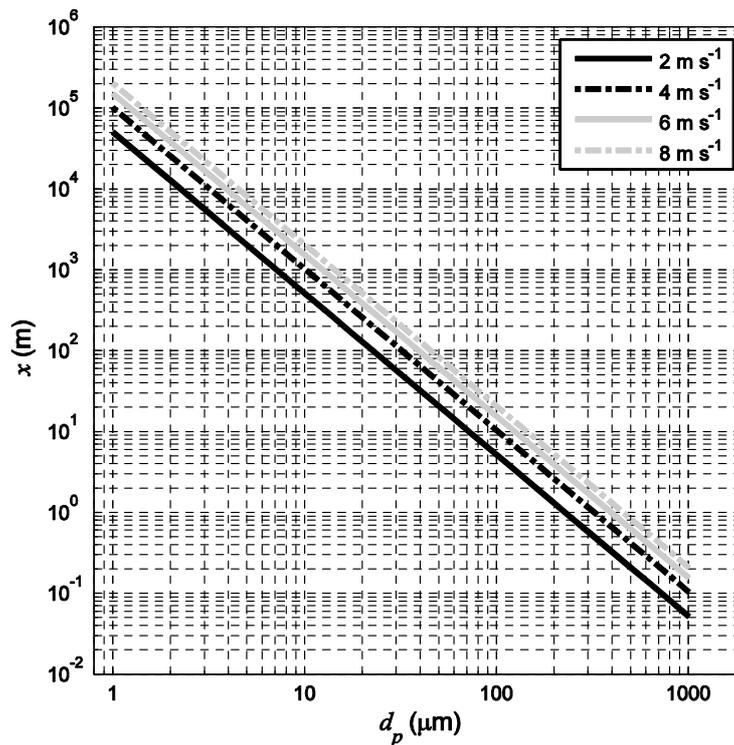
The horizontal (dispersion) distance over which a particle will be dispersed can be estimated using the formula:

$$x = \frac{U_z x z}{V_g}, \quad \text{Equation (5)}$$

- where:  $x$  = horizontal (dispersion) distance (m),  
 $U_z$  = wind speed at height  $z$  (m s<sup>-1</sup>),  
 $V_g$  = gravitational (or terminal) settling velocity (m s<sup>-1</sup>),  
 $= \frac{\rho_p d_p^2 g C}{18\eta}$ ,  
 $\rho_p$  = particle density (kg m<sup>-3</sup>),  
 $d_p$  = particle diameter (μm),  
 $g$  = gravitational constant,  
 $= 9.81 \text{ m s}^{-2}$ ,  
 $C$  = Cunningham slip correction factor (dimensionless),  
 $\approx 1$ , and  
 $\eta$  = dynamic viscosity of air at 20°C and 1 atm (STP),  
 $= 1.82 \times 10^{-5} \text{ Pa s}$ .

Figure 5.4 shows the relationship of  $x$  against  $d_p$  for particles in the size range of  $1 \leq d_p \leq 1000 \mu\text{m}$  for  $U = 2, 4, 6$  and  $8 \text{ m s}^{-1}$ .

Figure 5.4 Relationship of  $x$  against  $d_p$  for particles in the size range  $1 \leq d_p \leq 1000 \mu\text{m}$  for  $U = 2, 4, 6,$  and  $8 \text{ m s}^{-1}$ .



From Equation (5) it can be seen that  $x$  is proportional to  $1/d_p^2$ , therefore a ten fold increase in particle diameter leads to a hundred-fold reduction in the horizontal (dispersion) distance ( $x$ ). Equation (5) underlines the need to limit stockpile heights in order to reduce the potential distance over which wind-blown material can be transported once airborne ( $x$  is proportional to  $z$ ), as well as reducing the exposure of the material to the wind.

As noted in the Abbreviations and Acronyms at the beginning of this document PM<sub>10</sub> is particulate matter, which passes through a size-selective inlet with a 50% efficiency cut-off at  $10 \mu\text{m}$  aerodynamic diameter or  $d_a$ . The  $d_a$  is the diameter of a spherical particle having a density of  $1 \text{ g cm}^3$  that has the same inertial properties, i.e., the equivalent terminal settling velocity ( $V_{TS}$ ), in air as the particle of interest. The  $d_a$  for all particles  $>0.5 \mu\text{m}$  can be approximated using:

$$d_a = d_p \sqrt{\rho_p} \quad \text{Equation (6)}$$

This approximation allows  $u_{*t}$ ,  $U_t$  and  $x$  to be expressed in terms of  $d_a$ , as well as  $d_p$ , allowing calculation of these parameters for dust particles that would be classified as PM<sub>10</sub>.

## 5.4 Chapter Summary

Equations (1) to (5) permit calculation of the threshold friction velocity and threshold wind speed ( $u_{*t}$ ,  $U_t$ ) for the initiation of erosion and the horizontal distance ( $x$ ) over which dust particles can be transported having acquired sufficient momentum (from the wind) to overcome the gravitational and cohesive forces binding them to the surface. It should be noted that in practice:

- Wind stress is shared between the erodible and non-erodible surfaces leading to a decrease in the actual friction velocity.
- The clay content of the soil effects the moisture content thereby reducing  $u_{*t}$ . For soils with a clay content  $>4\%$  by weight,  $u_{*t}$  is reduced appreciably, and more so as the clay content increases.

Therefore the initiation of wind-driven erosion may be observed to occur at higher winds than predicted theoretically.

Equations (2) and (3) assume that erosion is occurring on a flat surface. The terrain surrounding quarries and surface mines is normally variable and topographically complex. Such surface complexities may act to enhance wind speed via channelling, or reduce wind speed via shielding, and thereby affect the extent to which wind-driven erosion occurs. Wind-terrain interaction within quarries is not well characterised.

Equation (5) underlines the need to limit stockpile height to reduce the potential distance over which wind-blown material can be transported once airborne.

## Chapter 6. Dust dispersion modelling

As noted in Chapter 2 the dust management process seeks to break the link between source, pathway and receptor. In practice evidence of acceptability of a site is based on a risk based model, drawing on meteorological conditions, site topography, process type, and receptor locations.

Dust dispersion modelling has been applied for the purposes of detailed assessment to well-defined point sources, e.g., cement kilns. It has been rarely applied in the wider UK minerals industry to model dust dispersion from quarries due to a number of intrinsic factors:

- Transient nature of the emissions,
- Uncertainties in emission factors<sup>4</sup>, and
- Inherent uncertainties in dispersion models dealing with complex terrain and transient open sources.

This chapter looks at methods of assessing dust dispersion. The principal method is dust dispersion modelling. Dispersion modelling is applied by Local Authorities and other public bodies to model pollutant dispersion over small geographic areas (e.g., to model discrete point sources) as part of LAQM.

### 6.1 Overview

Dust dispersion modelling is a process whereby a system is created to simulate a real-life situation. Modelling can be an inexpensive and versatile tool for solving problems related to physical processes, and is widely applied in research and development. Dust dispersion modelling is not a prerequisite for good minerals site design or operation. Whenever used, dust modelling studies at minerals sites should be validated by actual site dust measurement and data analysis.

The aim of a dispersion model is to allow identification of the potential impact of a source at nearby locations, particularly sensitive receptors (as defined in Table 3.3). Modelling also permits evaluation of dust control measures to determine any modifications necessary to improve dust control. Gaussian models are the most common mathematical models used for modelling the dispersion of airborne pollutants. Appendix 1 provides a broad outline of the fundamental principles of Gaussian atmospheric pollution dispersion models. Gaussian models are based on the assumption that the pollutant will disperse according to the normal statistical distribution. There are two packages which are widely used in the UK, and can be applied to model the dispersion of dust emitted from the extractive industries:

- UK ADMS 4 (**A**tmospheric **D**ispersion **M**odelling **S**ystem), and
- US EPA AERMOD (**A**merican Meteorological Society/**E**nvironmental Protection Agency **R**egulatory **M**ODEl).

The results of dispersion modelling simulations can be used to predict pollutant dispersion and deposition patterns, thereby helping to identify areas where potentially high pollutant concentrations may occur. To be of real use, reliable emissions and meteorological data are needed, together with an appropriate model. Two commonly used packages are detailed below.

### 6.2 ADMS

ADMS is an advanced steady-state Gaussian atmospheric pollution dispersion model for calculating concentrations of buoyant or neutrally buoyant particles or gaseous atmospheric pollutants emitted continuously from point, line (e.g., a road), volume and area sources, or intermittently from point sources. The model includes algorithms which take into numerous complex chemical and physical phenomena which act to enhance or limit pollutant concentrations within a plume, including: downwash effects of nearby buildings within the path of the dispersing pollution plume); effects of complex terrain; effects of coastline locations; wet deposition; gravitational settling (and dry deposition – based on gravitational settling); short term fluctuations in pollutant concentrations; chemical

reactions; pollution plume rise as a function of distance; jets and directional releases; averaging time ranging from very short to annual; and, condensed plume visibility. The system also includes a meteorological data input pre-processor. ADMS 4 can simultaneously model up to 100 emission sources, of which:

- Up to 100 may be point or jet sources,
- Up to 6 may be line, area or volume sources, and
- 1 may be a line source.

In order to cope with more complex terrains the FLOWSTAR advanced airflow model has been developed. This is capable of accounting for the flow effects over complex terrain, e.g., buildings, forests. Carruthers et al. (1988) have shown that FLOWSTAR models the flow well between tens of metres up to several kilometres over terrain with gradients between 1 in 2 (upwind slopes and hill summits) and 1 in 3 locally in hill wakes. Spatial scales treated by the model range from tens of metres up to several kilometres. The performance of the model has been evaluated against various measured dispersion data sets and has a wide range of users.

## 6.3 AERMOD

AERMOD is a near-field, steady-state Gaussian plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. It was developed by the American Meteorological Society and the US EPA and is the approved air quality dispersion model under US EPA 40 CFR Part 51 Appendix W, fully replacing ISCST3 (Industrial Source Complex Short-Term) model as the US EPA regulatory model in December 2006.

AERMOD includes treatment of both surface and elevated sources over both simple and complex terrain. It is able to model multiple stationary sources of different types including point, area and volume sources. In the stable boundary layer the distribution is assumed to be Gaussian in both the horizontal and vertical directions. However, in the convective boundary layer, i.e., the lowest portion of the atmosphere adjacent to the earth's surface, the vertical distribution is described using a bi-Gaussian probability density function, whilst the horizontal distribution is again considered to be Gaussian in nature.

AERMOD is able to model buoyant plumes and incorporates a treatment of "lofting" (plume rise), whereby the plume remains near the top of the boundary layer before mixing with the convective boundary layer. In general, Gaussian models are limited to treatment of flows over a simple terrain however AERMOD incorporates a simple method to approximate flows over complex terrain. The atmosphere is described by similarity scaling relationships using only a single measurement of surface wind speed, direction and temperature to predict vertical profiles of wind speed and direction, temperature, turbulence and temperature gradient. The model does not include dry or wet deposition of gases and only includes a simple treatment of dry deposition of particles using a reflection algorithm. AERMOD has not been widely used to model particle dispersion.

## 6.4 Limitations

Significant efforts have been made to capture the key particle loss terms within atmospheric pollution dispersion models, including the effects of:

- **Wet deposition** – direct transfer of dust to the Earth's surface via precipitation.
- **Dry deposition** – direct transfer of dust to the Earth's surface without the aid of precipitation.
- **Gravitational settling** – rate at which dust particles fall under the action of gravity.
- **Downwash** – suppression of uplift caused by the trapping of a plume in a downwind (lee) eddy, forcing it to the ground (e.g., occurs during flow over a break of a slope, leeward side of buildings).
- **Vegetative capture** – loss of dust particles to the surfaces of vegetation (i.e., grass, trees) via the above mechanisms (vegetative filtration) – also includes inertial impaction and interception.

Despite inclusion of the physical phenomena listed above, studies suggest that dust inputs from the following sources are poorly parameterised within the models:

- Particle re-suspension/re-entrainment – especially from haul roads and vehicles,
- Pit and fugitive emissions,
- Wind erosion, and
- Blasting events.

Atmospheric pollution dispersion models have been reported (Reed, 2005; Birch et al., 2008) to over-predict atmospheric dust loadings by a factor of 2-10. Therefore the modelled dust concentration can be considered to be an estimation of the maximum concentration. This may unnecessarily promote a negative perception of the quarry or mining operation as the site may be viewed as a high dust emitter. Unless properly managed, the findings of dust modelling studies could potentially have significant consequences from the operator's point of view in terms of public perception.

The spatial extent to which Gaussian models are typically applied is greater than 100 m, but less than 10 km, thus excluding its application to near- and far-field receptors. Within the 100-1000 m range, the distance over which particles can travel can be theoretically calculated in terms of the threshold friction velocity necessary to raise a particle (as described in the Chapter 5). In the case of far-field modelling, meteorology is expected to change over large spatial extents. The simplified treatment of atmospheric turbulence and meteorology limits the model to calculation of hourly pollutant concentrations, which is sufficient for PM<sub>10</sub> modelling as AQOs for PM<sub>10</sub> are given as either daily or annual means.

A major challenge to the modelling the dispersion of fugitive dust emissions from deep surface mines or quarries is the influence of in-pit meteorology. On the whole Gaussian plume dispersion models have been developed to model downwind dispersion of dust from sources across a flat or moderately undulating terrain. They are unable to account for the influence of complex flow regimes that exist within quarry voids. As fugitive dust emissions within a quarry are transported and dispersed by the local airflow field within the quarry, there is a need to develop transport and deposition models that reproduce the local effects produced by these flows. Such internal flow fields are best described by complex computational fluid dynamics packages that provide a multi-scale modelling approach, rather than by the conventional Gaussian plume models described here.

Birch et al. (2008) note the existence and effect of internal pit flows on the retention of fugitive dust emissions inside the quarry void. For shallow, open pit mines, only one-third of the fugitive dust emissions from mining activities escape the open pit. The location of the emission source within the pit, the terrain formation and the prevailing meteorological conditions interact in a complex manner to determine the degree of impact experienced beyond the pit boundary.

ADMS is currently not able to model terrains that contain gradients of greater than 1:3. This restricts the ability of the modelling package to replicate the influence of steeply changing terrain.

In situations where annual mean dust or PM<sub>10</sub> emissions are used as model inputs, the choice of one year against another usually only has a small effect on modelled concentrations from local sources, and can largely be ignored. If possible, meteorological, background and emissions data should all be derived from the same year. Meteorological conditions generally have a more significant impact on background concentrations than local concentrations, especially in the case of PM<sub>10</sub>, where an increase in winds originating from continental Europe can significantly increase the background (pre-existing) PM<sub>10</sub> concentration.

## 6.5 Meteorological data

Both ADMS and AERMOD are based on broadly similar principles: characterisation of the boundary layer structure using the Monin-Obuhkov length and boundary layer height. The key difference between ADMS and AERMOD is the methodology applied to pre-process meteorological data and the dispersion algorithms they employ. This can result in different predictions of pollutant concentrations in some situations. These two differences have made it difficult to determine why calculated pollutant

concentrations are different in particular cases. The difference in plume rise modules in ADMS and AERMOD is one reason for the differences observed between the outputs from the two models.

### 6.5.1 Sources of meteorological data for use in dispersion models

The use of high quality meteorological observations which have been properly quality assured and quality controlled (QA/QC'd) is an important consideration in modelling studies. There are a number of suppliers of meteorological data, for modelling purposes, in the UK including the UK Met Office, MeteoArchive, ADM, and World GeoData. Data providers should be able to advise customers on the location of observation sites for which observed meteorological data for modelling are available and the QA/QC process the data has undergone.

Common checks required for meteorological datasets are:

- Verification that the measurements are given in the correct units for the dispersion model, e.g., wind speed in  $\text{m s}^{-1}$  or as knots,
- Cloud cover (given in oktas) are within the appropriate range (0-8 or sky obscured),
- Wind directions are all within 0-360°, and
- % data capture.

The data provider should confirm whether the data are hourly sequential measurements, or whether missing hours have been filled. Some automatic stations provide data every three or five hours, and algorithms are used to calculate the missing data: where possible hourly measured data should be used. The meteorological data provider should be noted in any study report.

Local Authorities may be able to provide meteorological observations such as local wind speed and direction, temperature, and rainfall measurements, which can be used for modelling purposes if they have undergone suitable QA/QC checks.

In some cases all the meteorological observations required for a model may not be available from the same site. The data provider should be able to provide advice as to which combination of measurements from which observation sites will provide the appropriate combination of measurements.

LAQM.TG(09) details the methodology for the use of modelling studies for Screening and Assessment and/or Detailed Assessment purposes for LAQM Review and Assessment of PM<sub>10</sub>. It provides guidance on how percentiles and/or number of exceedences of the PM<sub>10</sub> AQO should be determined from the results of modelling studies. LAQM.TG(09) also provides guidance on how to calculate PM<sub>10</sub> exceedence statistics based datasets composed of partial or incomplete PM<sub>10</sub> or meteorological observations. LAQM.TG(09) can be freely downloaded from the Defra website.

## 6.6 Model validation and verification

Where modelling is undertaken it is necessary to demonstrate that the model used has been **validated** and **verified** appropriately.

- Model **validation** generally refers to detailed, peer-reviewed studies that have been carried out by the model supplier or a regulatory agency, such as the US EPA. Dispersion models used in Detailed Assessments should have been subject to detailed and documented validation trials.
- Model **verification** refers to checks that are carried out on model performance at a local level. This involves the comparison of predicted versus measured concentrations. Where there is a disparity between the predicted and the measured concentrations, the first step should always be to check the input data and model parameters in order to minimise the errors. If required, the second step will be to determine an appropriate adjustment factor that can be applied. In cases where there are local factors contributing to uncertainty, such as certain types of batch processes, complex topography, then local verification studies may be required, and/or an additional consideration of uncertainties taken into account.

As both the site operator and Local Authority need to have confidence in the results of the site assessment it is unlikely that a site assessment based on modelling data alone will be sufficient due to the limitations noted above. It is more likely that the results of modelling studies will be used to indicate the geographical extent of the exposed area and to estimate the dust concentration at receptors adjacent to the site or the population exposed to PM<sub>10</sub> concentrations above the AQO.

## 6.7 Chapter 6 Summary

Dust dispersion modelling can be applied to well-defined point sources, e.g., cement kilns. It has been rarely applied in the wider UK minerals industry to model the dispersion of dust from quarries due to a number of factors:

- Transient nature of the emissions,
- Uncertainties in emission factors<sup>4</sup>, and
- Inherent uncertainties in dispersion models dealing with complex terrain and transient open sources.

Dust dispersion modelling is applied by Local Authorities and other public bodies to model pollutant dispersion over small geographic areas (e.g., to model discrete point sources) as part of LAQM. Due to the factors listed above it has limited application to modelling dust concentrations arising from the extractive industries.

Dust dispersion modelling is not a prerequisite for good minerals site design or operation. Whenever used, dust modelling studies at minerals sites should be validated by actual site dust measurements and data analysis.

The aim of a dispersion model is to allow identification of potential impact of the source on nearby receptors, particularly sensitive receptors. Modelling also permits evaluation of dust control measures to determine modifications necessary to improve dust control. Gaussian models are the most common mathematical models used for modelling the dispersion of airborne pollutants. There are two key packages which can be applied to model the dispersion of dust emitted from the extractive industries:

- UK ADMS 4 (**A**tmospheric **D**ispersion **M**odelling **S**ystem), and
- US EPA AERMOD (**A**merican Meteorological Society/**E**nvironmental Protection Agency **R**egulatory **M**ODEl).

The modelled dust concentrations from ADMS and AERMOD may differ from measured concentrations for a several number of reasons:

- Estimates of background concentrations,
- Meteorological data uncertainties,
- Uncertainties in source activity data, e.g., emissions factors, and
- Meteorological model input parameters such as roughness length, minimum Monin-Obukhov parameter, and plume rise.

## **Part II: Source identification, control, measurement and management**

# Chapter 7. Source identification

## 7.1 Overview

Dust generation is site-specific. Source identification is the first step in establishing all possible sources of dust attributable to the site and contributory factors. It is required in order to understand:

- The frequency and emission rates of dust from the extractive process, and
- The potential impact on the surrounding environment, including sensitive receptors.

Source identification is an important step in determining:

- Appropriate mitigation measures, and
- Appropriate monitoring locations in order to demonstrate compliance with AQOs and planning conditions.

When undertaking source identification it is important to consider a number of material, process and site variables, including:

- Type of mineral,
- Scale of operations,
- Methods of working,
- Nature of excavation, processing, material transfer and storage activities, and
- Dust control measures employed on the site.

The variation in potential impacts between different mineral types is accounted for by a number of factors:

- **Nature of the mineral:** although more friable minerals crumble more easily during handling and may produce a greater number of dust particles,
- **Colour and opacity of the mineral:** high contrast dust from darker materials such as coal dust particles are generally more readily noticed,
- **Chemical composition of the dust:** this could affect the nature of the impacts upon soils and vegetation and may elicit a positive or negative effect. For example, limestone dust can result in neutralisation of acidic soils in nearby agricultural fields (known as “liming”),
- **Frequency of handling:** more frequent handling and processing may lead to greater dust emissions,
- **Scale of operations:** generally the more extensive the scale of operations, the more likely that dust will be a concern,
- **Site design:** haul roads, material handling, processing and storage facilities should ideally be located away from sensitive receptors (as defined in Table 3.3) so far as possible, in order to limit the impact of dust on receptors adjacent to the site,
- **Site activities:** their location and duration – a potential dust problem may be more tolerable if it occurs infrequently or is of short duration, and
- **Record of operation:** well-established and well-managed minerals operations are generally more accepted by the local community.

Local factors and background sources (e.g., arable farming, wind-blown dust) will also affect the assessment of dust. These factors include:

- Site geography and topography,

- Character and land use of the area surrounding the site,
- Site hydrogeology,
- Vegetative cover, and
- Prevailing meteorology, in particular wind speed, direction and rainfall.

## 7.2 Sources of dust

### 7.2.1 Material, process and site sources

Material, process and site sources of dust include:

- Earth movement and soil handling is a common activity associated with minerals extraction. Dust emissions associated with soil handling tend to be transient and depend on the dryness, silt and/or clay content of the material and transportation to mounds on the edge of site.
- Handling of overburden (all soil and ancillary material above the bedrock horizon in a given area) handling represents a dust source. Handling may include loading and haulage. The quantity of dust produced can be related to the amount of overburden moved and its rock type (and depends on factors such as drop height).
- Soil and overburden movement occurs throughout the lifetime of the site. The potential for dust emissions due to the handling of soil and overburden tends to be of relatively short duration. Dust emissions are dependent on extent of material transportation from storage piles (typically located on the periphery of the site) and may proceed intermittently due to phased restoration of the site.
- Drilling and blasting is a transient source of dust. Although the amount of dust produced can be considerable, blasting does have the advantage of limiting dust releases to discrete controlled periods, therefore with adequate dust mitigation in place the effect can be kept to a minimum. Drill rigs have significant dust emission potential, however most drill rigs now use shrouds and dust extraction. This means that any dust generation is normally localised to the immediate vicinity of the drill rig.
- Material extraction and handling activities, such as conveyor systems, as shown in Figure 7.1, are inherent to the extractive industries. Dust emissions associated with mineral extraction vary and are dependent on the material and handling techniques. The application of mitigation techniques such as wet suppression, dust guards, shuttering and covers on machinery will significantly limit the potential for adverse effects.

**Figure 7.1 Handling and processing equipment: dust covers on conveyor systems to minimise wind-blown dust and dust arising from handling operations.**



- Dust emissions from crushing and screening are largely controlled through EPR 2010 (as amended) and can be reduced by keeping crushing and screening plants covered, as shown in Figure 7.2. This reduces the exposure of potentially dusty materials to wind and thereby ameliorates the effect of wind-blown dust.

**Figure 7.2 Covered crushing and screening plants: used to limit dust emissions during materials handling.**



- Stockpiles are commonplace at most quarries and surface mines. Wind-driven erosion can lead to the dispersion of dust from stockpiled materials. It can be limited by enclosing stockpiles or through the exploitation of topographic features to provide shelter, e.g., trees or the placement of stockpiles in the quarry void. In some instances chemical stabilisers can be applied to the surface of stockpiles to limit erosion. The rate of erosion is dependent on the mineral type, particle size, volume of material stored, moisture content, which is limited by rainfall or the application of water, and exposure to wind, e.g., stockpile height and the use of storage housing.
- The loading of quarried and mined materials produce dust throughout extraction. The tendency for dust generation is dependent on the nature of material, whether wet or dry, volumes handled and equipment used and the resultant drop heights. Dust generated in this manner can be limited by reducing drop heights and building stockpiles in sheltered locations. In some circumstances, material can be wetted prior to movement loading.

**Figure 7.3 Dust arising from vehicle loading:** can be minimised by wetting material to be loaded and/or limiting vehicle loading to times when wind speeds are low.



**Figure 7.4 Dust arising from vehicle movement:** can be minimised through keeping the road clean, and/or the application of water to roads, and/or controlling vehicle speed.



- Vehicle loading and material transport off-site are potential sources of dust (as shown in Figure 7.3 and Figure 7.4). The significance of transport related dust sources is variable and depends on the mode of transport employed, the nature of materials handled, and the controls applied. If extracted materials are transported off-site by road then the size of vehicle and nature of roads (surfaced or unmade) are determinant factors. Dust emissions associated with material transport within the site can be limited by using conveyor belt systems to transfer materials. The use of concrete and tarmac roads) will reduce erosion and thus dust emissions, and vehicle fuel consumption, but due to the heaviness of site plant machinery are susceptible to damage. However, such permanent road fixtures are not practical for roads traversed by heavy plant. Consequently, on-site roads can be surfaced with a wide range of suitable materials to give the durability and flexibility required. For example, aggregate is often used as a temporary finish for internal haul roads used by dump trucks to reduce dust generation, as shown in Figure 7.5. In the most sensitive locations, the speed limit on haul roads should be controlled: ideally vehicle speed should be limited to 15 mph. In order to maintain site activity rates variable speed limits can be imposed elsewhere. Away from sensitive receptors vehicle speeds can be slightly higher.

**Figure 7.5 Spoil and tarmac road surfacing:** the use of made surfaces to minimise dust emission from vehicle movement.



Table 7.1 summarises the typical range of sources of nuisance dust and PM<sub>10</sub> associated with the extractive industries.

**Table 7.1 On-site dust sources, relevance, duration and potential for dust emission.**

Activity	Relevance for mineral types	Duration of activity	Potential for dust emission
Soil handling	Most minerals	Relatively short	<b>Significant</b> but depends on dryness and silt or clay content of the material and transportation to stockpiles.
Overburden handling	Most minerals, but quantities vary considerably	Varies. Can be intermittent over life of site	<b>Significance varies (high to low)</b> and highly dependent on the nature of overburden, particularly during unloading and haulage.
Drilling and blasting	Usually for hard rocks	Short, but can take place frequently	Without control, drill rigs can be a <b>very significant</b> source of dust. However, most drill rigs now use shrouds and any dust generation is very localised.  Properly designed and controlled blasts have limited potential for the creation of dust therefore <b>not generally significant</b>
Initial loading activities	All mineral types	Ongoing during extraction	<b>Significance varies (high to low)</b> and dependent on the nature of material, whether wet or dry, volumes handled and equipment used.
Crushing and screening	Most minerals, but not always at the place of extraction	Varies, generally ongoing	<b>Very significant</b> if unmitigated. Significance varies depending on type of equipment and exposure to wind. Controlled through the EPR permit at regulated sites.
Storage of minerals within site	Most mineral types	Usually ongoing during extraction	<b>Significance varies (high to moderate)</b> depending on the volume of material stored, moisture content, exposure to wind, covering of stockpiles.
Transport and load-out within site	All mineral types	Usually ongoing	<b>Significance varies (high to moderate)</b> depending on type of vehicle. If transported by road then the size of vehicle, speed and nature of roads (surfaced or unmade) are important factors.
Transport off-site (mainly by road)	All mineral types	Usually ongoing	<b>Not generally significant</b> (except near site exits due to the re-suspension of road dust) as lorries tend to be covered. Can be mitigated by road sweeping but this can also raise dust.
Soil and overburden storage	Most minerals	Varies	<b>Very significant</b> but depends on the condition of the material and exposure to wind, seeding or covering of the bund or mound.

## 7.3 Local and background sources

As noted in Section 1.1, dust is ubiquitous and has a broad range of sources and concentrations. Natural sources of dust include particles derived from (in no particular order): wind-suspended sea salt; combustion; volcanic or geothermal activities; and, natural weathering of minerals. Man-made sources of dust include: agriculture (especially arable farming); industrial activities, e.g., mechanical handling of minerals and allied materials; and, road transport. There are numerous background sources that can contribute to elevated dust concentrations (termed “secondary” or “additive sources”) which can be erroneously attributed to the extractive industries under some circumstances. These include:

- Wind blown dust from off-site sources, e.g., agriculture (especially arable farming, including field cultivation and harvesting, as shown in Figure 7.6), lorry parks, and so on.

- Domestic activities, e.g., the burning of solid or liquid fuel for heating,
- Industrial processes which produce smoke or other suspended particulates which are discharged into the air, e.g., solid or liquid fuel combustion; smelting; mechanical processes such as friction or attrition,
- Movement of vehicles on roads adjacent to the site,
- Construction activities, and
- Post-quarrying process activities, e.g., stone cutting, stone grinding, material grading, which can take place adjacent to the site of extraction.

**Figure 7.6 Dust from arable farming blowing across a road and onto adjacent land.**



Details of Part A1 industrial activities defined under EPR 2010 (as amended) in England authorised by the EA can be found on the EA website [www.environment-agency.gov.uk](http://www.environment-agency.gov.uk) under “What’s in your backyard?”. Details of Part A2 and B activities authorised by Local Authorities can be obtained from them.

Dust deposited around the site of a quarry or surface mine will be composed of a range of particle types. Chemical analysis of dust is not always appropriate or suitable, since disparate sources may emit physically or chemically similar particles. For example:

- Dust from agricultural tillage of soil in fields and dust from soil handling undertaken at the site.
- Dust from excavations associated with construction work, and dust from overburden handling at a mineral site.

For this reason, directional dust sampling (as outlined in Chapter 9) coupled with chemical and physical characterisation may need to be undertaken to determine possible sources of dust.

## **7.4 Meteorological and Topographical Considerations**

### **7.4.1 Meteorology**

Meteorological conditions have a significant effect on patterns of dust emission, dispersal and deposition. The effect of rainfall, wind speed and directional frequency are most pronounced for dust particles at the surface. The moisture content of surface borne particles can be increased through the application of water through surface wetting (“dampening down”) or rainfall which increases the inherent moisture content. The application of water increases surface cohesion and limits wind-driven erosion as detailed in Chapter 5. Rainfall also acts to remove airborne particles from the air to the surface via wet deposition (termed “scavenging”). Wet removal pathways depend on multiple and

composite physical and meteorological processes and are therefore complex processes to model and predict.

Some dust particles retain moisture more readily than others and will stay wetter longer. The drying rate of dust particle will also be influenced by the combined effect of sunlight and wind. In order to control dust emissions, consideration should be given to the:

- Frequency of rainfall or water application (subject to availability),
- Frequency of material disturbance or in the case of road surfaces, the weight, speed and number of vehicles travelling over the road, especially on dry days, and
- Meteorological conditions (temperature, wind speed, cloud cover) which determine the amount of rainfall and rate of evaporation (drying).

The potential for dust increases on days of little or no rainfall. The potential for dust is especially high during periods when evaporation exceeds rainfall and drying conditions prevail. Understanding of rainfall patterns can provide an indicative measure of the number of days per year dampening down will be required on-site to minimise dust emissions.

Rainfall equal to or more than 0.2 mm per day is widely accepted within the industry to be sufficient to effectively suppress wind-blown dust emissions for some time. The frequency of rainfall can be calculated from rainfall maps of the UK which can be obtained from the UK Met Office. Figure 7.7 shows the average number of days (termed "rain days") when rainfall was  $\geq 0.2$  mm per day across the British Isles over the 30 year period from 1971 to 2000. A rain day is a 24 hour period, normally commencing at 0900 UTC, in which at least 0.2 mm per day of precipitation is recorded. A rain day is equivalent to a "wet day".

More detailed UK-wide and regional monthly and seasonal maps for the same period can be downloaded for free from the UK Met Office website and can be used to estimate the potential rainfall. Tabulated values of the number of dry days for 2000-2010 can be obtained on a monthly and regional basis as well. Figure 7.8 indicates that in the case of this meteorological station, the wind originates predominantly from the south-west (SW), due to Atlantic air masses, which is typical for England.

The risk of dust advection is increased when the threshold wind speed for the initiation of dust emission is reached. For tilled bare soils the threshold is above  $3 \text{ m s}^{-1}$  (see Figure 5.3, Table 5.1 and Table 5.2). The risk can be increased when such conditions coincide with site activity during "dry days". Dry days are defined as days when  $< 0.2$  mm of rainfall are recorded over a 24 hour period. The number of dry days in a year can be calculated from the difference between the number of days in a year and the average number of rain days in a year.

The number of working days will vary from site-to-site and will depend on the site planning conditions and the demand for the extracted product. Assuming there to be 260 working days per year (52 weeks x 5 working days per week) it is possible to calculate the number of working days each sensitive receptor is at risk using the following equation:

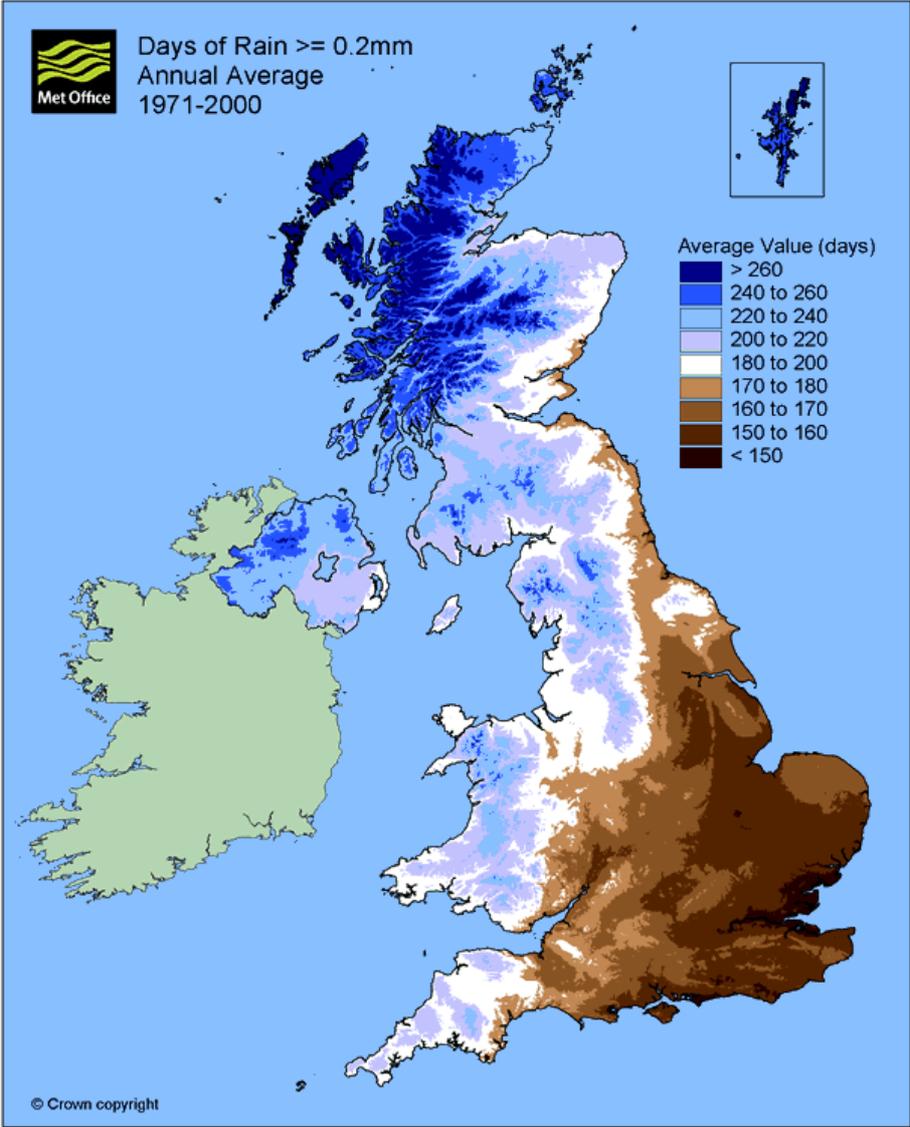
$$\% \text{ of year the wind originates from a specific sector} \times \% \text{ of dry days} \times \text{total number of working days per year (260)}.$$

This assessment provides an indication of the **likelihood of occurrence**. It does **not** provide an indication of:

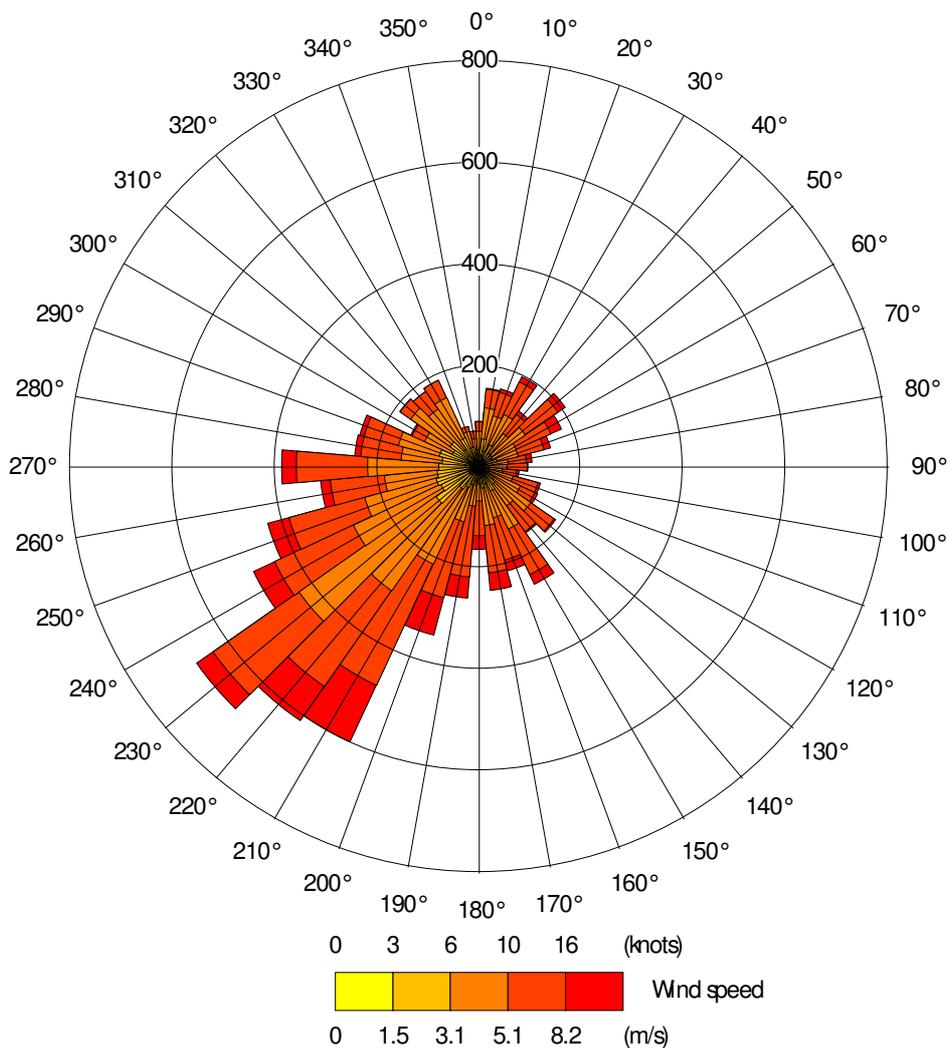
- What will occur on a given day in a year, or
- Typical concentrations.

It is advisable to undertake the assessment for the dominant and second most dominant wind sectors. This type of assessment should be undertaken at the planning application stage and then carried forward into the creation of the DMP.

**Figure 7.7** Map of the UK showing the annual average number of days when the rainfall  $\geq 0.2$  mm per day (termed “rain days”) (1971-2000).



**Figure 7.8 A wind rose showing hourly sequential meteorological observations.**



## 7.4.2 Topography

Topography (surface features) exerts a strong influence on local wind patterns and influences dust dispersion and deposition patterns. Surface features, e.g., woodland, buildings or other structures can be used to screen sites and or ameliorate the effect of wind, thereby reducing the potential for dust to be raised. Hills act to channel and direct wind flow, whilst open, exposed sites lacking surface features are often susceptible to dust blow.

Trees and woodland are significant in the removal of atmospheric dust and can be employed to limit dust dispersion as described in Chapter 5. Dust plumes close to the ground may be intercepted by surface features which remove dust from the air through a variety of physical mechanisms, e.g., interception or impaction. The movement of dust laden air is affected by structures obstructing air flow and channelling air movements into new directions and speed. This can direct dust towards, or away from, downwind areas and results in alterations in the dilution and suspension of dust in the air.

Thought should be given to tree planting during the planning and feasibility stage of site development. At the design stage, due consideration should be given to planning the placement of temporary structures such as topsoil, subsoil and overburden dumps to ensure that opportunities to minimise dust generation are taken.

## 7.5 Chapter 7 Summary

Dust generation is site-specific. Source identification is the first step in establishing all possible sources of dust attributable to the site and contributory factors. In order to adequately identify the amount of dust generated and subsequently emitted from an extractive process, and the extent to which it impacts on the surrounding environment, it is important to consider a number of material, process and site variables, including:

- Type of mineral,
- Scale of operations,
- Method of working,
- Site activities, and
- Dust control measures employed on the site.

The variation in potential impacts between different mineral types is accounted for by a number of factors:

- Nature of the mineral,
- Colour and opacity of the mineral,
- Chemical composition of the dust,
- Frequency of handling,
- Scale of operations,
- Site design,
- Site activities, and
- Record of operation.

Local factors and background sources will affect dust levels. These factors include:

- Site geography and topography,
- Character and land use of the area surrounding the site,
- Site hydrogeology,
- Vegetative cover, and
- Prevailing meteorology, in particular wind speed, direction and rainfall.

Particular consideration should be given to:

- Local topography, and
- Local meteorology,

These aspects exert a significant effect on dust emission, dispersal and deposition patterns. The next chapter will examine dust control techniques used to limit dust.

In instances where dust monitoring is required for source apportionment purposes, Chapter 9 outlines the process of defining a monitoring strategy and describes current, in-use techniques for the measurement and characterisation of nuisance dust and PM<sub>10</sub>.

## Chapter 8. Dust control techniques

### 8.1 Overview

Dust control through good process and site design and subsequent good housekeeping, i.e., “avoidance”, is the key method of controlling dust emissions from extractive activities. “End-of-pipe” abatement solutions<sup>17</sup> should be considered as a final option. Methods for the control of emissions are required to be stated in an ES and within the EPR permit, where applicable. Guidance on compliance with the conditions of an Environmental Permit have been issued by the Environment Agency and can be obtained from the Agency and/or their website.

The control approach selected should seek to exploit and optimise site topography and meteorology, as these can act to enhance or minimise dust emissions as discussed in the previous Chapter, as well as process design. The approach to control should adopt the principles of “Best Practical Means” under the terms of the Environmental Protection Act, and/or “Best Available Techniques” as defined under the Environmental Permitting Regime, as appropriate for the process regulatory regime. Chapter 3 provides detailed information on the regulatory and planning regimes used to control dust emissions from the extractive industries. Table 8.1 (cont.) Dust control techniques by source. summarises the range of control measures that can be applied.

Periodic evaluation of the site dust control measures should be undertaken to identify the success of those measures, in-line with the requirements of the DMP (see Chapter 2). Where control measures may be unproven within the context of the site or operation a higher frequency of evaluation may be appropriate.

Assessment of the success of the control measures should be based on a combination of site/procedural observations, monitoring results and complaints received. If improvement measures are to be undertaken the following information should be recorded in the DMP:

- Proposed corrective measures,
- Justification for corrective measure and intended outcome,
- Name of the person (and post) responsible for completing the task, and
- Deadline for achievement (month and year).

**Table 8.1 Dust control techniques by source.**

Source/process	Emission potential	Scope for control	Effectiveness
<b>Hydraulic excavators and loaders</b> (e.g., front loader, backhoe, face shovel, bulldozers) for the excavation, lifting and movement of material such as soil, overburden and mineral.	<b>HIGH</b> when dry or fine silty materials are being handled, particularly during strong windy weather.	Use of water sprays to moisten material being handled. Soils may be subject to a soil moisture content planning condition.	<b>MODERATE</b>
	<b>LOW</b> when coarse or wet materials are being handled during conditions of low wind speed.	Minimise drop heights when unloading material. Protect from exposure to wind where possible.	
<b>Blasting</b> to loosen rock to facilitate its removal by mechanical excavators.	<b>LOW</b> when coarse or wet materials are generated during conditions of low wind speed.	Avoid blasting under unfavourable weather conditions subject to safety consideration.	<b>MODERATE</b>

<sup>17</sup> “End-of-pipe” abatement solutions are techniques used to remove contaminants from a process air flow and typically implemented as the last stage of a process before the air is vented or delivered.

**Table 8.1 (cont.) Dust control techniques by source.**

Source/process	Emission potential	Scope for control	Effectiveness
<b>Tractor scrapers (soil strippers)</b> for cutting, lifting, transporting and placing, spreading or shaping of soils.	<b>MODERATE/HIGH</b> - when dry silty materials handled during windy weather.	Use of water sprays to moisten material being handled. Soils may be subject to a soil moisture content planning condition.	<b>LOW</b>
<b>Vehicles</b> for transport of material within the site.	<b>HIGH</b> particularly when travelling over unsurfaced and dry site roads.	Minimise on-site transportation distances. Use of water sprays to moisten road surfaces during dry weather. Use mechanical road sweepers during working hours, especially during dry weather, to limit visible dust emissions. Restrict vehicle speeds through signage/staff training. Use of covered conveyors to transport materials around the site.	<b>HIGH</b>
<b>Hydraulic breakers</b> for size reduction of large rocks.	<b>LOW</b>	Water spraying of rock prior to fragmentation when high degree of control required.	<b>MODERATE</b>
<b>Drill rigs</b> for drilling holes for placement of explosive charges.	<b>HIGH</b> when unmitigated.	Enclosure of plant with shrouds. Use of dust suppression (filters) on waste air vented from equipment.	<b>HIGH</b>
<b>Crushers &amp; screens/ graders</b> for size reduction of material to produce graded mineral products.	<b>HIGH</b> if unmitigated.	Dust suppression spraying of material to be crushed. Enclosure of plant.	<b>HIGH</b>
<b>Exhausts and cooling fans</b> on mobile plant processing quarried material.	<b>HIGH</b> if unmitigated.	Mobile plant exhausts and cooling fans will discharge above the horizontal to prevent dust mobilisation.	<b>MODERATE</b>
<b>Conveyors</b> for transporting material.	<b>MODERATE</b> if not protected from wind.	Enclosure of transfer points.	<b>HIGH</b>
		Wind boarding (inc. roofing) of conveyors.	<b>HIGH</b>
	<b>MODERATE/HIGH</b> for dry or fine silty materials, particularly during strong windy weather.	Water spraying of surfaces of material on conveyor	<b>HIGH/MODERATE</b>
		Cleaning belts with scrapers and collecting scrapings in container.	<b>MODERATE</b>
<b>Stockpiles</b> for storage of quarried materials and soil/overburden during extraction and site development phases.	<b>HIGH</b> when dry or fine silty materials are being stored/handled, particularly during strong windy weather.	Seed surfaces of completed mounds of overburden and top soil (restoration materials). Limit mechanical disturbance.	<b>HIGH</b>
		Shield from wind, e.g., through the use of tree planting or screening.	
		Use of water sprays to moisten surfaces during dry weather.	<b>MODERATE</b>

A summary of corrective measures and improvements should be forwarded to the Mineral Planning Officer or Environmental Health Officer for their information or approval depending on the site planning conditions.

## 8.2 Control methods

Dust control should be addressed at each phase of site development and operation. Careful thought should be given to planning and considering the relationship between site activities and sensitive receptors (as outlined in Table 3.3) beyond the site perimeter. The control hierarchy should be based on:

- Good operating and management practices to avoid emissions arising from extractive activities,
- Good process design or revision to minimise emissions,
- Abatement or control to reduce dust emissions, e.g., use of water bowsers and sprays, and
- Disrupting the emission pathway to sensitive receptors (i.e., shielding receptors through the use of earth banks or vegetative screening).

### 8.2.1 Water

The use of water, as available, to dampen down potentially dusty materials is a commonly used form of dust suppression. Water is applied to increase or maintain the moisture content of extracted materials. The most effective (and simplest) method of water application is spraying. Water sprayed onto a surface from a height, rather than direct to a surface, enhances dust removal through wet deposition: dust particles are removed from the air by collision with water droplets. Water sprays allow water to be applied to extracted materials throughout the extraction and storage process. The application of water increases the cohesiveness of surface particles and greatly reduces wind-driven erosion.

Periodic application of water is required due to water loss through evaporation due to the effect of wind and exposure to sunlight. There are some disadvantages to the application of water as it tends to increase the mass of materials, which may marginally increase handling costs, and lead to freezing or clogging in winter months. Excessive application of water can increase process costs especially if water has to be brought in from off-site as consent will have to be sought from the Environment Agency and the local water provider. This can be circumvented by the use of rain collected on-site as outlined in Box 2.

Balancing the application of water against the on-set of wind-driven erosion can be achieved by the use of wind speed activated water sprays. Wind speed activated water sprays dispense water on to stockpiles and during mineral handling operations when the wind speed equals or exceeds a specified value. The threshold wind speed for the onset of wind driven erosion is dependent on local factors, e.g., local meteorology and topography; soil and mineral type; mineral grain size; and, in-use dust management techniques, and will therefore be site specific. The potential for the onset of wind-driven erosion and dust propagation based on wind speed is given in Table 5.1 and Table 5.2. The application of water can be further optimised by the use of a rain gauge which can be used to determine local rainfall levels and therefore periods of consistently dry weather. Automated systems require computer-based process control and feedback systems. The application of a wind speed threshold based system at a sand quarry is described in Box 2. A more simple and cost-effective approach is to increase staff vigilance, through improved staff training, as outlined in Section 2.1.3. The appropriateness of undertaking specific site activities can be determined by site staff or the responsible person, depending on the prevailing meteorological conditions. Local wind speeds and meteorological conditions can be derived from local weather forecasts issued by the UK Met Office. Water droplet size is critical and a range of spray systems have been developed that produce fine water droplets. These include air atomising nozzles which shear the water with compressed air and sonic nozzles which use high frequency sound to produce fine droplets. Fogging systems have been designed which combine the production of fine droplets with high powered fans allowing fine mists to be dispersed over a wide area therefore limiting dust generation.

Untreated (grey) water can contain a range of pathogenic<sup>18</sup> micro-organisms. Water-borne infections can be passed from water to site staff if contaminated water is ingested or if water droplets, from spray systems used for dampening down, are respired. Consideration should be given to treating grey water prior to use. Steps should be taken to protect site staff and people living downwind of water sprays if

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<sup>18</sup> Disease causing.

they are to be used for dampening down. Particular care should be given to the use of grey water during periods of high wind speeds, when water droplets are most likely to be carried off-site by the action of the wind which may lead to increased exposure.

**Box 2      Dust suppression through wet suppression.**

**Case study: wet suppression**

Wet suppression is one the most widely used methods of dust mitigation in the extractive industries. Typically water bowsers and road-sweepers are employed in tandem to (1) dampen and (2) remove deposited material from hard surfaces, e.g. site roads, that would otherwise be re-suspended due to the action of the wind and/or or vehicle movement. Materials adhered to vehicle bodies or tyres are removed by vehicle spray washes located at site exits.

At a Surrey based sand quarry, sand was mixed with water and pumped around the site to limit dust emissions associated with material movement. Mist sprays were located on conveyors to reduce dust due to material handling. Water sprays located on the perimeter of sand stockpiles were used to dampen the surface in the event of dry and windy weather to minimise wind-driven dust emissions from stockpiles. Automatic activation of the water sprays occurred in the event of wind speeds in excess of a defined, site specific level for a period greater than 10 minutes from a particular direction, under persistent dry conditions (as measured by a rain gauge located on-site).

Water was used to dampen down stone as it was processed and worked at a sandstone quarry producing ~200 ktonnes per annum of cut and shaped sandstone in West Yorkshire. This reduced the concentration of dust arising from the cutting and shaping process. Dust transported from the cutting sheds to nearby residential properties was one of the key sources of dust nuisance complaint. This was significantly reduced whilst maintaining low levels of workplace dust exposure.

When considering the use of wet suppression in material handling thought should be given to the ability of the material to absorb water. For example limestone is hydrophilic (water loving), and readily absorbs water from the atmosphere and tends to require a lesser degree of water treatment when handled when compared to more hydrophobic (water repelling) materials such as coal.

### **8.2.2 Tree planting, hedge planting, and landscaping**

Tree and vegetative planting (screening) and landscaping can be effectively combined to mitigate dust arising from extractive activities by providing a:

- A well established vegetative screen composed of hedges and trees (planting in advance of the commencement of site operations), (should be also considered as part of site design) wind break, reducing the momentum of the incident wind, and
- Surface for the capture of airborne particles transported off-site.

In the UK the prevailing wind direction tends to be from the south-west and west and is associated with air masses originating from the Atlantic Ocean as illustrated in Figure 7.8. Tree and vegetative planting, and landscaping on the westerly and south-westerly site perimeter provide an effective wind break. Likewise, tree planting on the easterly and north-easterly perimeter will limit the wind-borne transport of dust off-site. The predominant wind direction, speed and frequency can be more accurately established through site-specific studies and local data.

Trees and landscaping improve the quarry environment in several further ways as they:

- Increase privacy,
- Reduce soil erosion,
- Provide shade and humidity,
- Provide wildlife habitats, and

- Improve aesthetic qualities.

If trees and hedges are planted of sufficient density and depth (approximately 10 m) they may achieve approximately 1 dB of noise reduction, but overall cannot be considered a significant method of noise reduction.

On a global level, trees are beneficial in helping to reduce greenhouse gases emitted during the mining and processing of quarried materials by taking up CO<sub>2</sub> from the atmosphere and sequestering carbon within their biomass. Trees can take up to 10 years to grow to maturity

Field measurements have demonstrated that mature, mixed woodland captures airborne particles at approximately three times the rate of grassland. There are marked species differences in the ability of trees to capture dust particles. Studies of five common hardy tree species that exhibit rapid growth and dense canopies ideal for providing a large, rough leaf surface area on which to dust particles showed that coniferous trees capture more dust particles than broad-leaf species. Pines (*Pinus* spp.<sup>19</sup>) capture significantly more particles than cypresses (*Cupressess* spp.). Of the broad-leaved species, whitebeam (*Sorbus aria*) captured the most and poplar (*Poplar* spp.) the least weight of airborne particles.

While tree planting and landscaping should not be seen as a replacement for the mitigation of dust emissions, they can have a beneficial effect in reducing wind speeds, limiting the dispersion of dust, and ameliorating the overall impact of quarries and surface mines.

### 8.2.3 Agglomeration, Coating and Foaming Agents

Agglomeration agents increase particle agglomeration, causing particles to bind to each other forming large, coarse particles which improve crusting and limit wind-driven erosion. Agglomeration agents tend to be applied to the extracted materials at transfer points.

Coating agents are chemical binders applied to the surface of stockpiles which dry to form an insoluble crust. The crust prevents the effects of weathering and wind-driven erosion.

Foam suppression of dust uses foam produced by the controlled introduction of water and compressed air which is passed into a foaming device to create micro-bubbles (50 and 200 µm in diameter). The bubbles burst causing the moisture and chemicals they contain to be integrated into the extracted product. This leads to smaller particles binding to larger particles. Foams can be applied during crushing, screening and the handling of aggregates. The advantage of the use of foam suppression is that it uses a small amount of water, approximately 1.5 litres per tonne of aggregate processed.

The main disadvantage of the use of agglomeration agents, coating agents, and foam is the additional cost. In extreme cases, where other methods such as enclosing stockpiles, the use of tree planting and landscaping, and dampening down are inadequate, the application of agglomeration agents, coating agents, and foams can prove useful in limiting dust emissions associated with stockpiled materials. Caution should be taken when choosing an agglomeration, coating and foaming agent as they could introduce unwanted contamination to extracted materials and/or lead to contaminated run-off.

### 8.2.4 Management

An effective system of people and paper-based management is essential for ensuring that all aims and objectives of the site's dust control protocols are recorded and communicated reliably within the company and to stakeholders (regulators and local residents) in order to mitigate the effects of dust arising from the extractive industry.

One effective method of dust management is the creation of a site-specific DMP as outlined in Chapter 5. In certain circumstances it may be advantageous to consult with external specialists or consultants to draw-up and introduce more rigorous site-specific dust control measures to improve dust management. Box 3 outlines an example of a limestone quarry where the downwind dust

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<sup>19</sup> spp. = several species.

deposition rates at its boundary were close to the threshold limit stipulated in the site's planning conditions. Following a site survey by a specialist dust consultant a range of measures were introduced which lead to a reduction in dust deposition rates downwind of the quarry.

**Box 3 Dust control through improved process management.**

**Case study: dust control at a limestone quarry**

Dust deposition rates downwind of a limestone quarry in the North of England were close to the exceedence threshold stipulated in the site's planning conditions. A multi-modal approach to dust mitigation was adopted to reduce dust deposition rates at its boundary.

Three key sources of dust were identified:

1. Vehicle movement on-site,
2. Exposed stockpiles, and
3. Processing plant emissions.

**Figure 8.1 Frisbee dust deposition gauge readings at (a) 150 m and (b) 400m downwind of the limestone quarry.**

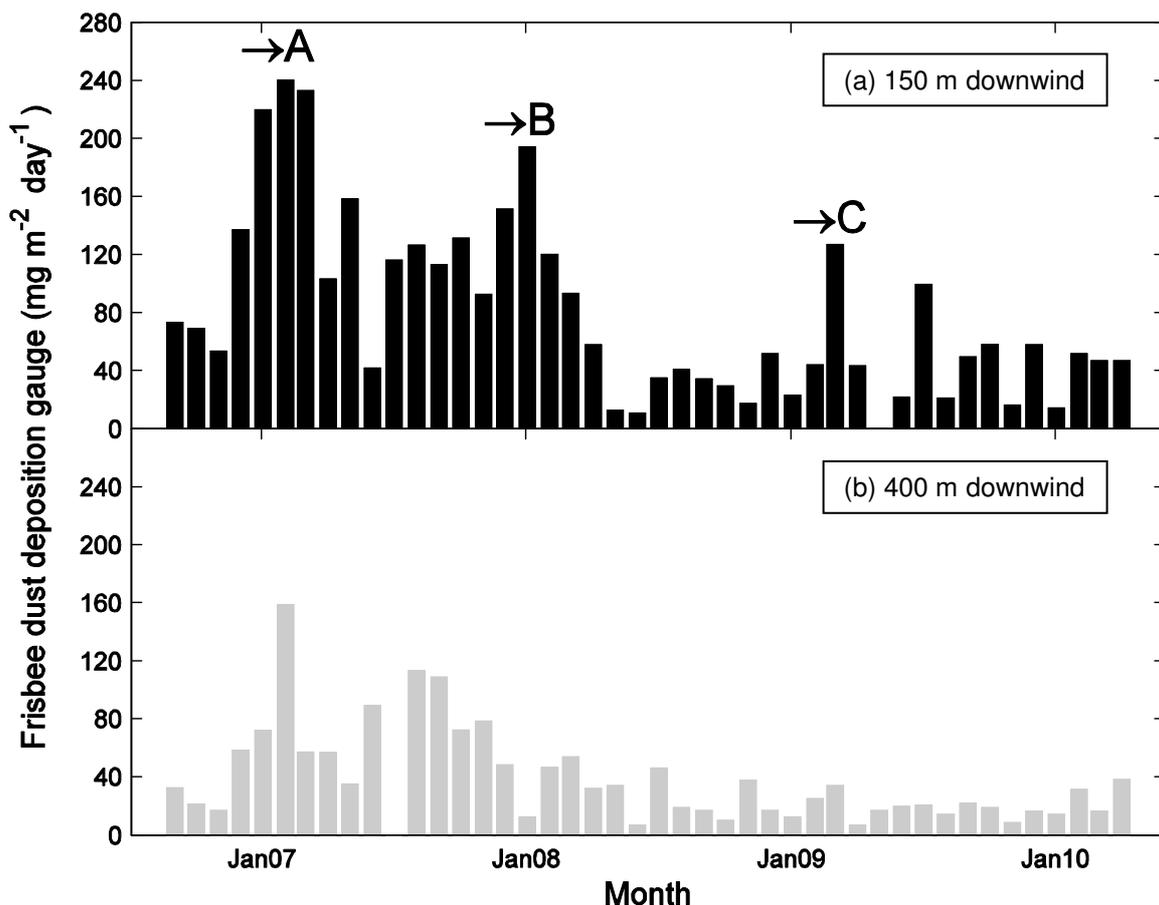


Figure 8.1 shows the progressive decrease over a three year period of the Frisbee dust deposition gauge readings at (a) 150 m and (b) 400m downwind of the limestone quarry. In January 2007 (“A”) flocculants were applied to the bunding screens. The following year in January 2008 (“B”) the site operator started to use wet suppression measures to limit dust emissions. Finally in March 2009 (“C”), a full range of suppression measures were introduced, including:

- Development of a series of suppression measures developed in accordance with accepted industry good practice. Maintenance of a high standard of housekeeping, e.g., the prompt cleaning of material spillages.
- Transportation of material from the working face and mobile crusher to the screening plant via conveyor system, thereby reducing the number of vehicle movements on-site.
- Regular service and maintenance of mobile plant and the fitting of exhausts to minimise fume emissions from plant equipment.
- Maintenance of haul roads: use of a water bowser during dry conditions on the access road, haul roads and other trafficked areas. Use of a wheel wash facility to prevent deposition of material onto the public highway. Deployment of a road sweeper in the event of dust or mud deposition onto the public highway. Daily inspections of the access road and public highway by the appointed responsible person on-site in order to identify the need for cleaning.
- All vehicles leaving the site are to be suitably sheeted.
- Implementation of a site speed limit of 15 mph on all access and haul roads.
- Use of water sprays or surface binders to maintain damp surfaces on exposed tip and stockpile faces during dry and windy weather.
- Use of surface binders will be employed to create a stable crust prior to dry weather conditions when the site is not operational, including weekends.
- Minimisation of loading and unloading drop heights.
- Minimisation of dust from blasting operations. This will include the use of filtration equipment on the exhaust emissions from drill rigs, and the removal of any loose material from the blast area, prior to detonation.
- Containment of stockpiles of fines in storage bays, which will be constructed as to be unaffected by the predominant westerly airflow. The top of the material in storage will not exceed the height of any external wall to prevent wind whip occurring. Encapsulation of the mineral processing and road stone coating plant.
- Progressive restoration of tip faces and other exposed areas.
- Appropriate training for all site staff to ensure that they are conversant with the site's dust control strategy.

The introduction of the measures described above demonstrated the site operator's commitment to maintain a high standard of site operations and minimised dust arising from the quarry. This generated goodwill with the local residents and the Local Authority and led to the continued operation of the site and the employment of the 40+ site workers.

## 8.3 Chapter 8 Summary

Dust avoidance is the key method of controlling dust emissions from extractive activities. “End-of-pipe” abatement solutions should be considered as a final option. The control approach selected should seek to exploit and optimise site topography and meteorology, as these can act to enhance or minimise dust emissions, as well as process design. The approach to control should adopt the principles of “Best Practical Means” under the terms of the Environmental Protection Act, and/or “Best Available Techniques” as defined under the Environmental Permitting Regime. The regulatory philosophy dictates that industry standards should be applied.

At the site design stage consideration should be given to the use of bunding, fencing and the planting of trees and/or hedges to enhance natural topographical features and to provide screening to limit wind-driven dispersion of dust.

Annual evaluation of the site dust control measures should be undertaken to identify the success of dust control measures. This is particularly applicable to new sites where control measures may be unproven within the context of the site or operation.

Assessment of the success of the control measures should be based on a combination of site/procedural observations, monitoring results and complaints received.

Dust control should be addressed at each phase of site development and operation. Careful thought should be given to planning and considering the relationship between site activities and sensitive receptors beyond the site perimeter, particularly those downwind of the site. Dust control can be achieved by:

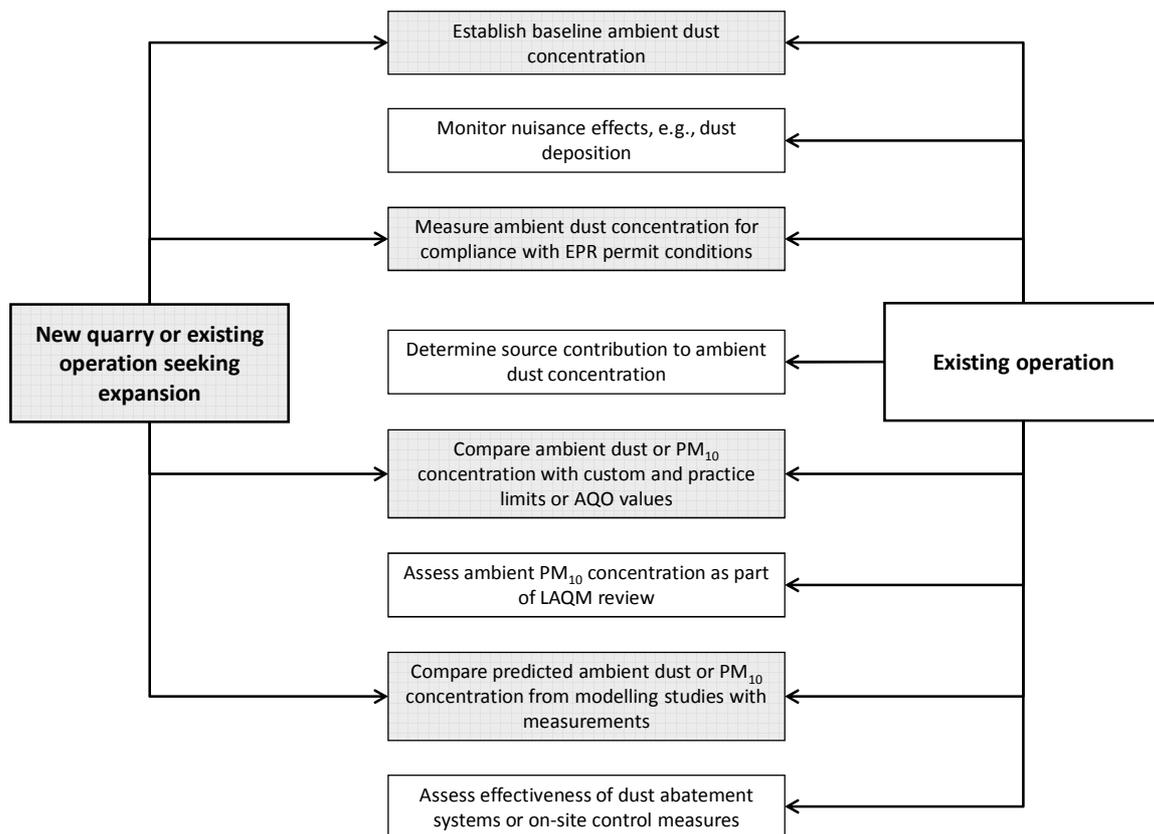
- Dampening down,
- Using agglomeration, coating and foaming agents,
- Management, and
- Monitoring.

The next Chapter examines current, in-use nuisance dust and PM<sub>10</sub> monitoring methods.

## Chapter 9. Monitoring

Monitoring may be required for a new quarry, an existing quarry or an existing operation seeking extension. The monitoring strategy adopted on a site must be designed to address the needs of that site in the context of its locality. Possible reasons for implementing a monitoring programme are given in Figure 9.1. The need for monitoring can be based on one or multiple reasons.

**Figure 9.1 Considerations for determining the implementation of a monitoring programme.**



### 9.1 Monitoring Strategy

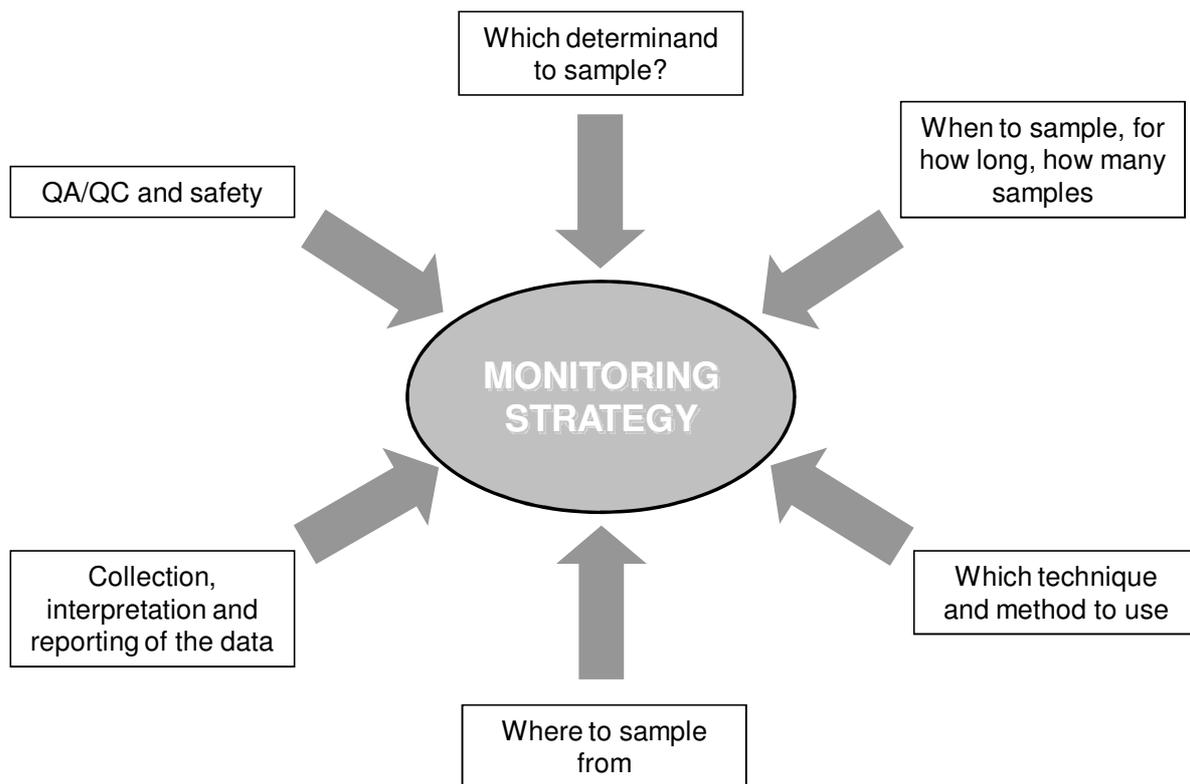
#### 9.1.1 Defining the monitoring strategy

Understanding the aims of the monitoring strategy can assist in the assessment design stage. The design stage produces the monitoring strategy and requires decisions to be made on:

- What parameter should be measured (dust or PM<sub>10</sub>) and which standard or criteria to monitor against?
- Where and when to sample?
- Duration of sampling.
- Number of samples.
- What technique and method to use?
- How the monitoring data will be verified?

The main elements of a monitoring strategy are summarised in Figure 9.2.

**Figure 9.2 Main elements of a monitoring strategy.**



The monitoring strategy, reason(s) and justification should be summarised in the site DMP (as outlined in Chapter 2). Careful design and planning of a monitoring strategy is needed to avoid producing unrepresentative data. It is important that the financial, and other implications, e.g., man hours, training, and equipment servicing, of embarking on a monitoring programme are fully understood before any action is taken. The commitment made to a monitoring programme (in terms of equipment, man hours, training and so on) should be proportional to the overall risk posed.

### 9.1.2 Selecting monitoring equipment

Equipment suppliers should be able to demonstrate that their equipment is fit for purpose, i.e., sufficiently robust for field deployment under a range of conditions and capable of monitoring over the required time period. It is preferable for monitoring equipment to have independent evaluation. Monitoring equipment should be selected on the basis of being the most appropriate technique for the measurement of nuisance dust or size selective particulate matter.

Section 9.2 provides information on current, in-use techniques for the measurement of dust and PM<sub>10</sub> arising from the extractive industries.

### 9.1.3 Infrastructure and other equipment and services

Dust samplers usually require a much lower level of site infrastructure than PM<sub>10</sub> monitoring equipment. Access to appropriate analytical facilities at a central laboratory may be required for detailed analysis of dust samples. Due to the complexity and sensitivity of PM<sub>10</sub> monitoring equipment there are numerous criteria that must be considered when determining where and how to sample. PM<sub>10</sub> monitoring considerations are given in Table 9.1. It is important to note that selecting, purchasing and commissioning the equipment for an automatic monitoring station can be a lengthy and expensive process (typically two to three months) and time should be allowed for this at the planning stage.

**Table 9.1 PM<sub>10</sub> monitoring considerations.**

Consideration	Comment
Monitoring enclosure	If the equipment is to be self-contained rather than housed in an existing building then an enclosure will need to be purchased. Consideration needs to be given to the size, portability, and visual impact requirements of the enclosure. These criteria will need to satisfy the needs of the particular location, or overall programme if the site is to be frequently re-located (for example using a mobile monitoring station). Planning permission may be required for monitoring enclosures. This is normally obtained from the relevant local or district council.
Air conditioning system	Unless two or more monitors are located in the same enclosure or room an air conditioning system will be unnecessary. It should be considered if instruments are to be located in a room or enclosure with limited ventilation. There may also be instances where the instruments themselves do not generate sufficient heat to warm the surroundings so a heating system may also be needed for winter months.
Sampling inlet	PM <sub>10</sub> monitors tend to require specialised sampling inlets. These are specifically designed to ensure collection of the correct sized particles for determination of the PM <sub>10</sub> mass concentration.
Power supply	The power supply to the monitoring enclosure/room must be of sufficient rating to support the equipment to be installed. A suitable trip is recommended in order to protect the equipment in the event of a power surge.
Telephone connection	In order to ensure that PM <sub>10</sub> monitors are operating satisfactorily, data should be downloaded remotely from monitoring stations on a daily basis. This data can be visually inspected allowing any problems to be identified. In order to achieve this installation of a telephone line and modem, or mobile phone and GSM modem <sup>20</sup> will be required. The type of system required will depend on location, cost of installation, and ongoing cost of calls and monthly rental. Most analysers can be connected directly to a broadband line with data then collected over the Internet.
Meteorological sensors	In order to make the best use of the measured air quality monitoring data for dispersion modelling or source apportionment analysis, it is often useful to install meteorological sensors at the monitoring station. These will enable the local wind speed/direction/temperature/humidity data to be analysed to determine the conditions which lead to high pollution, and which are the most significant pollutant sources. Consideration will need to be given to the visual impact of installing a meteorological mast and whether over-hanging vegetation or nearby buildings might interfere with the sensors. Meteorological measurements are usually most effective when the monitoring station is in a reasonably open location. The alternative is to purchase sequential meteorological data from the Met Office, but this may only be modelled or from a monitoring station many miles away.
Data logging	Most automatic air quality monitors now have their own sophisticated controlling software and built-in data loggers which can store up to a month or more of 15-minute averaged data. If more than one analyser is to be installed then a code-activated-switch will be needed in order to allow remote polling to download data from each of the analysers in turn. An alternative is to install a dedicated PC or data logger at the site to store all the data and control operation of the analysers including calibration cycles. Consideration will also need to be given as to whether additional parameters such as meteorology and analyser status need to be recorded, where these values will be stored, and how they will be downloaded.
Service and maintenance contract	Automatic PM <sub>10</sub> monitors are sophisticated and will require engineer support for repair and routine maintenance. Ideally, a contract should be set up to replace or repair any faulty equipment within 48 hours of call-out, ensure a minimum data capture level of 90% over the year or monitoring period, and to carry out routine servicing of the equipment every six months according to the manufacturers recommendation. It will be up to the operator to decide whether to take up a more expensive "all-inclusive" maintenance contract covering all eventualities, or to go for the cheaper but more risky option where individual (possibly expensive) items will have to be paid for in the event of breakdown.  Maintenance schedules for the replacement of consumable parts, diagnostic checks and equipment overhaul should in all cases follow manufacturer's recommendations. Routine and non-routine service visits must be fully documented to describe in detail any adjustments, modification or repairs undertaken. The exact service schedule and level of documentation should be agreed as part of the service contract.  A good service and maintenance contract on a well set-up, calibrated and maintained site should ideally ensure that any data loss is distributed evenly throughout the year. Further information on setting-up service and maintenance contracts for automated air quality monitoring equipment can be obtained from the LAQM help desk.

<sup>20</sup> A GSM modem is a specialised type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone.

**Table 9.1 PM<sub>10</sub> monitoring considerations (cont.).**

Consideration	Comment
Data management software or services	<p>Data from the monitoring stations needs to be reviewed on a daily basis in order to:</p> <ul style="list-style-type: none"> <li>• ensure that the equipment is still running satisfactorily, and</li> <li>• back-fill any data gaps if necessary.</li> </ul> <p>All or part of this service could be sub-contracted to a specialist consultant, with data linked in real-time to a web site for public information. However, if the site operator decides to carry out the task themselves then they will need to purchase the necessary software for:</p> <ul style="list-style-type: none"> <li>• data download, functional review, editing and comparison with AQOs, and</li> <li>• reporting and uploading to a website (if required).</li> </ul> <p>Most suppliers of air quality monitoring equipment will be able to provide software for this purpose.</p>

### 9.1.4 Initial monitoring and measurement approach

For new quarries initial nuisance dust monitoring might be undertaken to determine background dust concentrations. For existing quarries, measurements are typically undertaken to determine current dust concentrations. These two approaches are used to measure the impact of dust from the quarry or surface mine on sensitive receptors. A similar approach should be adopted for the measurement of PM<sub>10</sub> concentrations.

An initial assessment can be undertaken to provide information on the likely locations where exceedences or complaints may occur. This information can be used to select monitoring sites for undertaking more detailed studies (in the case of continued monitoring during the site's operation).

For an initial assessment it is sufficient to use simple assessment by a competent person and/or basic monitoring techniques. Integrating measurement methods such as passive samplers, although fundamentally limited in their time resolution, are useful for a variety of area-screening, exposure assessment, and network design functions. Site numbers and distribution should be selected so as to maximise data on the spatial distribution of pollutant concentrations as appropriate. The sites selected should be located:

- At sensitive receptors (as outlined in Table 3.3) in the case of nuisance dust.
- At a point in-between the source and receptor when measuring dust flux.
- Where there is likely to be human exposure in the case of PM<sub>10</sub>.

Data from a variety of location types may be necessary to build up a reasonably complete picture of ambient exposure patterns in and around sites.

If the results of the initial monitoring programme indicate dust and/or PM<sub>10</sub> concentrations may exceed the custom and practice thresholds for dust or the statutory AQO for PM<sub>10</sub>, sampling it may be necessary to carry out additional monitoring using methods which are capable of time resolution consistent with the pollutant averaging times specified in the objectives.

### 9.1.5 Use of hand-held monitors

Hand-held monitors can be used to obtain a snapshot of pollution concentrations. They can be used to identify "hotspots" and are useful for supplementing visual assessment. They may provide screening data that may be a useful in deciding whether more detailed monitoring is required.

### 9.1.6 Detailed monitoring and measurement

Once the preliminary survey has been completed and the monitoring results indicate that the objectives or criteria for dust and/or PM<sub>10</sub> are likely to be exceeded, then it may be helpful to refine the monitoring strategy, in order to more clearly identify the source contributions. In such cases, it may be useful to:

- Undertake monitoring of wind speed and direction, to assist with the interpretation of results and to identify local, additive sources, e.g., the contribution from local, arable farming, to measured exceedences.
- Carry out monitoring at several locations, e.g., upwind and downwind sites. This will allow a more accurate assessment of the contributions of the different sources to the measured values to be carried out. "Directional" monitoring equipment (which can be used to determine dust sources by direction, or allow measurements to be collected only within a pre-defined wind direction) can be employed.
- Consider the use of various dust characterisation techniques, e.g., optical microscopy, SEM-EDX, ICP-MS and other analysis methods (as described in Section 9.5) to assess the source contribution to the measured values. Chemical and physical characterisation of particles is a costly and lengthy process and is only advisable in cases where precise source apportionment using more simple techniques, e.g., wind sectoring, have failed to identify the exact source of exceedences of custom and practice thresholds for dust or the statutory limits (AQOs) for PM<sub>10</sub>. Characterisation techniques can be an effective method of source apportionment and can be cost effective in certain circumstances and can provide an alternative to lengthy monitoring.

### 9.1.7 Sampling period

The most comprehensive dust monitoring will be a mix of continuous and intermittent sampling to establish long-term trends and capture transient events, respectively. Continuous sampling is relatively costly, requiring periodic inspection and servicing of equipment. It will provide good data capture with limited staff input. Single measurement points are insufficient to adequately monitor site operations, but ideal for intermittent spot sampling, e.g., the measurement of transient dust events. Typical sampling periods are:

- Short-term (transient) dust events of 1 hour or less,
- Daily mean PM<sub>10</sub> measurement for assessment of achievement of AQO,
- Dust sampling of typically between one week to one month to demonstrate compliance with custom and practice thresholds, and
- Longer term sampling to show seasonal and annual variations in dust or PM<sub>10</sub> concentrations.

The sampling period should be sufficient to provide dust concentrations representative of the particular case under consideration.

### 9.1.8 Site selection

In order to obtain useful dust or PM<sub>10</sub> monitoring data, the measurements made must be representative of the study area of interest. Monitoring sites should be situated appropriately for the monitoring strategy. For example:

- Directional (flux) monitors should be located at a point between the source and receptor, e.g., along the site boundary, in order to assess dust propagation towards off-site receptors.
- Deposition samplers should ideally be located at the receptor site otherwise they should be located between the source and receptor.
- PM<sub>10</sub> monitoring sites should be located where there is likely to be human exposure, e.g., along the site boundary or next to property adjacent to the site of mineral extraction.

However, this may not be practical in all situations as monitoring equipment should be situated in a safe and secure location.

Background monitoring may be required if there is a need to monitor long-term trends in pollutant concentration. Background monitoring sites are less likely to be affected by very local factors, e.g., changes in site activities and extraction rates.

Consideration of the following criteria can be used when screening for potential areas of concern:

- **Existing monitoring data:** background monitoring can be used to help assess future monitoring requirements.
- **Modelling:** results of dispersion modelling simulations can be used to predict pollutant dispersion and deposition patterns, thereby help to identify areas where pollutant problems may occur. As noted in Chapter 6 to be of use, reliable emissions and meteorological data are required as model inputs.
- **Sources and emissions:** compilation of a list of on-site dust sources as described in Chapter 7 and their potential to produce emissions will help to indicate where exposure may be significant.
- **Additive sources:** there are numerous background sources that can contribute to elevated dust and PM<sub>10</sub> which can be erroneously attributed to the extractive industries. Details of Part A1 industrial activities defined under EPR 2010 (as amended) in England authorised by the EA can be found on the EA website under “What’s in your backyard?”. Details of Part A2 and B activities authorised by Local Authorities can be obtained from the relevant Local Authority.
- **Meteorology and topography:** the prevailing weather conditions and local topography will strongly influence the dispersion of dust.

Table 9.2 outlines specific issues to consider when selecting a site for nuisance dust and PM<sub>10</sub> monitoring. These criteria are not listed in any particular order and are equally weighted, There is no strict hierarchy in which these should be applied.

**Table 9.2 Nuisance dust and PM<sub>10</sub> monitoring site selection considerations.**

Issue	Recommendations
Sampling (inlet) height	Sampling should be undertaken at 1.5-2 m above ground level (AGL) to provide measurements within the human breathing zone. If this is not practicably achievable the inlet should be sited <10 m AGL, ideally <5 m AGL, as dust concentrations decrease with height.
Obstructions	Ideally monitors should not be located in the lee (downwind face) of tall buildings or walls as wake effects can cause re-circulating air flows and lead to the build-up of pollutants. Buildings and walls can also act to shield the pollution source. As a general rule, the top of obstructions should subtend less than a 30° angle with the horizontal of the sampling point.
Overhang	The sampling position should be open to the sky, with no overhanging tress or structures, as these can act as very efficient pollutants sinks. Monitors should be situated at least 20 m from the drip-line of trees.
Interfering sources	It is important that all potential dust sources in the vicinity, whether from minerals operations or third parties (e.g., farmland) are properly assessed. Sampler locations should be determined to take the range of dust sources in the locality into account.
Accessibility	Sampling sites must be accessible for servicing calibration and/or data collection. They should be sited in a secure location where the risks of vandalism or accidental damage (e.g., by wildlife or on-site activities) are minimised.
Services	Where required, adequate services should be available to the monitoring site as described in Table 9.1.

### 9.1.9 Sampler arrangement

The method, frequency and positioning of a sampling array will be determined after consultation with the appropriate stakeholders and will therefore be site-specific. As noted in Section 9.1.8, in order to obtain useful nuisance dust or PM<sub>10</sub> monitoring data, the measurements made must be representative of the study area of interest.

Dust monitoring sites should be located at or towards sensitive receptors (as defined in Table 3.3). An example of sensitive receptor or personal exposure monitoring network for the measurement of dust or PM<sub>10</sub> adjacent to an extractive process, where there are three sensitive receptors or locations of human exposure, is shown in Figure 9.3.

**Figure 9.3 Sensitive receptor monitoring for the measurement of deposited nuisance dust or PM<sub>10</sub>.**

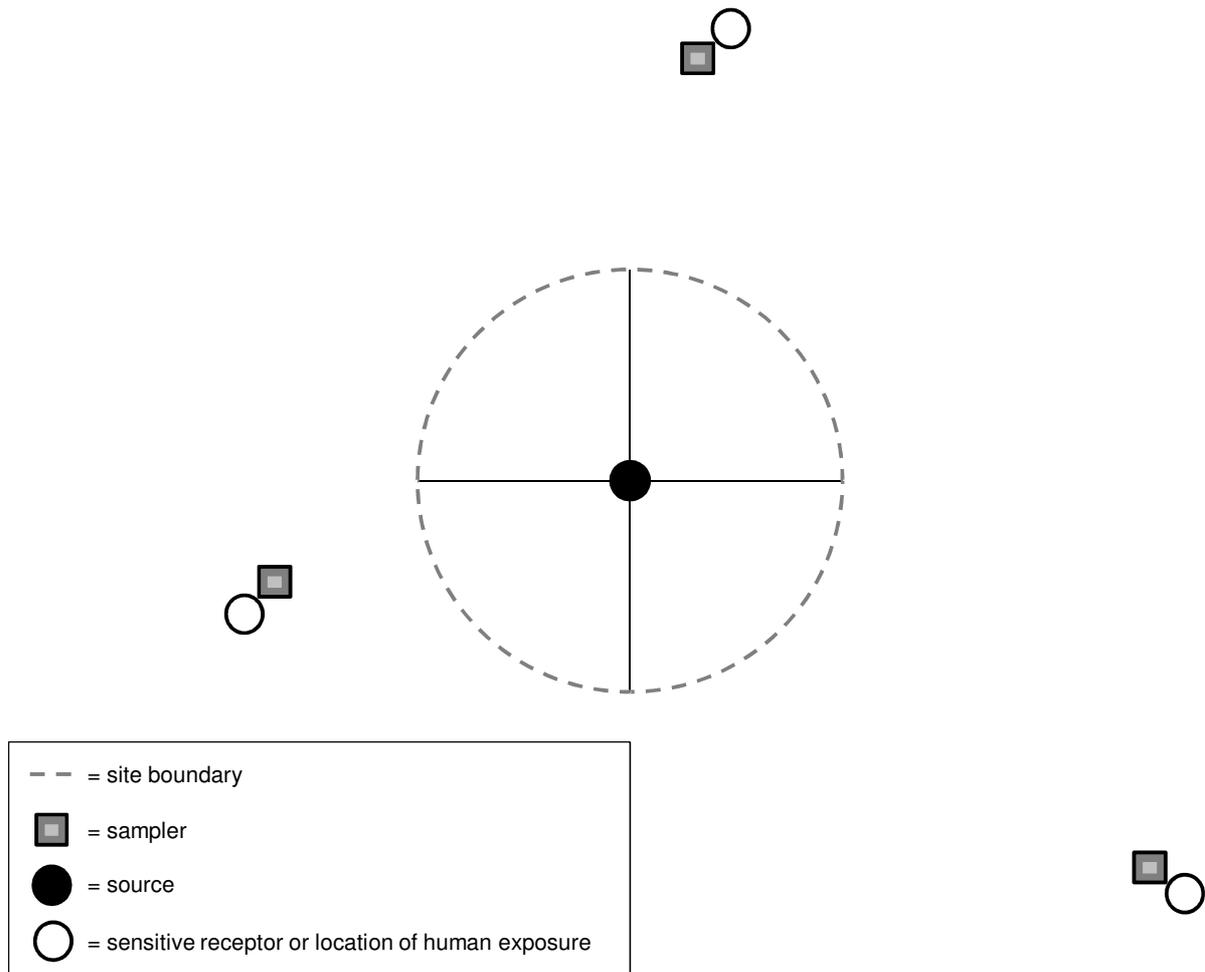
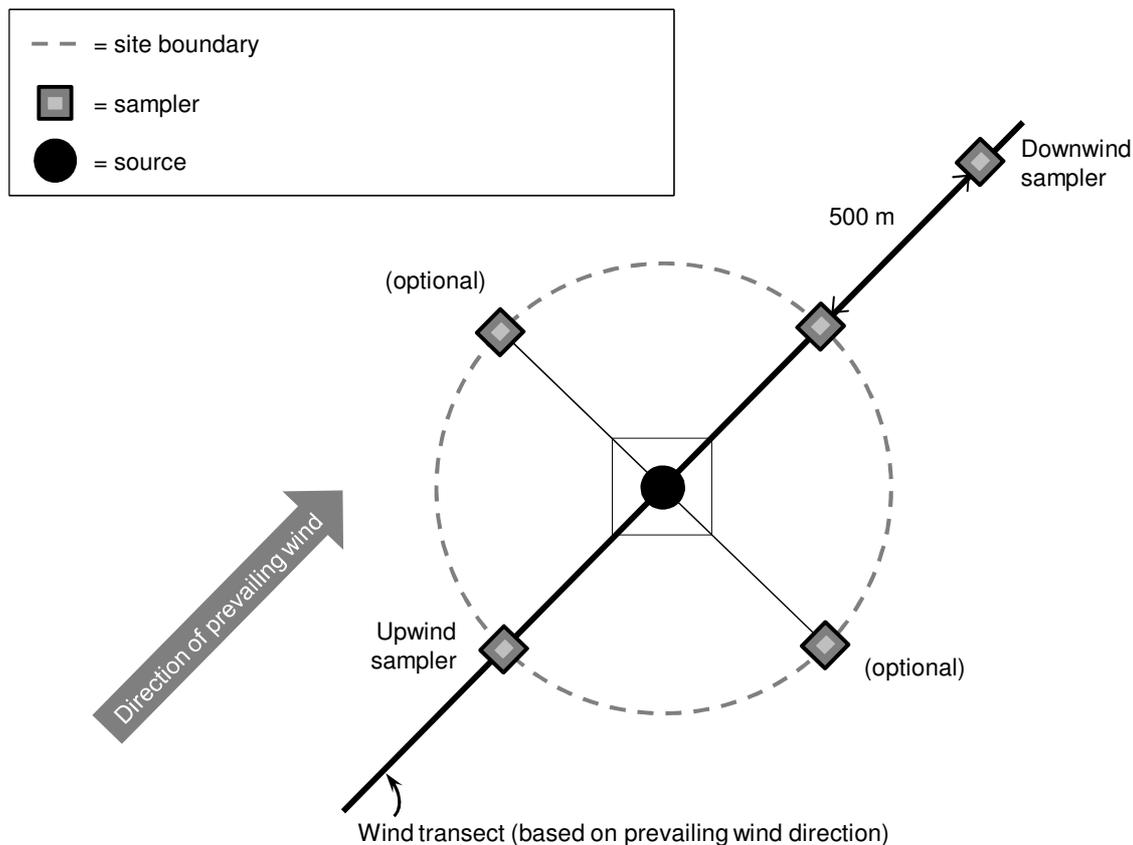


Figure 9.4 shows an example of boundary fence monitoring. This approach is used when measuring the off-site dust flux.

- The area around the source is divided into quadrants. The axis along which the site has been divided is determined by the prevailing wind direction. In the UK the prevailing wind direction is from the south-west.
- Samplers are placed 180° apart (or 90° if more detailed measurements are required) along the site boundary as this represents the extent of the site operations and the maximum limit of public exposure.
- Along the axis (transect) of the prevailing wind direction it may be advisable to place a sampler 500 m from the site boundary to provide a measure of the downwind concentration. The 500 m separation distance represents the extent to which smaller diameter particles ( $10 \leq d_p \leq 30 \mu\text{m}$ ) from the site are likely to be transported from the site by the action of the wind as described in Section 5.2, though this distance is dependent on wind speed, particle diameter and source strength.
- The use of an upwind sampler can be used to provide a measure of the background dust concentration, i.e., the concentration prior to the addition of any dust arising from the site operations. The difference between the downwind and upwind samplers is the impact of the quarry.

**Figure 9.4** Boundary fence monitoring for the measurement of dust flux or PM<sub>10</sub>.



### 9.1.10 Costs

The cost of monitoring and instrumentation should be balanced against the perceived risk. Ultimately, the cost of dust or PM<sub>10</sub> monitoring will depend on many different factors, including location, number of monitoring sites and the duration of the programme. Typical monitoring, instrumentation and additional costs, e.g., staff costs and routine maintenance, are considered below.

#### Typical Instrumentation Costs

Table 9.3 provides an indicative cost of the commonly used dust monitors, automated PM<sub>10</sub> samplers and optical particle counters.

**Table 9.3** Indicative costs of common monitoring techniques (instrument purchase only).

Cost (£)	Particulate methods	Suspended dust	Deposited/directional dust
100-1,000	Deposit gauges Dust slides Petri dishes		✓ ✓ ✓
1,000-5,000	Simple filter-paper samplers Soiling meter DS500	✓ ✓	✓
5,000-10,000	Portable light-scattering aerosol spectrometers	✓	

**Table 9.3 (cont.) Indicative costs of common monitoring techniques (instrument purchase only).**

Cost (£)	Particulate methods	Suspended PM	Deposited/directional PM
10,000-15,000	β-gauges Portable light-scattering aerosol spectrometers	✓ ✓	
15,000-25,000	Automatic sequential particulate samplers, e.g., Partisol, TEOM and FDMS samplers	✓ ✓	

### Additional costs

As well as purchase of equipment there are other costs associated with dust monitoring, including:

#### Staff costs – site operation

Frequent documented site visits are an essential component of air monitoring. The frequency of visits required will depend on the type of dust gauge or PM<sub>10</sub> monitor being used. Passive samplers (e.g., depositional or directional dust gauges) require much less frequent attendance (typically weekly, fortnightly or monthly). For PM<sub>10</sub> samplers that utilise PM<sub>10</sub> sampling onto filters it is important to note that filters need to be changed and weighed regularly. Filter weighing and conditioning can be costly and expensive. Some older types of gravimetric PM<sub>10</sub> monitor may require daily site visits (although newer versions incorporate automatic filter exchange mechanisms which allow the instrument to operate unattended for up to two weeks). For automatic PM<sub>10</sub> analysers, e.g., the TEOM, FDMS, telemetry systems can provide an efficient and cost-effective method for data acquisition, but do not obviate the need for regular visits by operators. Site visits should be performed as frequently as operational needs, geographical constraints and available manpower permit.

#### Staff costs – data processing

Automatic analysers produce large quantities of data, which need to be collected efficiently and stored for subsequent analysis. Although passive and active sampler methods produce much less data than automatic continuous methods, large monitoring surveys can soon accumulate large datasets which become unmanageable if not efficiently processed and archived.

#### Routine maintenance

For active sampling equipment the routine maintenance of monitoring equipment is essential and represents an additive, on-going cost in addition to that of the monitoring equipment. Failure to deal with equipment damage or failure can lead to erroneous measurements and can jeopardise both the number of measurements made over a specific period of time (data capture) and the overall quality of the measurements. An on-going programme of routine maintenance will be required to:

- Carry-out site checks on equipment, sampling systems, safety and security.
- Perform manual equipment calibrations if necessary.
- Carry-out routine equipment maintenance and repair where necessary, at regular intervals, according to the instrument manufacturer's recommendations.

In addition to routine servicing, provision should be made for emergency "call out" breakdown or repair visits from the service unit, in order to minimise equipment down-time. The routine maintenance costs of complex samplers, e.g., automatic samplers, will be more considerable than those for passive samplers.

Passive samplers are generally robust and require minimal maintenance.

### Typical PM<sub>10</sub> survey costs

Table 9.4 provides approximate cost of a PM<sub>10</sub> monitoring survey.

**Table 9.4 Approximates costs of PM<sub>10</sub> monitoring survey.**

Project task	Estimated cost (£)
Six-month to one year monitoring survey contracted 'all-inclusive' to specialist consultancy	10,000-25,000
Purchase and installation of multi-pollutant site including PM <sub>10</sub> in purpose-built enclosure. Power and phone to be connected, calibration gases to be purchased, data collection software to be purchased	50,000-75,000
Annual 'all-inclusive' service and maintenance costs	3,000-8,000 per site
Annual data management and QA/QC costs	5,000-10,000 per site
Annual staff costs for site visits	5,000-10,000 per site
Annual cost of electricity/phone	2,000-3,000 per site
Annual software and web site maintenance fees	1,000-2,000
Annual filter weighing costs for gravimetric PM <sub>10</sub> monitoring. Cost dependent on number of filters, reporting requirements	3,000-10,000 per year

#### 9.1.11 Data Quality Assurance and Quality Control (QA/QC)

Where PM<sub>10</sub> samplers are used, in order to minimise measurement uncertainty of monitoring programmes it is important to apply appropriate QA/QC procedures. A documented quality assurance and control programme must be followed in order to ensure robust and reliable measurements.

The frequency and type of field calibrations required for automatic analysers should be defined in a Quality Assurance Programme for the site or network. A comprehensive calibration record and instrument checklist should be completed after each site visit and retained for subsequent QA/QC auditing. Details of calibration procedures and examples of suitable calibration sheets are available in the Automatic Urban Network Site Operator's Manual, which can be obtained from the LAQM helpdesk. The Environment Agency provides advice on QA/QC of monitoring data under their Monitoring Certification Scheme (MCERTS).

The fundamental aims of a QA/QC programme are as follows:

- Data should be representative of ambient concentrations in the area under investigation.
- Measurements need to be sufficiently accurate and precise to meet the defined monitoring requirements.
- Data must be inter-comparable and reproducible. Results from multi-site networks need to be internally consistent and comparable with national, international or other acceptable standards.
- Measurements should be consistent over time, particularly if long-term trend analysis is to be undertaken.

Proper QA/QC practice is necessary to ensure data integrity and guarantee the data quality required for meeting the overall monitoring objectives.

#### QA/QC for dust measurements

As noted above, passive dust sampling equipment is much more robust and straightforward to operate and service than active equipment. QA/QC is generally a function of the sampling technique and is available from the equipment supplier.

## QA/QC for PM<sub>10</sub> measurements

The data quality objective for PM<sub>10</sub>, as stipulated in the Directive, i.e., how close the measured value is to the true value, is  $\pm 25\%$ . For indicative monitoring techniques, the EC Directives set an accuracy objective of  $\pm 25\%$ .

All analysers (regardless of type) should be operated in accordance with the instructions provided in the manual for the equipment utilised. The sampling heads should be cleaned regularly and sample flow rates measured as recommended in the manual. Data from some analysers may also need to be re-scaled in order to allow comparison with the AQOs (as discussed in Section 3.5). The LAQM helpdesk should be contacted for more information. Suitable calibration factors (e.g., particle density, as shown in Table 9.8) need to be applied to the measurements from for some monitors, e.g., as light scattering devices.

For users of the Thermo Scientific Partisol 2025 gravimetric sampler, the Met-One BAM and the FDMS, further guidance can be found in the Site Operators' Manual, produced by Defra for the operators of AURN sites. This can be obtained from the LAQM helpdesk.

### Filter materials

There are a number of materials used for filters in gravimetric samplers, e.g., PTFE, quartz fibre and PTFE-coated glass fibre. The present CEN standard EN12341 specifies quartz filters, but current drafts of the new PM<sub>10</sub> CEN standard (which will replace EN12341) do not recommend any specific filter material. Detailed comparisons<sup>21</sup> have shown that different types of filters differ from each other in their collection efficiencies and in their water absorption characteristics. These differences will affect reported measurements from any gravimetric sampler. The comparative study concluded that PTFE-bonded glass fibres (Emfab) performed best and were therefore most suitable for monitoring ambient particulate matter. Whichever filter material is selected, it is recommended that operators use the same type of filter consistently throughout any monitoring survey.

### Filter conditioning and weighing

Filter conditioning and weighing should be undertaken in-line with the protocol laid out in BS-EN12341, which includes control of the weighing room atmosphere to temperature of  $20 \pm 1^\circ\text{C}$  and a relative humidity of  $50 \pm 5\%$ .

Filters will need to be pre-conditioned for at least 48 hours (or much longer for some types) before the initial weighing, in open dust protected sieve trays, in the air conditioned weighing room (temperature and relative humidity conditions as specified above). After exposure, filters must be re-conditioned for at least 72 hours under the same conditions, before re-weighing.

Before weighing a filter, it should be examined for pinholes and other imperfections by backlighting with an area light source similar to an x-ray film viewer.

Balances used for this purpose should have a resolution of 10  $\mu\text{g}$ . They are to be calibrated annually, using calibration weights that are traceable to national standards. In addition to the full annual calibration, regular routine checks should also be carried out, to ensure no substantial deviation from the expected settings. This is done using a check weight at the start of each weighing session (as a minimum), or better still, before every set of filters weighed within a session, and at intervals throughout. Blank filters should also be weighed at the start and end of each batch of clean and exposed filters.

In situations where there are inadequate in-house facilities for filter conditioning and weighing, it may be necessary to contract these activities out to a suitable external laboratory.

### Sampler operation

The samplers should be operated in accordance with the manual for the sampler utilised. The sampling heads should be cleaned regularly and sample flow rates measured as recommended in the manual. The filter exposure period and total sample flow must be recorded at each filter change.

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<sup>21</sup> Brown et al., 2005.

Ambient temperature and pressure may need to be recorded if the sampler does not make automatic corrections.

Many gravimetric samplers are equipped with sophisticated data logging systems to record their operating status of the analyser during filter exposure. Typically, this includes: filter exposure times, flow through filter, temperature and pressure measurements, errors occurring during sampling, filter ID information and date of exposure. This daily information should be recorded and used during the process of ratification. It is recommended that a **minimum** of 18 hours valid sampling, i.e., there is 75% data capture per 24-hour sampling period, is required for a **valid** 24 hour (daily) mean.

### Field blanks

In any gravimetric particulate monitoring programme, field blanks should be included as a matter of course and in a systematic way. Field blanks are filters which are placed in the gravimetric monitor with the filters to be exposed (in the case of a sequential sampler, in the filter canister), but are not exposed. Like the exposed filters, they are conditioned and weighed before and after going to the site. The field blank mass (which should be close to zero) is subsequently subtracted from the exposed filter masses, for all filters in the same batch.

Long-term records should be kept of field blank measurements, and any changes (upward or downward trends in field blank mass, or step changes) should be investigated.

### 9.1.12 Data and sample storage

Paper and electronic records and samples (where possible) should be stored safely for later consultation. This provides an audit trail from calibrations, sampling and analysis to reporting.

### 9.1.13 Validation

It is important to screen the measurement data, initially by visual examination, to see if they contain spurious and unusual measurements: this is how equipment faults or episodes of exceptionally high pollution are detected.

### 9.1.14 Ratification

The initial data validation should be followed by more thorough checking at three or six month intervals to ensure that they are reliable and consistent. This latter process is called data "ratification". Essentially, the data ratification procedure involves a critical review of all information relating to a particular data set, in order to verify the data. When the data have been ratified, they represent the final data set to be reported.

### 9.1.15 Reporting of monitoring results

A summary of the site's monitoring data should be reported periodically (at least annually) in the site's environmental report. Consideration should be given to:

- Reporting of current **and** previous performance, including simple statistics, e.g., daily or annual mean mass concentrations of dust or PM<sub>10</sub> and data capture rates. **It is also important to record the measurements units that have been used and any correction factors which have been applied to the data,**
- Demonstration of compliance with custom and practice thresholds for dust, statutory AQOs for PM<sub>10</sub> or planning conditions,
- Comparison of monitoring results to (1) national network sites and (2) similar sites, e.g., quarries or surface mines, where there are similar:
  - Materials extracted,
  - Output rates, and
  - Activities.

- Site and equipment information.

Consideration of these factors will separate out regional episodes (especially in the case of PM<sub>10</sub>) and assist in identifying any local issues. Where elevated concentrations have been measured, the reasons for the elevated concentrations should be stated.

Even the simplest air monitoring programme can quickly produce a large amount of data. Simple statistical summaries would therefore be useful to obtain a clear overall picture and to minimise the amount of information needed to describe the pollution situation. These statistical summaries form the basis of calculations to compare measured results with the objective.

The type of information required may include:

- Hourly, daily, monthly, seasonal and annual mean dust concentrations,
- Exceedences of specified custom and practice thresholds or limit values,
- Hourly, daily, monthly maximum values,
- Variation of concentration with wind direction, and other meteorological factors,
- Trends over time, and
- Mapped (spatial) concentrations.

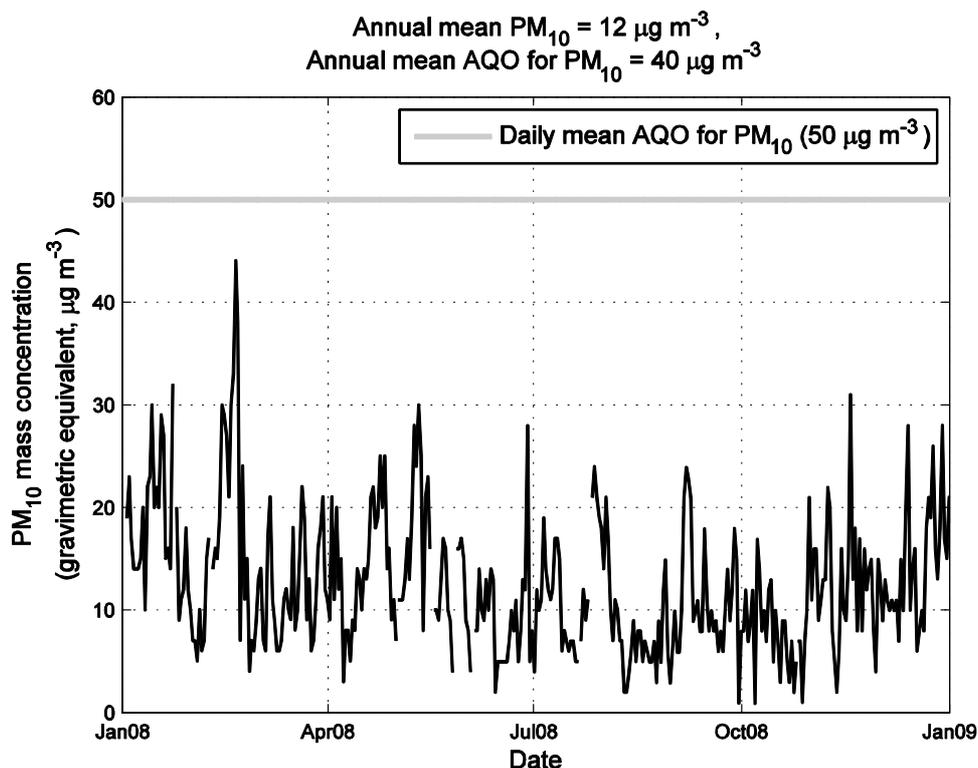
A selection of different ways to analyse and present dust and PM<sub>10</sub> monitoring data is given below.

### Methods for analysis and reporting of air quality data

#### Tables

Data are presented in the form of lists, for example, tables of measured dust concentrations for different intervals of time at selected measurement sites. Tables provide the largest sets of data for general analysis at minimal expense.

Figure 9.5 PM<sub>10</sub> time series plot.



### Time series

A time series plot of concentrations against specified time intervals provides a very useful way to quickly visualise a large dataset as shown in Figure 9.5. These can be used to identify possible data anomalies, to compare data from different monitoring sites or fluctuations of different dust levels at the same site. Diurnal or seasonal variations in dust concentrations can also be readily viewed. It may be helpful to demonstrate where exceedences have occurred: this can be achieved by adding the custom and practice threshold in the case of dust or the PM<sub>10</sub> AQO (as shown by the grey line in Figure 9.5) in the plot.

### Trend analysis

By performing a regression analysis on statistics such as annual mean concentrations, it is possible to assess how air quality compares to previous years and identify whether pollution concentrations are changing over time. Statistically significant trends, or even a reasonable overview of how concentrations are changing, usually only become meaningful when complete data records extend over five years or more.

### Calculation of measurements and exceedence statistics

Specific statistics need to be calculated from the ratified data for comparison with the custom and practice thresholds and AQOs. The following definitions are commonly used:

- The 24-hour mean is the mean concentration for the preceding 24 hours. If the 24-hour mean is calculated from hourly means then at least 18 valid hourly means are required to produce a valid 24-hour mean, i.e., 75% data capture is required to calculate a valid 24-hour mean concentration. A daily mean specifically refers to a 24-hour mean calculated for the period between 00:00 and 23:59 hours.
- The annual mean is calculated from hourly average concentrations over a year, yielding one annual mean per calendar year, for automatic data. The annual mean for non-automatic data is the mean of the relevant sampling periods over a year. Annual means are based on 365 days (366 days for leap years) and 90% data capture is required.

Commercial software, often available from the equipment suppliers, can be used to produce standard reporting formats. **When reporting data it is important to clearly specify what concentration units have been used.**

### Wind or pollution roses

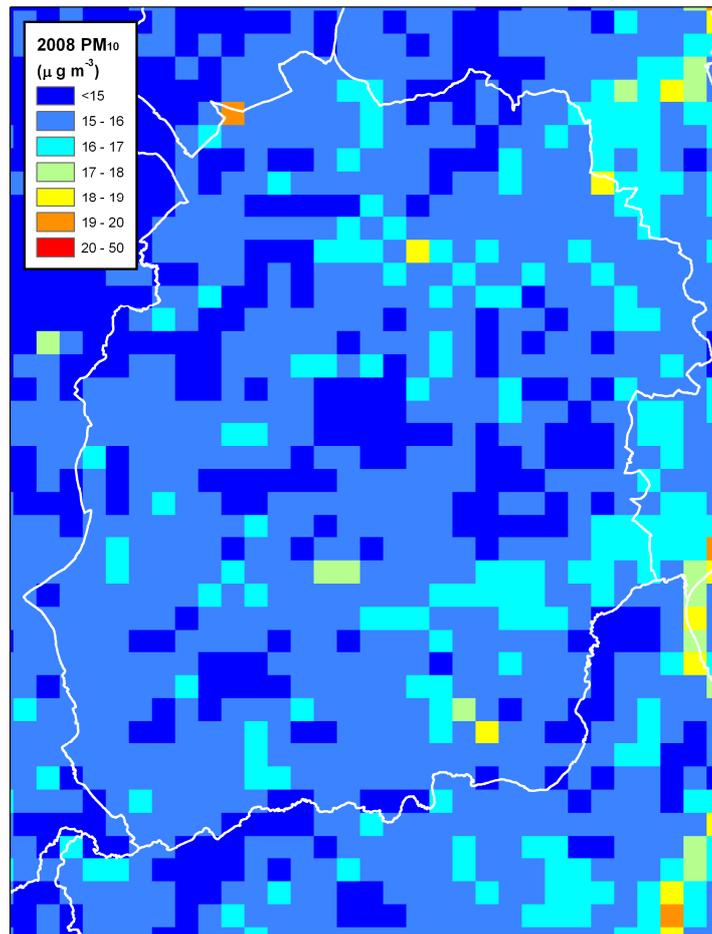
Wind or pollution roses can be applied to assist in determining the source of dust and PM<sub>10</sub>, especially in situations where there are other contributory sources that may give rise to high dust and PM<sub>10</sub> concentrations that may be attributed to a quarry or surface mine.

- Wind (velocity) roses show the average wind speed in each sector. They are used to provide an indication of the percentage of time wind was recorded from a particular direction.
- Pollution roses relate air pollution measurements to wind direction. They are used to indicate the average pollutant concentration in each wind sector. Pollution roses can be used to demonstrate the dust source and the commonly effected receptors.

### Mapping

Mapping of concentration data or statistics using GIS systems can be used to assess spatial patterns of pollution and exposure, identifying “hot spots” and assisting in monitoring network design. **Error! Reference source not found.** shows the background PM<sub>10</sub> concentration within the area (1 x 1 km grid squares) encompassed by West Oxfordshire District Council. **Error! Reference source not found.** shows the interpolated dust concentration from seventeen dust gauges situated around an industrial site. This allows areas of high dust concentration to be easily identified.

**Figure 9.6** GIS mapped background PM<sub>10</sub> concentration in the area (1 x 1 km grid squares) encompassed by West Oxfordshire District Council. © Crown copyright. All rights reserved Defra, Licence number 100022861 [2009].



## 9.2 Nuisance dust and PM<sub>10</sub> measurement techniques

### 9.2.1 Overview

Dust emissions from the extractive industries have a range of impacts as described in Section 1.2 which result from short-term exposure (acute effects) or long-term exposure (chronic effects). Day-to-day operational procedures, including staff vigilance, are typically sufficient to limit short-term events (ranging from a few minutes to several hours), whereas monitoring can be used to provide a measure of long-term (ranging from a few weeks to many months) effects.

Due to the variable nature of dust (e.g., source type and magnitude, and, particle size, shape, and composition) it can be measured in a number of ways. Nuisance dust and PM<sub>10</sub> monitoring techniques can be classified as follows:

- Passive systems are normally used for nuisance dust monitoring and generally do not require a power source and are relatively inexpensive. The amount of material sampled over a known period of time can be assessed either by determination of discolouration (visual assessment of staining or via reflectometry) or by measuring the mass of deposited material.
- Active systems require a power source and are used for measurement of dust.

Custom-and-practice thresholds to assess potential amenity effects are widely used for both optical and mass methods, but data from visual and mass methods are not inter-changeable. It is advisable not to specify a particular method as an exclusive requirement for any monitoring programme (such as

for a baseline study, or as part of Planning Conditions) unless there are clear and unambiguous reasons for doing so (such as a requirement to assess ambient PM<sub>10</sub> concentrations to demonstrate compliance with AQO). Instead, the site operator and the regulator should agree on the method(s) and threshold(s) to be used allowing the parallel objectives of effective site management and accountable regulation to be achieved.

The method used should be appropriate to the issue of potential concern, and proportional to the perceived risk. This will enable both the site operator and the regulator to be confident that site dust thresholds will be appropriate for both the site and its surroundings.

The principal approaches to dust monitoring are:

- Visual monitoring via simple observation of dust deposition onto a surface and dispersion on and off-site.
- Dust deposition
  - Surface soiling: discolouration (obscuration) of a surface caused by the accumulation of dust on a surface (such as glass microscope slide or sticky pad) due to the deposition of dust.
  - Dust mass: typically measured using a passive deposition gauge which appears similar to an inverted Frisbee.
- Dust flux is the measurement of the horizontal transport of dust. It can be measured as mass (using a quadruple collector, also known as the BS 1747 Part 5 or CERL, collector) or with different types of cylindrical adhesive (sticky pad) dust sampler.

Dust deposition measurements and dust flux measurements are not inter-changeable. Nor is it necessarily possible to accurately determine the equivalent mass deposited on one deposition gauge type, based on measurements made with another type, as different deposition samplers have different dust collection efficiencies. Whichever dust monitoring method is used, it is essential that it is used in accordance with the supplier's recommendations and the appropriate assessment criteria are applied to the data.

PM<sub>10</sub> monitoring can be undertaken using a range of samplers. PM<sub>10</sub>, dust deposition and dust flux measurements are not inter-changeable. Figure 9.7 summarises dust measurement methods by type, cost and complexity.

Figure 9.8 provides a simplified decision flow chart for choosing the method for the assessment of dust and PM<sub>10</sub> concentrations.

**Figure 9.7 Summary of dust measurement methods by type, cost and complexity.**

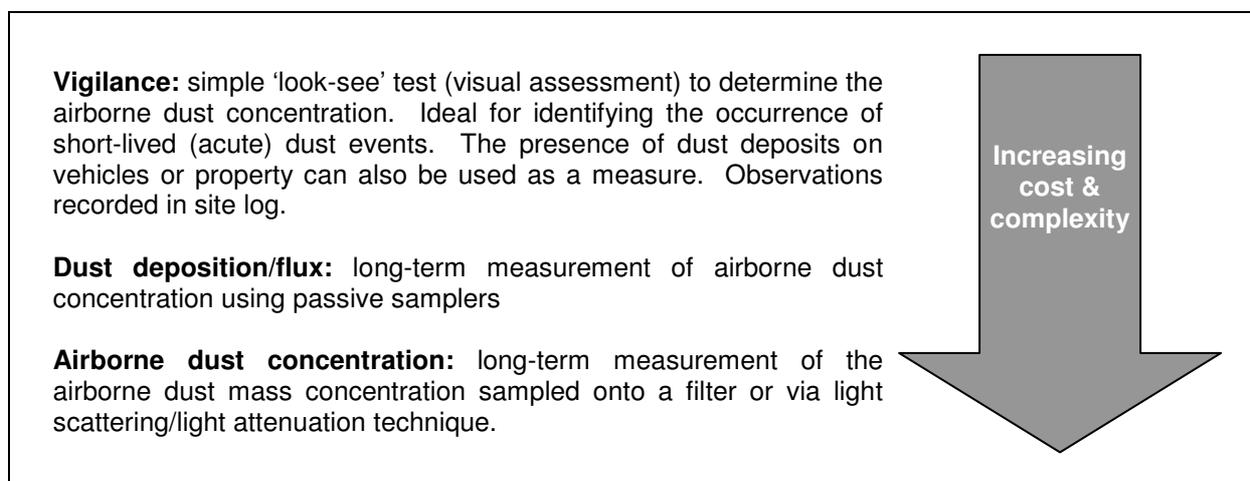
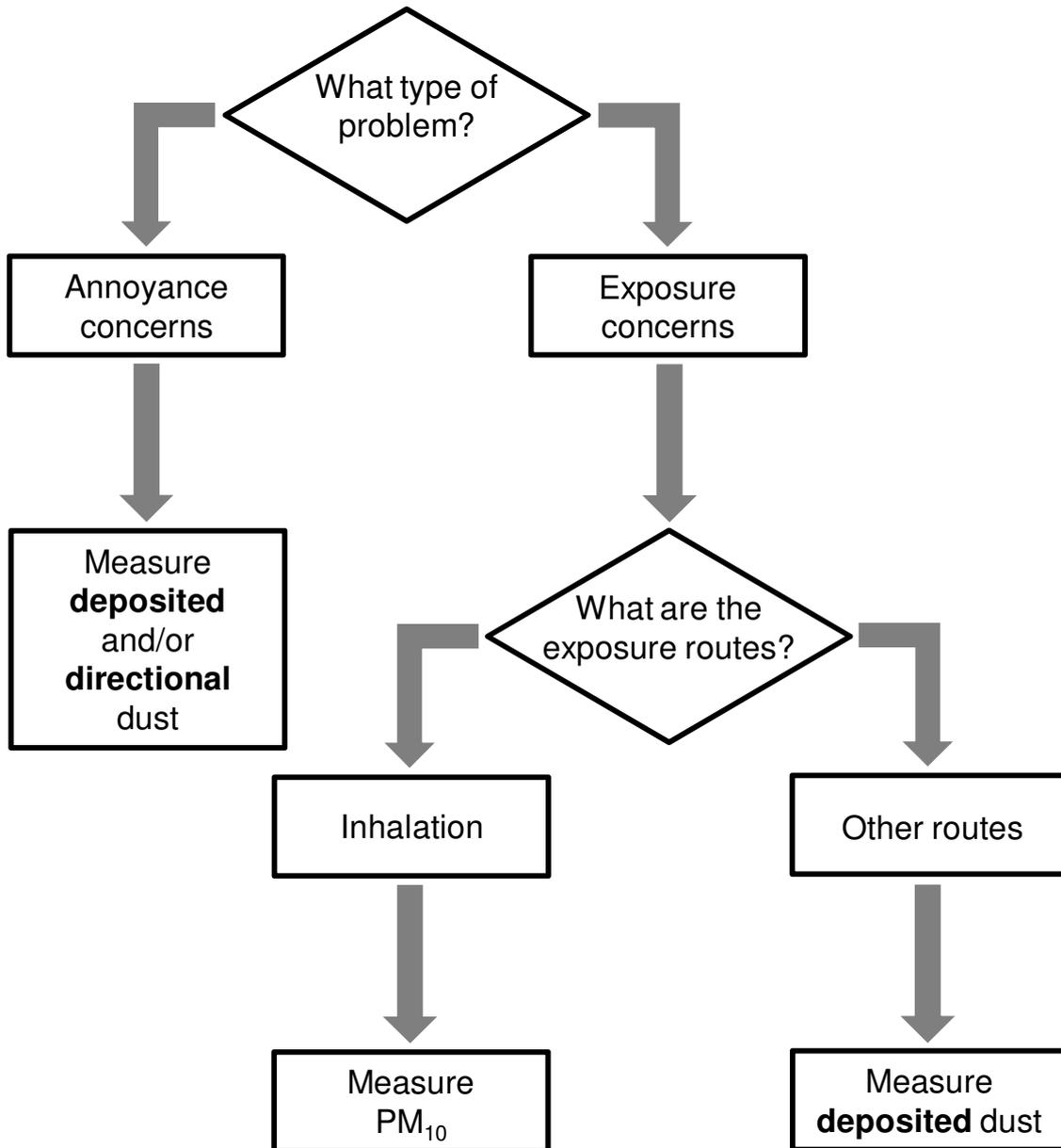


Figure 9.8 Simplified decision flow chart for choosing determinand.



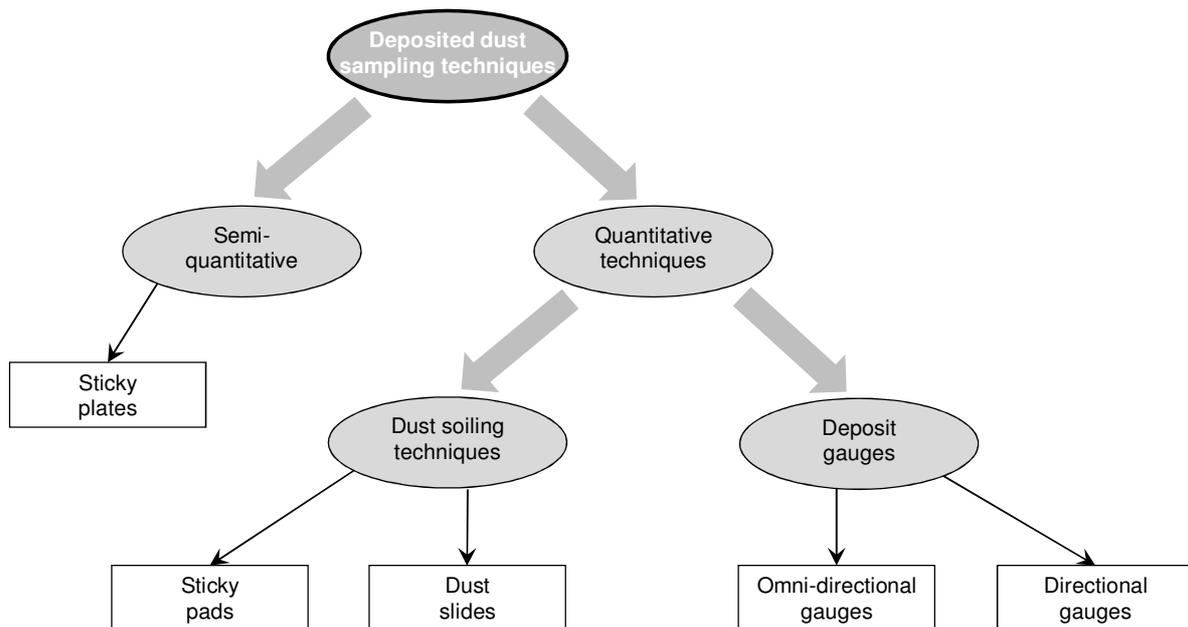
### 9.2.2 Deposition and soiling methods of dust measurement

Deposition and soiling methods are commonly used to measure dust loadings rather than PM<sub>10</sub> concentrations. They tend to be relatively crude but fairly cheap. The two basic approaches adopted are:

- Quantity of dust deposited, and
- Surface soiling.

Figure 9.9 summarises the main approaches for sampling deposited dust.

**Figure 9.9 The main approaches for sampling deposited dust.**



### Dust deposit gauges

Deposit gauges are a passive technique used for dust sampling, i.e., they do not employ a pump to draw dust into the apparatus/instrument in order for it to be measured. Deposition gauges tend to be semi-quantitative/qualitative in nature. There are several deposition methods in current use as described below.

Field trials comparing BS 1747 directional dust gauge, Frisbee gauge and sticky pad or tape method have provided mixed results. The degree of agreement is dependent on:

- Local site activity and the generation of re-suspended dust,
- Number of dust sources,
- Homogeneity of dust sources,
- Colour and density where more than one dust type is present, and
- Particle size and concentration.

### BS standard deposit gauge (BS 1747: Part1)

The BS Standard Deposit Gauge consists of a large, upward turned bowl mounted at a height of 1.2 m. The gauge is employed in the field to measure the amount of material deposited over a month via wet or dry deposition into the bowl. This technique has been progressively refined over the past 40 years. Gravimetric assessment of insoluble material deposited on a  $\text{mg m}^{-2} \text{ day}^{-1}$  basis can be derived by water extraction of the material collected over the period of a month on the collection plate. One of the key design constraints of the deposition gauge is that is that the deposited material is susceptible to loss in high winds. Consequently, the BS 1747 Part 1 deposition gauge has largely been superseded in practice by the use of the Frisbee deposition gauge.

### Frisbee deposition gauge

The Frisbee dry foam deposition gauge consists of an inverted Frisbee-type plate mounted horizontally at 1.75 m above the ground. This sampling technique was developed in the 1980s at the Warren Spring Laboratory (see: Vallack and Chadwick, 1992). Gravimetric assessment of the insoluble material deposited is on a mass of material deposited per unit area per day ( $\text{mg m}^{-2} \text{ day}^{-1}$ ). This is derived by water extraction of the material captured on the collection plate over the period of a month.

**Figure 9.10 A dry foam Frisbee dust deposit gauge (image courtesy of Ian Hanby).**



The Frisbee Gauge is specifically designed to be aerodynamically efficient, reducing the effect of eddies on particle collection thereby minimise airflow disturbance and maximising particle collection. The collection efficiency of the Frisbee gauge is 1.36 times greater than that of BS 1747: Part 1 deposition gauge<sup>22</sup>. The Frisbee gauge is the preferred technique of dust deposition measurement by the Environment Agency.

At the end of each sampling period the Frisbee is removed and washed to remove the deposited solids. The deposited solids are collected and filtered. The mean rate of dust deposition (of undissolved solids) is calculated thus:

$$\frac{(W_2 - W_1) \times 24.7}{T} \text{ mg m}^{-2} \text{ day}^{-1} ,$$

where:  $W_1$  = initial dry weight of filter (mg),  
 $W_2$  = final dry weight of filter plus dust (mg),  
 $T$  = length of exposure period (days), and  
24.7 = factor to account for active surface area of deposit gauge.

#### **Directional dust gauge (quadruple collector or BS 1747: Part 5 or CERL-type directional gauge)**

The Directional Dust Gauge consists of four vertical tubes facing in four separate directions. This gauge does not measure dust deposition, rather the horizontal flux of dust, by compass quadrant. Measurements with this gauge are not related to nuisance effects, rather the horizontal transfer of mass.

<sup>22</sup> Taken from Vallack & Shillito (1995).

**Figure 9.11** Directional dust gauge also referred to as a quadruple collector, BS 1747: Part 5 or CERL-type directional gauge.



The Directional Dust Gauge consists of four vertical tubes facing in four separate directions. This gauge does not measure dust deposition, rather the horizontal flux of dust, by compass quadrant. Measurements with this gauge are not related to nuisance effects, rather the horizontal transfer of mass.

The directional dust gauge is a directional (flux) monitor and should be located on, or adjacent to, the site boundary to assess dust propagation towards off-site receptors. Gravimetric assessment of insoluble material transferred on a  $\text{mg m}^{-2} \text{ day}^{-1}$  basis can be derived by water extraction of the collection plate. Sampling is typically undertaken for a period of 10 days to one month. The combined mass of dust collected in the four cylinders **does not** equate to the non-directional (deposited) dust mass, because the collection efficiency of the sample inlets varies due to the prevailing wind speed<sup>23</sup>.

### Soiling methods

Soiling methods are alternative methods of determining the extent dust deposition and are viewed to be a more direct measure of the nuisance effect caused by dust. Soiling measurements are typically cheaper to perform than deposition gauge methods but are not quantitative. Two basic approaches exist:

#### Glass slide method

The glass (dust) slide method involves the exposure of a glass microscope slide horizontally in the field for a week at a height of 1-2 m for a week. The method is designed to replicate the behaviour of dust on outside surfaces which naturally involve dust redistribution by rainfall and wind rather than providing a measure of the all the dust that falls on the surface of the glass slide. On return to the laboratory the reduction in reflectance at a 45° angle to the surface is assessed using a gloss-meter

<sup>23</sup> Bush et al., (1976).

(an instrument that measures specular reflection from a surface). The results are expressed in soiling units (SU) per week (SU week<sup>-1</sup>) derived by subtracting the reflectance value from 100. One soiling unit is a 1% reduction in reflectance. Typical soiling rates reported for the UK are 10 SU per week for background locations, rising to 30 SU per week in more polluted areas. The custom and practice threshold for glass (dust) slides is 20 SU per week (averaged over four, one week samples).

### Sticky pad method

The sticky pad (self-adhesive tape or film) method of assessing the level of soiling involves the exposure of white or colourless self-adhesive tape or pad to the dust source over a period of 1-2 weeks (after which time the adhesive surface might become saturated). The subsequent reduction in reflectance, as measured using a smoke stain reflectometer or optical scanning device, is averaged over the exposure period and expressed as the percentage effective area coverage (i.e., percentage reduction in reflectance) per day.

Typical UK EAC values range from 0.01% per day (EAC% day<sup>-1</sup>) in rural areas to 1 EAC% day<sup>-1</sup> in urban areas.

Table 9.5 provides the suggested complaint thresholds for dust deposition based on the EAC% per day. Dust gauges of this type can be used to measure the dust flux, which can be assessed in a similar manner to dust deposition (although it should be noted that, as for mass-based samplers, dust flux and dust deposition data obtained using sticky pad samplers are not interchangeable). For directional sampling, the self adhesive tape is wrapped around the cylindrical sample head allowing sampling through a 360° arc, termed “poly-directional sampling”. Consistent orientation of the sample head to a known reference point, such as north on a compass, will allow the source of the dust to be identified. The sticky pad method is normally considered the preferred technique for the measurement of dust soiling.

**Figure 9.12** Boundary fence dust monitoring using a DustScan DS100 directional dust gauge (image courtesy of Hugh Datson).



**Table 9.5 Suggested complaint thresholds for dust deposition based on the EAC% per day.**

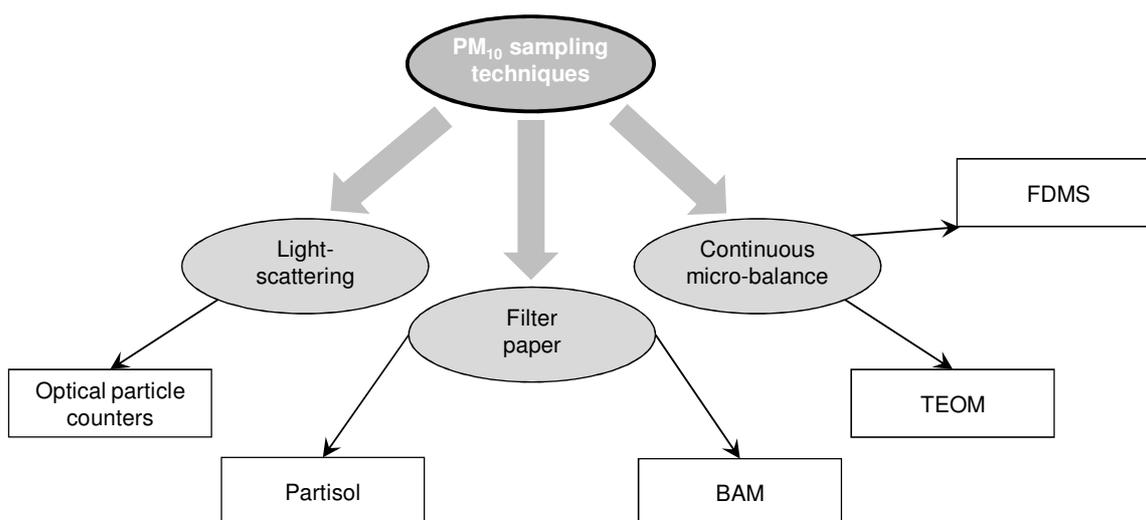
EAC% per day	Complaint threshold
0.2	Noticeable
0.5	Possible complaints
0.7	Objectionable
2.0	Probable complaints
5.0	Serious complaints

Dust samples from all dust deposition and soiling gauges can be preserved and geo-chemically analysed via optical microscopy, inductively coupled plasma-atomic emission spectroscopy (ICP-AES), scanning electron microscopy (SEM) and X-ray diffraction spectroscopy (XRD), thus providing unique source identification on the basis of dust grain size and chemical composition. Samples can be archived and re-assessed at a later date.

### 9.2.3 PM<sub>10</sub> measurement

Monitoring concentrations of PM<sub>10</sub> in ambient air is not straightforward. This is due to the complex nature and composition of PM<sub>10</sub>. One issue is that it is not possible to calibrate PM<sub>10</sub> samplers in the traditional sense, e.g., by the use of a standard gas for gas analysers. There are also sampling issues caused by the use of sample heaters. Sample heaters are used to drive-off excess moisture but also cause the loss of semi-volatile components. The loss of volatile PM<sub>10</sub> is a lower consideration when sampling PM<sub>10</sub> from the extractive industries due to its non-volatile nature. Measurements provided by automated PM<sub>10</sub> samplers are strongly influenced by smaller diameter particles (<10 µm) from local combustion sources. The method selected for the collection and determination of the particle mass thus has an influence upon the mass concentration that is subsequently reported. Figure 9.13 summarises the main approaches for sampling PM<sub>10</sub>.

**Figure 9.13 The main approaches for sampling PM<sub>10</sub>.**



Automated PM<sub>10</sub> samplers should be used when demonstrating compliance with UK AQO for PM<sub>10</sub> of:

- 50 µg m<sup>-3</sup> measured over a 24 hour period (not to be exceeded more than 35 times a year), and
- An annual mean of 40 µg m<sup>-3</sup>, as noted in Section 3.5.

**Where possible, sampling should be carried out using PM<sub>10</sub> monitors that comply with the European reference sampler or an instrument that has been demonstrated to be equivalent.**

Measurements should be undertaken with the same operational set-up of instruments, model versions and filter media as used in UK-based equivalence trials. Changes in any of these parameters may mean that the instrument is not giving results equivalent to the reference method. Automated samplers have been employed for demonstrating compliance with statutory AQOs since their introduction. These instruments are described below.

### **Tapered Element Oscillating Micro-balance (TEOM)**

The Thermo Scientific series 1400 TEOM is an automated airborne particulate sampler that employs a piezo-electric microbalance to measure the mass of material deposited on a filter. The TEOM is composed of a sensor, a control unit and a heated (50°C) inlet. Sampled air passes at a constant rate through a filter, attached to a vibrating hollow tapered element. As PM collects on the filter, the frequency of the vibration of the element decreases and the mass of PM collected over a period of 15 minutes or one hour can be calculated in real-time without the need for filter extraction and weighing. The TEOM can be used for continuous, on-line monitoring. The TEOM can provide measurement of TSP, PM<sub>10</sub>, PM<sub>2.5</sub>, and PM<sub>1</sub> mass concentration depending on inlet type. The TEOM has been used widely to provide continuous automated sampling and significant (temporal and spatial) datasets exist for comparative purposes.

In recent years limitations in TEOM measurements have been recognised due to its use of a heated inlet which leads to the loss of semi-volatile material. This has led to under-reporting of airborne PM<sub>10</sub> concentrations. For this reason the PM<sub>10</sub> mass concentration reported by TEOM does not meet the equivalence criteria of the European reference method within the UK, **without suitable correction**. The Volatile Correction Method (VCM) for the derivation of gravimetric equivalent PM<sub>10</sub> mass concentrations from TEOM PM<sub>10</sub> mass concentration measurements is described in Section 9.2.4 and permits suitable correction for demonstration of compliance to provide a nominal 'gravimetric-equivalent result'.

### **Filter Dynamics Measurement System (FDMS)**

The Thermo Scientific series 8500 Filter Dynamics Measurement System (FDMS) is an automated self-referencing airborne particulate sampler providing measurement of the non-volatile and volatile PM fractions, e.g., nitrate, organic and sulphate-based compounds, which are typically lost when sampling airborne PM using the TEOM. The FDMS allows accurate reporting of the PM<sub>10</sub> mass concentration which meets the UK equivalence criteria as described in Section 9.2.4. The FDMS can be used for continuous, on-line monitoring without the need for filter extraction and weighing. The FDMS provides a running 1 hour average mass concentration (in µg m<sup>-3</sup>) of PM<sub>10</sub>, PM<sub>2.5</sub> or PM<sub>1</sub> which is updated every six minutes.

TEOM Series 1400a (Revision B) monitors can be modified by addition of a FDMS kit to provide PM<sub>10</sub> mass concentration which meets the UK equivalence criteria as described in Section 9.2.4.

### **β-attenuation gauge**

The β-attenuation gauge (β-monitor, β-gauge, BAM) permits dynamic mass measurement of PM<sub>10</sub>. Sampling of the PM<sub>10</sub> occurs through a size-specific sampling head which passes to a collection chamber, depositing onto a fibrous collection substrate. The attenuation of a β-source of known strength is used to infer the mass of particulate material collected over a known period (typically 24 hours) and hence the atmospheric PM<sub>10</sub> loading. The BAM can be used for continuous, on-line monitoring without the need for filter extraction and weighing. The collection substrate runs through the instrument as a spooled tape and can therefore be preserved and re-assessed post-collection.

There are several limitations of this instrument which restrict its application to semi-quantitative airborne PM<sub>10</sub> assessment. Principal among these are particle size effects, which lead to collection of an inhomogeneous layer of deposited material. Substrate inhomogeneity, which can be exacerbated by deposit inhomogeneity, limits instrument precision. Material volatilisation/water absorbance by the deposited material over the sampling period can potentially lead to under- and over-reporting of the airborne PM<sub>10</sub> mass concentration and in severance of the fibrous collection substrate.

### **Partisol gravimetric sampler**

The Thermo Scientific series 2025 Partisol sequential air sampler is an automated airborne particulate sampler that collects size-selected (TSP, PM<sub>10</sub>, PM<sub>2.5</sub>, and PM<sub>1</sub>) particulate matter on filters for weighing (gravimetric analysis) or physico-chemical analysis. The Partisol can hold 16-filters, which can be used sequentially to provide for unattended operation for up to two weeks between site visits. One obvious drawback, when compared to the TEOM and FDMS, is that the Partisol is only capable of providing a **24 hour average**, whereas the TEOM and FDMS can provide one measurement every 15/30/60 minutes depending on the user defined time-base. As the Partisol employs filter sampling this method permits further characterisation of the sampled material. The need for filter weighing before and after exposure, this (and filter methods in general) cannot be used for continuous, on-line monitoring. The Partisol complies with CEN Reference Method 12341 (BS EN 12341:1999) and is the reference method for the measurement PM<sub>10</sub> mass concentration for demonstration of compliance with EU and UK AQOs.

**It is important to note that the ability of gravimetric methods to meet the UK data quality objectives for the demonstration of compliance with AQOs is highly dependent on correct filter handling, weighing and conditioning as described on p.75.**

The Partisol can also be used to log ambient temperature, RH, wind speed and direction through the addition of further sensors. Thermo Scientific manufacture a smaller, portable PM<sub>10</sub> sampling unit: the model 2100 Min-Partisol. The Mini-Partisol can be powered by a 12-VDC power supply (e.g., car battery, solar charger). This unit can only be operated for 24-hours and holds only one filter paper.

### **DustScan DS500 PM<sub>10</sub> weekly gravimetric sampler**

The DustScan DS500 poly-directional sampler provides non-continuous filter sampling of PM<sub>10</sub>. The inlet of the DS500 incorporates a size selective jet impactor that allows PM<sub>10</sub> to be sampled onto a cassette-mounted filter. A 12-VDC (battery) powered pump maintains the sample flow rate at 5 LPM.

The DS500 provides **weekly** PM<sub>10</sub> mass concentration measurements. One drawback of this approach is that if the daily PM<sub>10</sub> concentration is high, e.g., when conditions are dry and the site activity rate is high, exceedences of the daily AQO for PM<sub>10</sub> (50 µg m<sup>-3</sup>) may not be detected. This could lead to under-reporting of the number of instances when the daily AQO is exceeded which would otherwise be captured by the Partisol, TEOM or FDMS gravimetric samplers. **The DS500 is not a reference method compliant technique as it does not provide a measure of the daily mean PM<sub>10</sub> mass concentration** (as defined on p.76). Box 4 shows that the DS500 provides good agreement with weekly mean PM<sub>10</sub> mass concentrations measured with a Partisol PM<sub>10</sub> monitor.

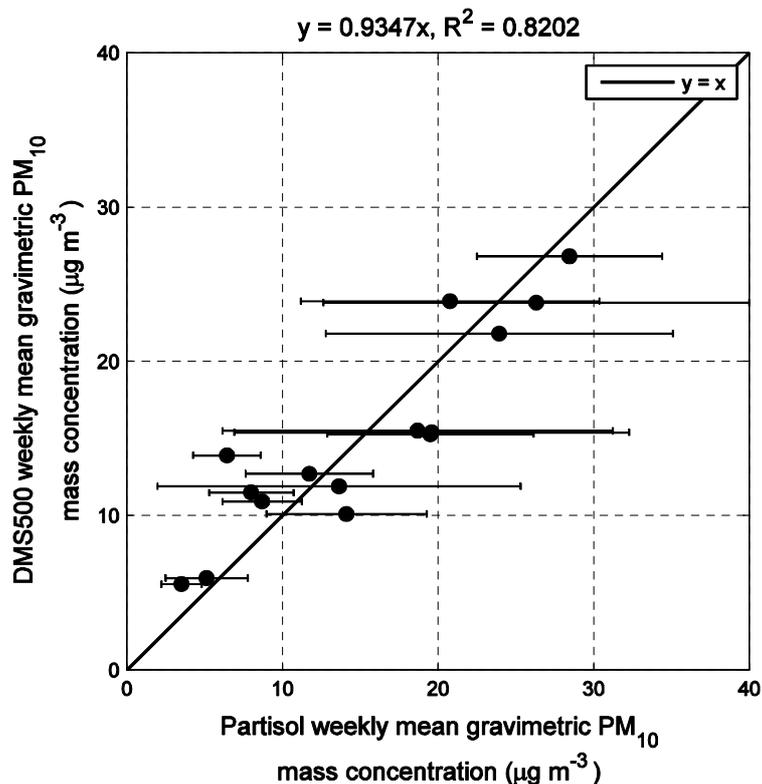
As noted for the Partisol sampler (see above) obtaining the PM<sub>10</sub> mass concentration measured by this method is dependent on correct conditioning gravimetric assessment, i.e., correct filter handling, weighing and conditioning pre- and post-deployment, in order to obtain an accurate measure of the PM<sub>10</sub> mass concentration.

### Indicative measurements of PM<sub>10</sub> mass concentration

Daily measurements of airborne PM<sub>10</sub> mass concentrations were taken using a Partisol 2025 sampler at a working sand quarry with an associated bagging plant. The measurements were taken from September 2007 to February 2008. The Partisol measurements were averaged and compared to co-located measurements of weekly PM<sub>10</sub> mass concentrations taken using a DS500.

The results show good agreement between the weekly mean PM<sub>10</sub> mass concentrations reported by the two techniques: the DS500 was capable of providing indicative measurements of the airborne PM<sub>10</sub> mass concentration. Further comparison with measurements taken at a range of sites, and under a range of meteorological/seasonal conditions would be required to establish a more robust relationship.

**Figure 9.14** Comparison of weekly averaged PM<sub>10</sub> measurements made with a Partisol 2025 and a DustScan DS500 directional dust gauge (data courtesy of Tarmac Ltd and Alex Grant AirQ). The horizontal error bars indicate standard deviation of the weekly mean Partisol measurements and provide an indication of the daily variation in the weekly averaged Partisol data. Partisol data was excluded if the weekly data capture was <75%.



## 9.2.4 Equivalence criteria for PM<sub>10</sub> samplers

Table 9.6 provides the correction factors applied to the measurements from commonly used automated PM<sub>10</sub> samplers (described in Section 9.2.3) allowing suitable correction of PM<sub>10</sub> mass concentration to provide a nominal “gravimetric-equivalent result”. Conversion of the measured PM<sub>10</sub> mass concentration to a nominal “gravimetric-equivalent result” permits the use of the measurement for demonstration of compliance with the PM<sub>10</sub> AQO.

**Table 9.6 Summary of UK equivalence tests and correction factors.**

Instrument	Outcome of test	Correction factor applied to give PM <sub>10</sub> gravimetric mass
TEOM (PM <sub>10</sub> )	Fails the equivalence criteria	Apply VCM correction factor‡: $TEOM_{VCM} PM_{10} = TEOM PM_{10} + (1.87 \times \text{Regional FDMS } PM_{10} \text{ purge})$
FDMS Model B <sup>†</sup> (PM <sub>10</sub> )	Meets the equivalence criteria	None
FDMS Model B (PM <sub>2.5</sub> )	Meets the equivalence criteria	None
Partisol 2025* (PM <sub>10</sub> )	Meets the equivalence criteria	None
OP SIS SM200 (PM <sub>10</sub> )	Meets the equivalence criteria	Subtract 1.29 µg m <sup>-3</sup> from the measured mass and divide by a factor of 0.819
Met-One BAM (unheated) (PM <sub>10</sub> )	Beta – Meets the equivalence criteria  Mass – Meets the equivalence criteria with correction for slope and intercept	Beta – divide measured mass by 1.21  None

† The Model B FDMS is no longer commercially available.  
\* The Partisol 2025 was operated with Teflon coated glass-fibre filters.  
‡ Further information on the VCM correction can be found in the Appendix 3 and on-line at the Volatile Correction Model web portal.

### Implications for data reporting

**When reporting data from one of the instruments listed in Table 9.6 the PM<sub>10</sub> monitoring data should be suitably corrected to provide a gravimetric equivalent mass concentration and the correction factor used should be reported.**

## 9.2.5 Optical Particle Counters (OPCs)

The scattering of monochromatic light can be successfully used to measure particles >0.1 µm in diameter (and up to 50 µm). Light scattering or Optical Particle Counters (OPCs) are a reliable tool for measuring the properties of homogenous spherical particles. Complications arise when measuring heterogeneous airborne particle populations such as those encountered in the atmosphere. Small particle-to-particle variations in composition, size and shape lead to variations in the refractive index of the sampled particles. **Therefore OPC measurements can only be considered semi-quantitative.** The instrument must be properly calibrated and have a size-selective inlet. Calibration of light-scattering devices is normally carried out by measuring the mass of particles deposited on an in-line filter in order to obtain a local calibration factor. Some OPCs have integral filter blocks (e.g., Grimm Model 1.100 series OPC) whilst others (e.g., Turnkey Osiris) require separate in-line filter to be operated in-parallel. Four commonly used OPCs are described in Table 9.7.

**Table 9.7 Commercially available OPCs.**

Instrument	Manufacturer	Acceptance range
Grimm Model 1.100 series (18V DC supply, combined met station, filter holder permits sample collection and analysis)	Grimm Aerosol Technik Gmbh & Co. KG., Bavaria, Germany	0.1-0.2 to 10-30 µm (dependent on variant)
MetOne Esample (12V DC supply, combined met station)	Met One Instruments Inc., OR, USA	TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , PM <sub>1</sub> (inlet dependent)
Turnkey Osiris (12V DC supply, combined met station, EA preferred OPC instrument)	Turnkey Instruments Ltd., Northwich, Cheshire	0.5 to 20 µm TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , PM <sub>1</sub> (inlet dependent)
TSI Model 8535 DustTrak II (replaces the TSI Model 8520 DustTrak) (12V DC supply, combined met station)	TSI Inc., MN, USA	PM <sub>10</sub> , PM <sub>2.5</sub> (inlet dependent)

**Figure 9.15 A Turnkey Osiris OPC and anemometer mounted on a house adjacent to a quarry.**



The temporal resolution of OPCs tends to be of the order of <1 minute, hence they are ideal for spot measurements of transient activities, e.g., the measurements of fugitive sources or hot-spots. OPC

instruments typically have a small integral memory sufficient for storing a few hours worth of measurements and can be battery or mains operated. The small, lightweight and portable nature of OPCs allows them to be housed in discrete, compact enclosures that can be easily mounted onto site furniture, e.g., site huts and perimeter fencing posts, allowing combined dust and meteorological measurement as shown in Figure 9.15. Serial interfaces and telemetry allow remote data download.

OPCs employ a light scattering cell that permits measurement of particle size and number loading (expressed in terms of the number (*N*) of particles per cm<sup>3</sup>). The equivalent particle mass concentration (µg m<sup>-3</sup>) can be calculated by assuming:

- All particles are spherical, and
- A uniform bulk particle density.

Table 9.8 provides the bulk densities of three commonly quarried materials. The material densities given in Table 9.8 allow calculation of the mass concentration of PM<sub>10</sub> based on the number concentration. It should be stressed that in order to derive an approximate mass concentration a bulk particle density must be used that reflects that of the predominant material under consideration.

**Table 9.8 Bulk densities of three commonly quarried materials.**

Material	Density (g cm <sup>-3</sup> )
Calcite (CaCO <sub>3</sub> )	2.7-2.9
Granite	2.4-2.7
Limestone	2.1-2.9

For particles of a known diameter it is possible to determine the mass concentration using the relationship:

$$M (\mu\text{g m}^{-3}) = \left( \frac{N (\text{cm}^{-3}) \times 1 \times 10^6 (\text{cm}^3 \text{m}^{-3}) \times \rho (\text{g cm}^{-3}) \times \left( \frac{4\pi r^3}{3} \right) (\text{cm}^3)}{1 \times 10^6 (\mu\text{g g}^{-1})} \right)$$

The total airborne particle mass concentration can be calculated by integrating (summing) across all sizes within the instrument's measurement (also termed "acceptance") range.

### 9.3 Co-monitoring of nuisance dust and PM<sub>10</sub>

The results from PM<sub>10</sub> and nuisance dust measurements are not inter-changeable. Box 5 provides an example of where directional AAC% and PM<sub>10</sub> concentrations were measured simultaneously. The measurements demonstrated that there was no relationship between nuisance dust and PM<sub>10</sub> concentrations at the site.

In exceptional circumstances, i.e., in instances where extractive processes are located adjacent to an AQMA, it may be necessary during the initial phase of the site operations to simultaneously measure nuisance dust and PM<sub>10</sub> concentrations in order to demonstrate compliance with the AQO for PM<sub>10</sub>, and moreover to demonstrate the source of the PM<sub>10</sub>.

### Combined dust AAC% and PM<sub>10</sub> measurements at an aggregates quarry

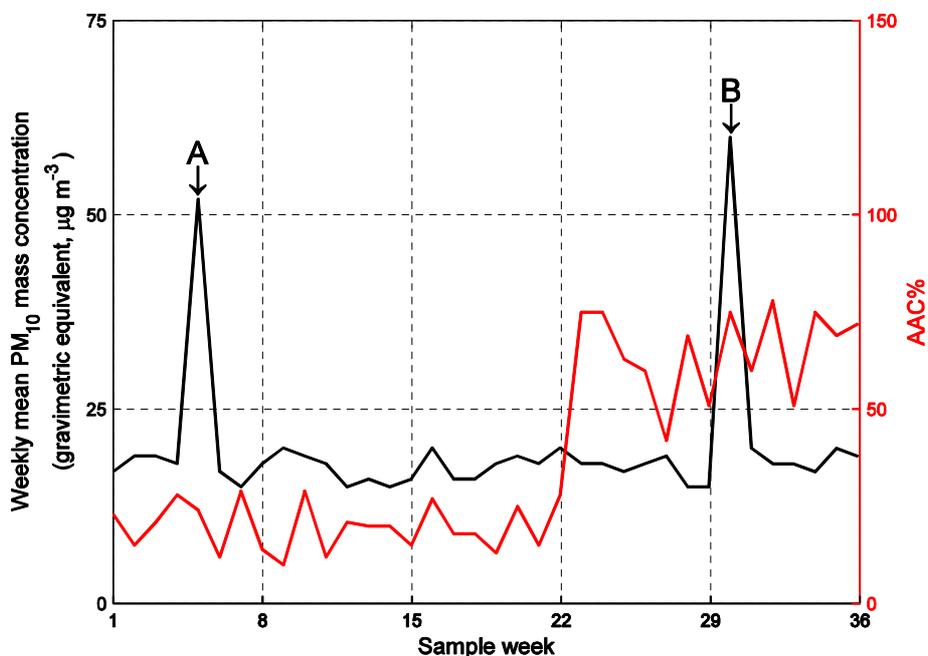
The pre-application dust assessment for a new sand and gravel quarry, which included a concrete batching plant, near two major motorways had determined that the proposed operations were unlikely to cause a breach of National AQO for PM<sub>10</sub>. Due to concerns raised by local residents, the District Council imposed two planning conditions requiring a scheme for dust and PM<sub>10</sub> monitoring and mitigation to be in place prior to the commencement of operations. One condition specifically identified the need for PM<sub>10</sub> monitoring due to the proximity of the above site to an existing AQMA (relating to nitrogen dioxide emissions from vehicles travelling along the motorway).

A scheme for directional dust and PM<sub>10</sub> monitoring was devised to meet the requirements of the planning consent. A DS500 combined PM<sub>10</sub> and directional sticky pad type dust gauge was situated on the western site boundary – between the concrete batching plant and the nearest off-site dust receptor – to provide gravimetric PM<sub>10</sub> and directional nuisance dust measurements. Two DS100 directional dust monitors were deployed to monitor nuisance dust at other locations on the site boundary between the phases of site operations and dust receptors to the east and south of the site.

The average PM<sub>10</sub> concentration, based on measurements between January and September 2008 was 17.5 µg m<sup>-3</sup>. Figure 9.16 shows a time series plot of the weekly PM<sub>10</sub> mass concentration and AAC% during this time. Of the 36 weekly average PM<sub>10</sub> samples obtained, only two were at or above the 40 µg m<sup>-3</sup> 24-hour threshold. In both instances, where an exceedence of the 24 hour mean AQO for PM<sub>10</sub> occurred, the dust concentration did not exceed the prevailing long-term trend.

Overall, the District Council agreed that it was reasonable to conclude that site activities were unlikely to cause a breach of the AQO for PM<sub>10</sub>. A subsequent review of the directional dust data measured between September 2008 and March 2010 also concluded that AAC% and EAC% were not at levels likely to cause nuisance to off-site receptors.

Figure 9.16 Time series plot of nuisance dust (AAC%) and weekly PM<sub>10</sub> mass concentrations.



Directional dust monitoring is ongoing at the quarry. The dust reports are reviewed at regular intervals at the site liaison group meetings, which include local residents and officers of the District Council.

## 9.4 Directional sampling

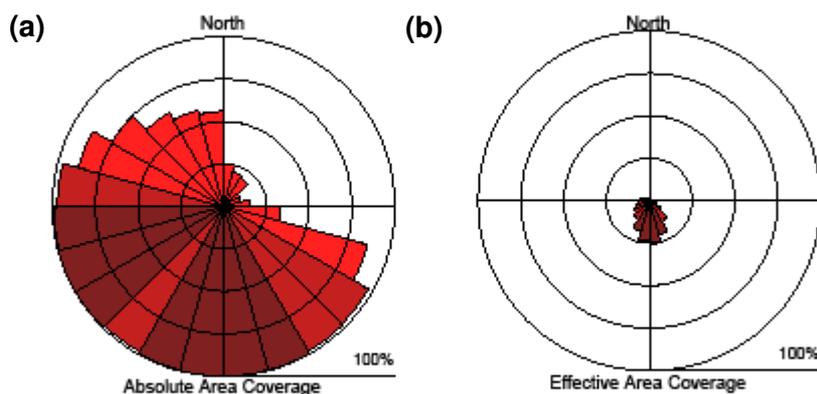
Dust deposited around the site of a quarry or surface mine will be composed of a range of particle types. Chemical analysis of dust is not always appropriate or suitable, since disparate sources may emit physically or chemically similar particles. For example:

- Dust from agricultural tillage of soil in fields, and dust from soil handling undertaken at the site.
- Dust from excavations associated with construction work, and dust from overburden handling at a mineral site.

For these reasons directional sampling may need to be undertaken to accurately determine the origin of dust or PM<sub>10</sub>. Directional sampling provides improved source identification of dust and PM<sub>10</sub> but at a much reduced cost when compared to chemical or physical characterisation. Directional sampling can be achieved by:

- Wind sectoring: comparison of the dependency of the measured dust and/or PM<sub>10</sub> concentration with wind speed and direction, and
- Omni-directional sampling: use of an appropriate sampler or sampling head that allows collection of dust or PM<sub>10</sub> across the full 360° range or four, 90° quadrants. Figure 9.17 shows a rose diagram of %AAC and %EAC derived from a sticky pad type dust gauge (see p.85).

**Figure 9.17** A rose diagram showing the (a) Absolute Area Coverage (density, %AAC) and (b) Effective Area Coverage (discolouration, %EAC) from a sticky pad dust gauge.

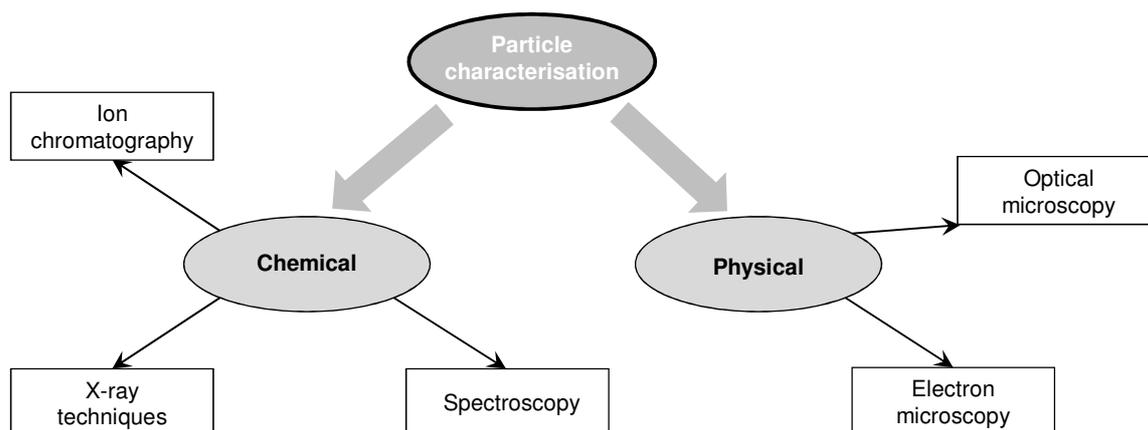


## 9.5 Chemical and physical characterisation

Chemical and physical characterisation of particles is a costly and lengthy process and is only advisable in cases where precise source apportionment using more simple techniques, e.g., wind sectoring, have failed to identify the exact source of exceedences of custom and practice thresholds for dust or the statutory limits (AQOs) for PM<sub>10</sub>. Characterisation techniques can be an effective method of source apportionment and can be cost effective in certain circumstances and can provide an alternative to lengthy monitoring.

Dust and PM<sub>10</sub> particles can be characterised using a range of geo-chemical techniques as shown in Figure 9.18. It is important that all sources of contamination and physical degradation must be minimised during all aspects of sample handling, including collection, transport, storage, and analysis in order to provide reliable characterisation. Unused samples should be labelled, archived, and stored appropriately to allow characterisation at a later date.

**Figure 9.18 Particle characterisation.**



### 9.5.1 Chemical characterisation

Determination of the chemical composition of dust can be a useful technique for source apportionment. The technique used is dependent on the compound(s) under investigation, e.g., sodium and chloride in the case of sea salt, and the concentration. The principle techniques used to characterise dust particles are:

#### Ion Chromatography (IC)

Ion Chromatography (IC) is an analytical technique, which can identify specific ions that are present within an aqueous sample, both quantitatively and qualitatively.

The technique uses a mobile liquid phase (eluent) that is pumped through a resin column or stationary phase which together form a continuous liquid system.

Various configurations of mobile phase and selective columns can be used depending upon the ions of interest and the limits of detection required.

When looking at aqueous extracted particulate filters, (negatively charged) anions such as chloride, nitrate and sulphate, and (positively charged) cations such as sodium, ammonium and calcium are of most interest. It is especially useful for looking at particulate contributions made by sulphates, nitrates and the presence of sea salt. Sub ppm levels of analysis are easily achievable by using chemical background suppression and conductivity detection.

For analysis, <1 ml of sample is injected into the stream of eluent, which is then carried through the separator column. Multiple analyses of ions (usually between 5 and 8) can be carried out in one run – with the monovalently charged ions being eluted from the column first, followed by the divalent ions next and so on until the run ends. This allows for easy identification of each individual ion, based upon its elution time and quantification using injected calibration standards.

#### Spectroscopy

Spectroscopy is often used for the identification of substances through the spectrum emitted from or absorbed by them. Sample extracts must be prepared from a representative portion of a sample and are commonly thermally degraded as part of the analysis process. Therefore the sample cannot be recovered at the end of the analysis for further study.

The two most commonly used spectroscopic techniques are Atomic Absorption Spectroscopy (AAS) and, Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). These techniques permit quantitative analysis of the elemental composition of dust particles. On the whole the techniques described below are costly, requiring expensive, complex instrumentation, and due to their high sensitivity, require specialist installation and operation.

### **Atomic Absorption Spectroscopy (AAS)**

Atomic Absorption Spectroscopy (AAS) is a flame atomisation technique, which can be used to study up to 70 elements down to ppb levels accurately and conveniently. This technique is one of the most popular methods for the determination of metals.

The quantity of interest in atomic absorption measurements is the amount of light at a resonant wavelength which is absorbed as the light passes through a cloud of atoms. As the number of atoms in the light path increases, the amount of light absorbed also increases in a predictable way. By measuring this absorbed light, a quantitative determination of the amount of analyte element present can be made. The use of special light sources and careful wavelength selection allow the specific quantitative determination of individual elements in the presence of others.

The atom cloud required for these measurements is produced by nebulising a solution of the sample into a flame, aligned in the light beam, whilst supplying enough thermal energy (fuel and oxidant) to the sample to allow it to dissociate into its component free atoms. Under optimum flame conditions, most of the atoms will remain in the ground state form and are capable of absorbing light at the analytical wavelength from the source lamp.

A more advanced and more widely used sampling technique for atomic absorption is the graphite furnace. In this technique a tube made of graphite is placed in the sample compartment of the spectrometer with the light path passing through it. A small volume of quantitative sample is placed directly into the tube through a small opening in the top. The tube is then electrothermally heated through a programmed temperature sequence until the sample is dissociated and absorption of the atoms occurs. This gives rise to a peak shaped signal which can then be integrated quantitatively.

### **Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)**

Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is one of the most commonly used techniques for multi-elemental analysis. It is capable of resolving elemental concentrations as low as 1-100 parts per trillion (ppt).

A solution of the sample is nebulised and introduced to an ultra-high temperature (~6,000°C) Argon plasma torch. The nebulised sample gains energy from the torch and the atoms eventually release one electron to form singly charged ions. The ions pass through an ions lens, which focuses the ions into mass spectrometer region of the instrument where the ions are detected.

Qualitative analysis is provided by the separation of atomic ions in a mass spectrometer, quantitative analysis is achieved by measurement of the magnitude of the ion current. ICP-MS produces simple spectra free from inter-elemental interference. ICP-MS can be used for isotope ratio studies making it particularly applicable to the study of lead isotopes, which can be usefully employed for tracer studies or source apportionment.

### **X-ray techniques**

X-ray techniques are non-destructive micro-analytical techniques which reveal information about the crystallographic structure, chemical composition, and physical properties of individual dust particles. These techniques tend to be used alongside Electron Microscopy methods of particle characterisation. X-ray techniques are based on observing the scattered intensity of an X-ray beam hitting a sample as a function of incident and scattering angle, polarisation, and wavelength or energy.

X-ray analysis has a lower detectability limit of about 0.1% (by weight). The choice of X-ray analysis technique tends to be influenced by choice of Electron Microscopy technique, as discussed in Section 9.5.2, used to determine the physical properties of individual dust particles.

Figures 9.22 to 9.28 show example images of quarry dust particles derived from a range of micro-analysis techniques. Figure 9.22 shows the output from Quantitative Evaluation of Minerals by Scanning Electron Microscopy and EDX (QEMScan, SEM-EDX) micrograph of dolerite particles.

### Energy Dispersive X-ray spectroscopy (EDX) methods

Energy Dispersive X-ray spectroscopy (EDX) methods include X-Ray Fluorescence (XRF) spectroscopy and Proton Induced X-ray Emission (PIXE) spectroscopy. EDX methods are used to provide both qualitative and quantitative chemical analysis of multiple elements simultaneously. The difference between XRF and PIXE is the type of fundamental particle that is used to elicit the production of X-rays.

XRF uses X-rays from an X-ray tube or a secondary target to bombard the sample. The elements in the sample become energetically excited causing the sample to fluoresce. Element specific X-rays are emitted as the electrons within the elemental atoms return from their excited state to their original ground state. The emitted energy and its intensity can be used to determine elemental concentrations.

Proton Induced X-ray Emission analysis (PIXE) uses high-energy protons to excite the elements in the sample. High-energy protons are produced from a cyclotron or van der Graff gun.

### Wavelength Dispersive X-ray Fluorescence Spectroscopy

In Wavelength Dispersive X-ray Fluorescence (WDXRF) spectroscopy the sample is bombarded with high-energy X-rays. The photons emitted by the sample are diffracted before hitting the detector. This is accomplished by placing an analyzing crystal between the sample and the detector.

There are two types of WDXRF spectrometers: simultaneous and sequential. In simultaneous WDXRF spectrometers, multiple detectors placed at different angles are used to analyse multiple elements simultaneously. In sequential WDXRF Spectrometers, the crystal is turned while elements are analysed sequentially. Sequential WDXRF spectrometers typically have better intensity, but take longer to record measurements.

## 9.5.2 Physical characterisation

### Optical Microscopy

Optical or Light Microscopy (LM) utilises light refraction via a lens system to form enlarged images of microscopic objects. The image is focused on the detector, which can be the human eye or a camera. The non-destructive nature of LM makes it ideal for initial analysis of samples. Particle identification can be provided through a combination of the physical and optical properties of a particle, e.g., size, shape, surface texture, colour, refractive indices, crystallographic properties, and birefringence<sup>24</sup>, and hence its source determined.

The contrast between the background support and the particle is often the most important consideration when trying to view an object by LM. The field of view can be improved through the use of several techniques:

- **Phase contrast microscopy:** small phase shifts introduced by rings etched accurately onto glass plates change the optical path of light passing through the microscope. This allows the light passing through a transparent specimen to be converted into amplitude or contrast changes in the image allowing the specimen to become more visible. These changes are due slight variations in the refractive indices of the items under examination.
- **Differential Interference Contrast microscopy (DIC):** also known as Nomarski Interference Contrast (NIC) or Nomarski microscopy. DIC is an optical microscopy illumination technique used to enhance the contrast in unstained, transparent samples. Polarised light is introduced to the microscope and then split, passed through the object under consideration, and then recombined allowing the object to take-on a three-dimensional appearance.
- **Light polarisation:** a polariser is a device that converts a beam of light of undefined or mixed polarisation into a beam with well-defined polarisation. Depending on how the polarised light

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<sup>24</sup> Birefringence, or double refraction, is the decomposition of a ray of light into two rays (the ordinary ray and the extraordinary ray) when it passes through certain types of material, such as calcite crystals or boron nitride, depending on the polarisation of the light.

beams are applied or combined allows optically isotropic<sup>25</sup>) and anisotropic materials to be easily resolved.

Example images of calcite particles analysed using LM are shown in Figure 9.20 and Figure 9.21. The images were taken under plane-polarising light (PPL) under cross-polarising light (XPL), respectively.

Determination of the shape and size is often the first step in single-particle analysis. Particles down to of a few microns in size can be resolved using OM, but more accurate shape and size determination is only possible for particles larger than several micrometers in diameter. Particle shape can provide information about the probable particle formation mechanism. For example metal particles formed in high temperature processes, e. g., smelting or welding, tend to form near-perfect metal spheres. Soot particles from combustion sources, e.g., vehicle engines, tend to form aggregates or complex branched-chain (termed “fractal”) structures composed of dark, spherical soot particles. By comparison, mineral particles formed via weathering, attrition or mechanical abrasion, appear irregular in shape. Examples of the different particle types are shown in Figure 9.24, Figure 9.25 and Figure 9.26.

### Electron Microscopy

The minimum detectable diameter of particles resolved by optical microscopy is limited by the wavelength of visible light to between 0.4 and 0.7  $\mu\text{m}$ . Detailed analysis of smaller diameter particles requires the use of radiation with a shorter wavelength than light. In electron microscopy, the microscope floods the sample with excitation energy but focuses only a proportion of the scattered or secondary radiation (composed of electrons) to provide an image.

Scanning Electron Microscopy (SEM) is widely used to provide micro-analysis of dust particles. It offers magnification levels up to 100,000 times offering high-resolution, three-dimensional images of particles of as small as 0.1  $\mu\text{m}$  in diameter. This allows topographical and morphological features to be distinguished. Chemical micro-analysis can be performed alongside SEM using a range of micro-analytical techniques, e.g., X-ray analysis, providing detailed source apportionment of dust particles. Figure 9.22 shows micrographs of dolerite particles characterised using Quantitative Evaluation of Minerals by SEM (QEMScan, SEM-EDX). Specific chemical and mineralogical components of each particle are colour-coded allowing easy identification.

SEM samples are mounted on substrate holders and bombarded with electrons emitted from an electron gun. The electrons interact with the sample and are scattered. In SEM the scattered electrons are detected above the sample. Electrons emitted from the substrate holder can cause interference, occluding the particle’s component elements. For this reason, spatial resolution in SEM is low. The interaction between the electron beam and particle can lead to sublimation of volatile compounds, e.g., sea salt, which is commonly found in dust particles. Figure 9.23, Figure 9.24, Figure 9.25 and Figure 9.26 show SEM micrographs of a range dust particles.

## 9.6 Combined chemical and physical analysis

In some cases, it is advantageous to combine both chemical and physical analysis of dust particles. This approach can be used to provide accurate source apportionment of chemically similar particles, but with different diameters. Box 5 outlines a case study where combined chemical and physical analysis of dust particles was used to distinguish different particle types and apportion the source of dust particles collected at a quarry.

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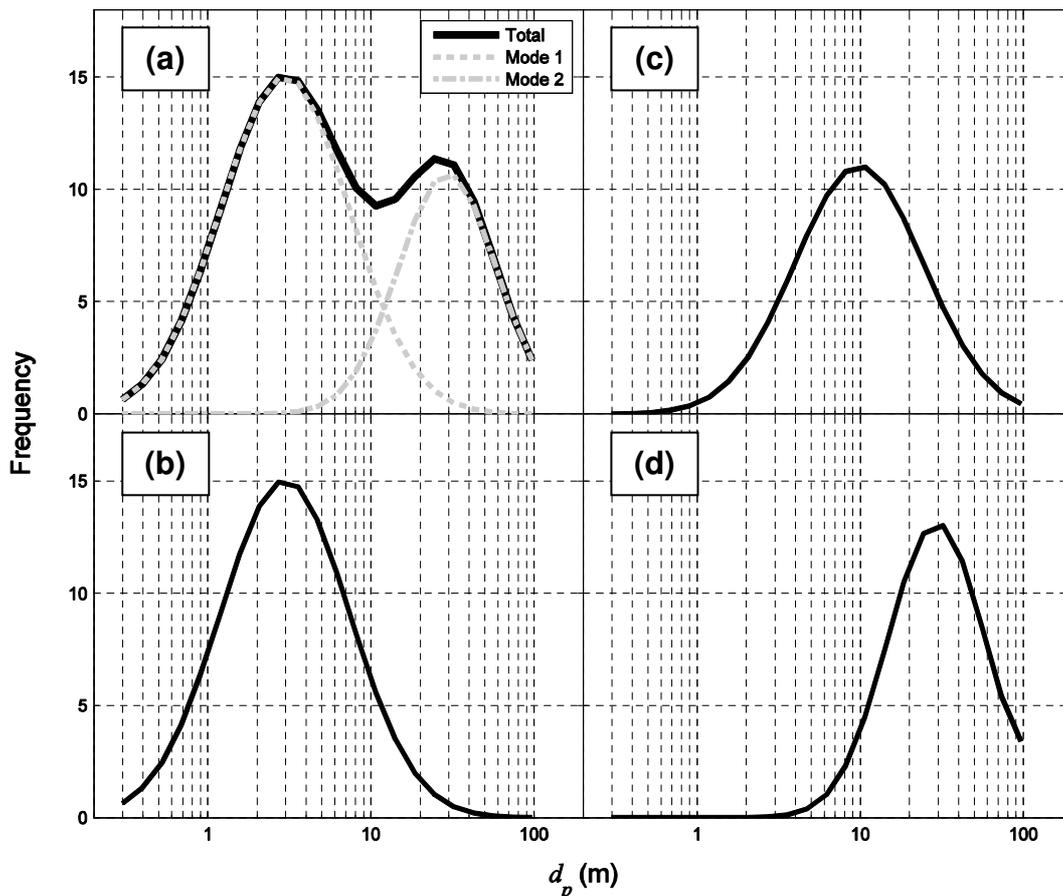
<sup>25</sup> An isotropic material has identical optical properties in all crystallographic directions.

### Case study: Dust source identification through chemical and physical analysis

Dust samples collected on four Frisbee dust deposit gauge adjacent to a quarry were analysed by using Scanning Electron Microscopy with Energy Dispersive X-ray Spectrometry (SEM/EDS). Full characterisation of the samples used approximately 100 individual particles to determine particle type, size and relative frequency. This methodology allowed discrimination between different types of dust particles allowing apportionment of likely sources (Merefield et al., 1999).

Examination of a reference sample of material sampled in the quarry should the presence of calcium silicate particles. SEM/EDX analysis revealed the presence of two distinct particle types (or “modes”) as shown in Figure 9.19(a). The first mode was characterised by particles of ~3 µm in diameter, the second mode by particles of ~30 µm. The calcium silicate particles collected using a Frisbee dust gauge in sample 1, as shown in Figure 9.19(b), showed the presence of a mode at ~3 µm. Given the chemical and physical similarity of these particles to the reference sample it was thought that it was highly probably that these particles originated from the quarry. Similarly the calcium silicate particles collected using a Frisbee dust gauge in sample 2, as shown in Figure 9.19(c), showed the presence of a mode at ~30 µm. It was highly likely that these particles had originated from the quarry. The calcium silicate particles collected using a Frisbee dust gauge in sample 3, as shown in Figure 9.19(d), showed the presence of a mode at ~10 µm. Though chemically similar it was concluded that these particles had not originated from the quarry, rather another uncharacterised source.

Figure 9.19 Particle type and size distribution plots of calcium silicate in (a) reference sample taken in the quarry, (b) Frisbee dust gauge sample 1, (c) Frisbee dust gauge sample 2, and (d) Frisbee dust gauge sample 3.

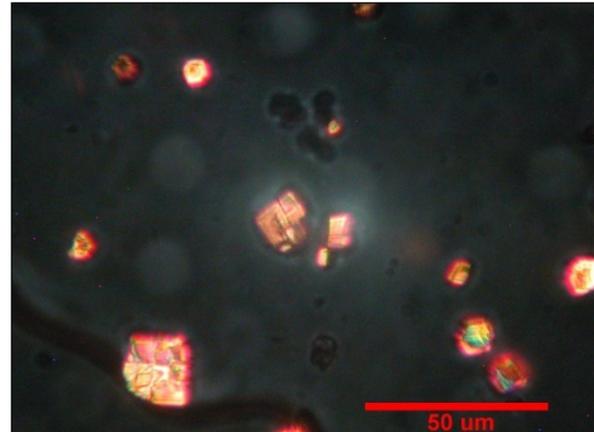


Combined chemical and physical analysis can provide a powerful tool for source apportionment providing accurate source identification of dust particles.

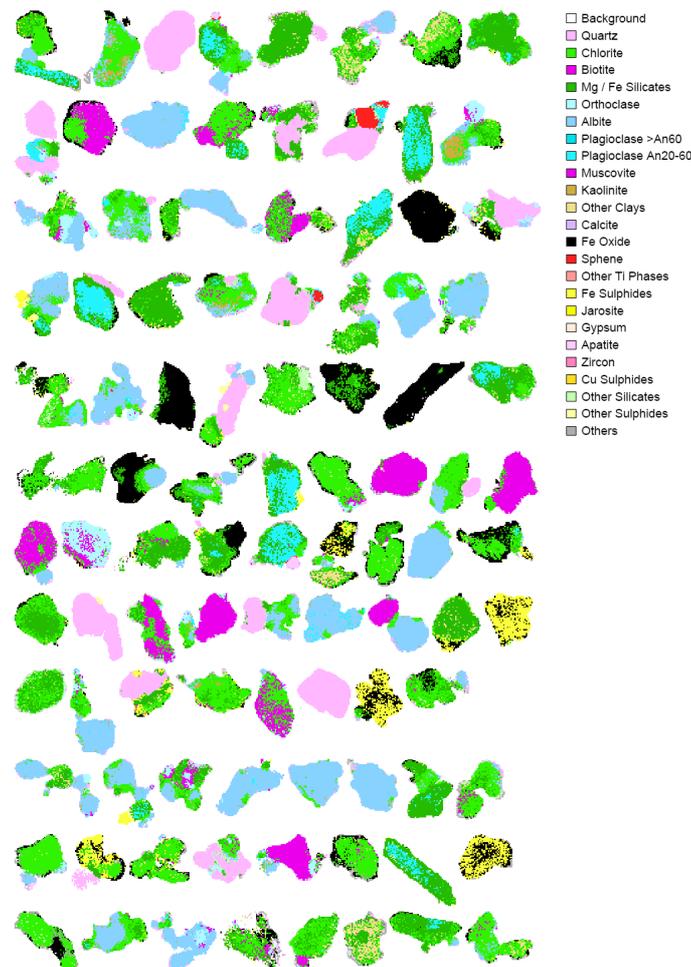
**Figure 9.20** Light microscope image of pollen and calcite particles at high (400x) magnification taken under plane-polarising light (PPL) (image courtesy of Hanson Aggregate).



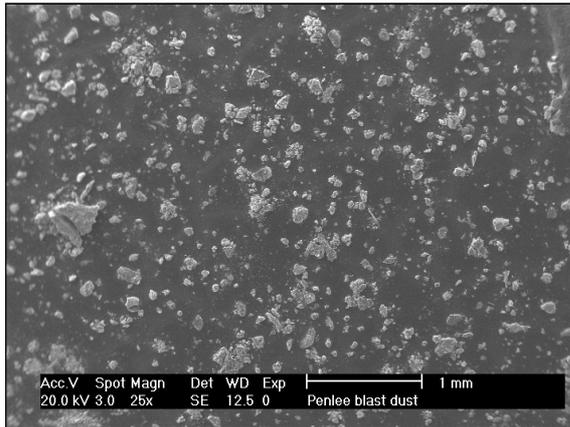
**Figure 9.21** The same image as shown in Figure 9.22 but under cross-polarising light (XPL) (image courtesy of Hanson Aggregate).



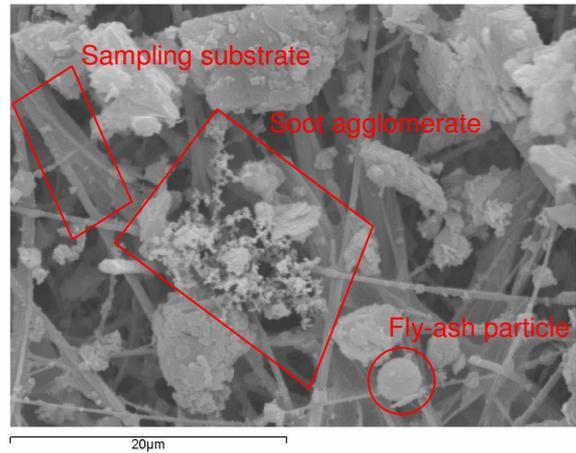
**Figure 9.22** Quantitative Evaluation of Minerals by Scanning electron microscopy (QEMScan, SEM-EDX) micrograph of dolerite particles collected on a sticky pad directional dust sampler (micrograph courtesy of the University of Exeter in Cornwall/Hugh Datson, DustScan Ltd.).



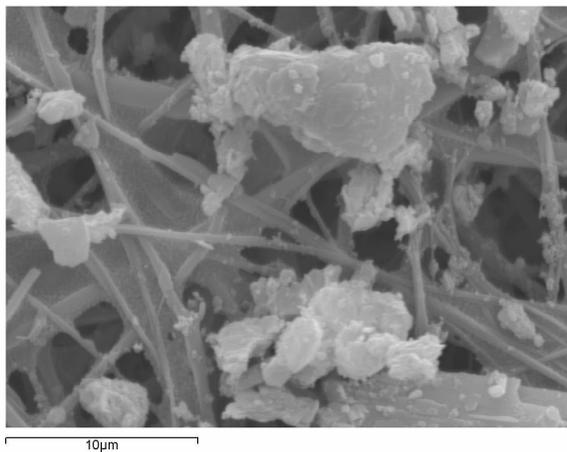
**Figure 9.23** SEM micrograph of dolerite collected on a sticky pad directional dust sampler (micrograph courtesy of the University of Leeds/Hugh Datson, DustScan Ltd.).



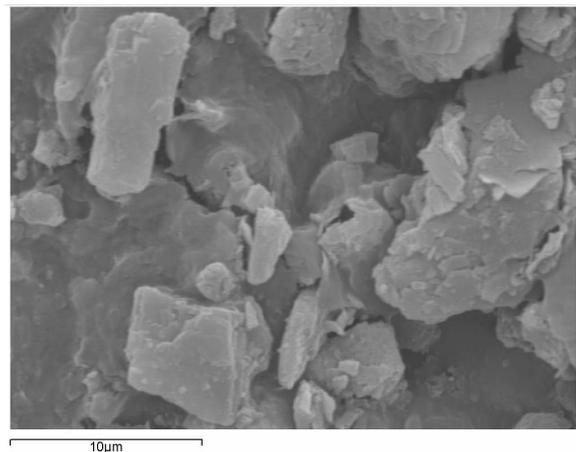
**Figure 9.24** An SEM micrograph of PM<sub>10</sub> particles collected adjacent to a granite quarry. The micrograph shows angular mineral particles including feldspar, quartz and hornblende. The micrograph also shows a soot agglomerate and spherical fly-ash particles on a filter substrate (micrograph courtesy of Ian Stone, Advance Environmental).



**Figure 9.25** An SEM micrograph of PM<sub>10</sub> particles collected adjacent to a granite quarry. The micrograph shows angular mineral particles including feldspar, quartz and hornblende (micrograph courtesy of Ian Stone, Advance Environmental)



**Figure 9.26** An SEM micrograph of dust particles collected using a Frisbee-type gauge adjacent to a granite quarry. The micrograph shows angular mineral particles including feldspar, quartz and hornblende and clay (micrograph courtesy of Ian Stone, Advance Environmental)



## 9.7 Reviewing and reporting

Periodic reviewing and reporting the results of monitoring programmes and any particle characterisation studies is the final stage in monitoring and the DMP. Assessing the effectiveness of the control, management and measurement methods employed to limit and measure dust emissions from extractive activities is an important process.

Reviewing and reporting allows corrective actions to be identified (if not already done so) and incorporated into the DMP, where implemented. The review and reporting exercise should be undertaken by the person responsible for the determining the aims of monitoring programme and/or DMP, though this will be dependent on company size and structure.

Section 2.1.6 outlines the information that should be included when undertaking periodic reviewing and reporting the results of monitoring programme and any particle characterisation studies.

## 9.8 Chapter 9 Summary

The monitoring strategy adopted on a site must be designed to address the needs of that site. Monitoring may be required for a new quarry, an existing quarry or an existing operation seeking extension. In order to obtain useful dust or PM<sub>10</sub> monitoring data, the measurements made must be representative of the study area of interest. Monitoring sites should be located:

- At sensitive receptors (as outlined in Table 3.3) in the case of nuisance dust.
- At a point in-between the source and receptor when measuring dust flux.
- Where there is likely to be human exposure in the case of PM<sub>10</sub>.

This may not be practical in all situations as monitoring equipment should be situated in a safe and secure location.

The cost of monitoring and instrumentation should be balanced against the perceived risk. This will enable both the site operator and the regulator to be confident that site dust thresholds will be appropriate for both the site and its surroundings. The cost of dust or PM<sub>10</sub> monitoring will depend on many different factors, including location, number of monitoring sites and the duration of the programme. The method used for dust or PM<sub>10</sub> monitoring should be proportional to the perceived risk.

Due to the variable nature of dust (e.g., source type and magnitude, and, particle size, shape, and composition) it can be measured in a number of ways. The principle approaches to dust monitoring are:

- Visual monitoring via simple observation of dust deposition onto a surface and dispersion on and off-site.
- Dust deposition
  - Surface soiling: discolouration (obscuration) of a surface caused by the accumulation of dust on a surface (such as glass microscope slide or sticky pad) due to the deposition of dust.
  - Dust mass: typically measured using a passive deposition gauge which appears similar to an inverted Frisbee.
- Dust flux is the measurement of the horizontal transport of dust. It can be measured as mass (using a quadruple, also known as BS 1747 Part 5 or CERL, collector) or with different types of cylindrical adhesive (sticky pad) dust sampler.

Dust deposition measurements and dust flux measurements are not inter-changeable. Nor is it necessarily possible to accurately determine the equivalent mass deposited on one deposition gauge type, based on measurements made with another type, as different deposition samplers have different dust collection efficiencies. Whichever dust monitoring method is used, it is essential that it is used in

accordance with the supplier's recommendations and the appropriate assessment criteria are applied to the data.

PM<sub>10</sub> and dust deposition and dust flux measurements are not inter-changeable. PM<sub>10</sub> monitoring can be undertaken using a range of samplers, such as:

- Tapered Element Oscillating Micro-balance (TEOM),
- Filter Dynamics Measurement System (FDMS),
- $\beta$ -attenuation gauge,
- Partisol gravimetric sampler,
- Weekly gravimetric DustScan DS500 PM<sub>10</sub> weekly gravimetric sampler, and
- Optical particle counters, e.g., Grimm Model 1.100 series, MetOne Esample, Turnkey Osiris and TSI Model 8535 DustTrak II.

The FDMS and Partisol are considered to provide PM<sub>10</sub> gravimetrically equivalent measurements (conforming to BS EN 12341) whilst PM<sub>10</sub> measurements made using other instruments tend to require application of a suitable correction factor to provide the gravimetric equivalent PM<sub>10</sub> mass concentration.

Directional sampling may need to be undertaken to accurately determine the origin of dust or PM<sub>10</sub>. It provides improved source identification of dust and PM<sub>10</sub> but at a much reduced cost when compared to chemical or physical characterisation.

Chemical and physical characterisation of dust and PM<sub>10</sub> can provide more exact source apportionment when compared to directional sampling. Dust and PM<sub>10</sub> particles can be characterised using a range of geo-chemical techniques:

- Chemical characterisation
  - Ion Chromatography (IC),
  - Atomic Absorption Spectroscopy (AAS),
  - Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), and
  - X-ray techniques.
- Physical characterisation
  - Optical microscopy, and
  - Electron microscopy, principally Scanning Electron Microscopy (SEM).

If chemical and physical characterisation is undertaken it is important that all sources of contamination and physical degradation must be minimised during all aspects of sample handling, including collection, transport, storage, and analysis in order to provide reliable characterisation. Unused samples should be labelled, archived, and stored appropriately to allow characterisation at a later date.

## References

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# **Appendices**

**Appendix 1: Gaussian atmospheric pollution dispersion models**

**Appendix 2: Toolbox talk: raising dust awareness**

**Appendix 3: Consultation**

# Appendix 1

## Gaussian atmospheric pollution dispersion models

Gaussian models are the most common mathematical models used for predicting the dispersion of atmospheric pollutants, including dust. They are based on the assumption that the pollutant will disperse according to the normal statistical distribution.

The generalised version of the Gaussian equation used for point-source emissions is:

$$\chi = \frac{1}{2\pi u_s \sigma_y \sigma_z} e^{-(y^2)/2\sigma_y^2} \bullet e^{-(H^2)/2\sigma_z^2}$$

where:

$\chi$	=	hourly concentration at downwind distance $x$ ,
$Q$	=	pollutant emission rate ( $\text{kg m}^{-3}$ ),
$u_s$	=	mean wind speed at release height ( $\text{m s}^{-1}$ ),
$\sigma_y, \sigma_z$	=	standard deviation of the lateral and vertical concentration distribution (dimensionless),
$y$	=	crosswind distance from source to receptor (m), and
$H$	=	emission source height.

The terms  $\sigma_y$  and  $\sigma_z$  are the standard deviation of the horizontal and vertical Gaussian distributions that are used to represent the plume of the pollutant. These coefficients are based on the atmospheric stability and generally become larger as the distance downwind from the source becomes greater (i.e., the plume disperses). Hence the values of  $\sigma_y$  and  $\sigma_z$  become larger to represent a plume with a low peak but wide spread.

When using this equation for calculation of pollutant dispersion, there are some assumptions that must be made in order for the equation to be valid: (1) the emissions must be constant and uniform, (2) the wind direction and speed are constant, (3) downwind diffusion is negligible compared to vertical and crosswind diffusion, (4) the terrain is relatively flat, i.e., no crosswind barriers, (5) there is no deposition or absorption of the pollutant, (6) the vertical and crosswind diffusion of the pollutant follow a Gaussian distribution, (7) the shape of the plume can be represented by an expanding cone, and (8) the use of the horizontal and vertical standard deviations,  $\sigma_y$  and  $\sigma_z$ , requires the turbulence of the plume to be homogeneous throughout the entire plume.

Gaussian atmospheric pollution dispersion models only provide information on the mass concentration of a pollutant at  $x$  metres from the source. Information on the particle size distribution (in terms of particle number, volume) can be provided by the application of an aerosol dynamics model to the resultant output.

# Appendix 2

## Toolbox talk: raising dust awareness

The slides below provide an outline of the material that can be provided as part of a toolbox talk to site staff and are based on a presentation currently used within the industry. The aim of the talk is to raise awareness of the issues surrounding nuisance dust and PM<sub>10</sub> arising from the extractive industries. The issues briefly covered include:

- Definition of dust
- Dispersion distances of dust particles
- Sources
- Extent of dust problems
- Dust impacts
- Control measures
- Monitoring
- The concept of the dust management plan

This presentation can be adapted and further information can be added, as required, from the material presented in this document or to inform staff of particular site-specific issues.

## Slide 1

# DUST AWARENESS

## Toolbox Talk

1

## Slide 2

### Dust – what is it?

- Dust is defined by BS 6069 as particulate matter less than 75  $\mu\text{m}$  in diameter (1  $\mu\text{m}$  = a micron = one millionth of a metre, and is the size of a very fine silt particle)
- Particles <1  $\mu\text{m}$  are broadly associated with combustion, e.g., smoke
- Particles <10  $\mu\text{m}$  in diameter ( $\text{PM}_{10}$ ) are respirable
- Particles in the range above 10  $\mu\text{m}$  are associated with the public perception of nuisance
- The process by which dust becomes airborne is referred to as 'dust emission'. This requires energy to overcome gravitational and cohesive forces binding dust particles to the surface (occurs at wind speeds >10 mph = 5 m s<sup>-1</sup>)

2

## Slide 3

### Dust and quarrying

**Dust generation is an inevitable consequence of mineral working, is readily perceived and is becoming increasingly objectionable**

- Smaller particles (<10  $\mu\text{m}$ ) remain airborne for longer but account for a small proportion of dust particles. They deposit slowly and can disperse over a wide area
- Can affect residents up to 1 km from their source
- Intermediate particles (10-30  $\mu\text{m}$ ) can travel between 200-500 m from their source
- Larger particles (30+  $\mu\text{m}$ ), which make up the greatest proportion of dust, can usually travel up to 100 m from their source
- Complaints are most likely generally within 100-200 m of the source

3

## Slide 4

### Sources

- Process operations
- Haulage (on and off road)
- Ancillary 'manufacturing' operations within quarries (e.g., batching plants, concrete plants, asphalt plants etc)
- Wind blown dust from paved areas, stockpiles, exposed faces etc
- Surface stripping and handling and storage of overburden

4

## Slide 5

### Extent of dust problems

- Type of material (coal – black)  
(sand/cement – white/brown)
- Scale of operations
- Length of operation
- Process activities on site
- Climate/meteorology (rainfall/wind speed/wind direction)
- Topography (surface features, e.g., hills, trees)

5

## Slide 6

### Dust impacts (1)

#### Nuisance dust

- Often down to individual perception
- Variation in usual background dust levels
- Deposition on a surface which is normally free from dust
- Contrast in colour between deposited dust and the surface
- Amount of deposited dust
- Adverse publicity influencing the observer

6

## Slide 7

### Dust impacts (2)

#### Health effects

- Monitoring results have shown that there are limited adverse impacts on the air quality in the area surrounding quarries
- Increases in PM<sub>10</sub> concentrations around quarries and mines have been noted, but exceedences of the national, statutory Air Quality Objectives for PM<sub>10</sub> are extremely rare
- No published cases of adverse health effects on residents living near to quarries

7

## Slide 8

### Control measures

#### Passive/planning:

- Placing dust generating activities where maximum protection can be obtained from topography, woodland etc
- Tree planting
- Screening, landscaping
- Overburden removal kept to a minimum, spray exposed surfaces (chemical binders)
- Restrict vehicle speeds
- Surfaced roads

#### Active/responsive:

- Use of sprays, mists
- Water bowsers
- Road sweepers
- Sheeting vehicles
- Temporary suspend activities in dry, high wind conditions

8

## Slide 9

### Monitoring examples

- Directional dust gauge
- Depositional (Frisbee) dust gauge (concentrations >200 mg m<sup>-3</sup> day<sup>-1</sup> may possibly lead to complaints)
- PM<sub>10</sub> monitoring (Air Quality Objectives for PM<sub>10</sub>):
  - daily (mean) limit value of 50 µg m<sup>-3</sup>, not to be exceeded more than 35 times per year, and
  - an annual (mean) limit value 40 µg m<sup>-3</sup>)
- Weather station
- Windsock: wind speed and direction
- Visual assessment

9

## Slide 10

### Dust action plan (1)

Seen by regulatory authorities as a positive, proactive approach to controlling dust to acceptable levels

- **Planning** (requirement to demonstrate the site's intention to engage in active dust mitigation, and to demonstrate to the LA that management procedures and monitoring equipment in place)
- **Good Environmental Practice** (ISO 14001)
- **Community relations** (effective response to complaints/issues)

#### What is it?

Site specific document that brings together all aspects of dust control measures/management

- Identifies individual areas/processes where dust could be an issue with the control measures and actions requires
- Defines management/operator responsibilities
- Contains dust control flow sheet (step by step procedure)

10

## Slide 11

### Dust action plan (2)

**Emphasises that effective dust control depends on the involvement of all site personnel**

Thereby minimising impact on local residents and the environment and minimising the possibility of enforcement action by LA and complaints from local residents

- **Highlights the need to**
  - Be vigilant at all times
  - Adhere to operating procedures
  - Report dust issues
  - Suggest dust control improvements

11

## Slide 12

**ANY QUESTIONS?**

12

# Appendix 3

## Consultation

**The following organisations were consulted during the preparation of this document.**

British Aggregates Association (BAA)

Minerals Products Association (MPA)

Silica and Moulding Sands Association (SAMSA)

The Chartered Institute of Environmental Health (CIEH)

Planning Officers Society (POS)

Derbyshire Dales District Council

Suffolk County Council

Teignbridge District Council

University of Exeter

University of Leeds

University of Nottingham

Aggregate Industries (AI)

Advance Environmental

DustScan Ltd.

CEMEX

Hanson

Johnsons Wellfield Quarries Ltd.

Sherburn Stone Co. Ltd.

Smith & Sons (Bletchington) Ltd.

Sibelco UK

Tarmac Ltd.

UK Coal



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