A critical evaluation of the challenges facing dust management within gold mining regions of South Africa

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ABSTRACT

Windblown dust remains a persistent problem within South African urban and peri-urban areas due to the prevailing dry climatic conditions, extensive surface mining and mineral processing. Despite deposition monitoring guidelines and national dust regulations, South Africa still has persistent dust problems in especially gold mining districts.

The main aim of the research is to critically evaluate all the potential challenges within dust management which could be responsible for persistent dust problems within gold mining regions of South Africa. The research methodology included a literature review to provide important information regarding the requirements for successful dust management internationally. Data were gathered by using the survey method through questionnaires and interviews as this type of survey method allows for descriptive reporting where respondents provide information on their attitudes and perceptions.

In total 37 questionnaires were distributed among two district municipalities, seven gold mining companies, ten interested and affected parties including two non-governmental organizations, as well as five specialists. A total response rate of 81.1 % was achieved. The results of the questionnaires revealed that the most significant challenges to dust management within gold mining regions of South Africa are the following: monitoring networks; monitoring methods; deposition standards; financial provisions; technical skills and capacity; lack of specific dust management plans within air quality management plans; limited regulation and enforcement; limited information and participation of government, lack of participation of interested and affected parties as well as specialists' expertise. All the challenges identified were then successfully linked back to the referenced literature from which the challenges were initially derived. The main aim of this research was thus successfully completed by initially identifying the challenges facing dust management within gold mining regions of South Africa and then critically evaluating them and making recommendations.

Key words: Dust, climatic conditions, gold mining, deposition, monitoring, deposition standards, dust problems, dust management.

Opsomming

Windgedrewe stof is ‘n deurlopende probleem in Suid-Afrika se stedelike en buitestedelike gebiede as gevolg van die huidige droë klimaatstoestande, omvattende mynbedrywighede en die bewerking van minerale. Ten spyte van neerslag-moniteringsriglyne en nasionale goudstofregulasies, het Suid-Afrika steeds hardnekkige stofprobleme in veral goudmyndistrikte.

Die hoofdoel van hierdie navorsing was om ‘n kritiese evaluering te doen van al die potensiële uitdagings wat te doen het met stofbestuur in goudmynstreke in Suid-Afrika. Die navorsingsmetodologie wat gevolg is, het ‘n literatuuroorsig ingesluit om belangrike inligting te verskaf oor die vereistes onderliggend aan suksesvolle stofbestuur internasionaal. Data is versamel deur ‘n opname-metode te gebruik wat vraelyste en onderhoude behels het. Hierdie metode maak beskrywende verslagdoening moontlik waar respondente inligtingverskaf oor hulle houdinge en persepsies.

In totaal is 37 vraelyste uitgestuur aan twee distriksmunisipaliteite, sewe goudmyn-maatskappye, tien belanghebbende en betrokke partye wat twee nie-regeringsorganisasies ingesluit het, sowel as vyf spesialiste. ‘n Totale reaksiekoers van 81.1% is verkry.Die resultate van die vraelyste het aangetoon dat die grootste uitdagings vir stofbestuur in goudmynstreke in Suid-Afrika te vind is in: moniteringsnetwerke, moniteringsmetodes, neerslagstandaarde, finansiële voorsiening, tegniese vaardighede en kapasiteit, gebrek aan spesifieke stofbestuurplanne binne die bestek van die lugkwaliteitplanne, beperkte regulering en afdwinging, beperkte inligting en deelname van die regering, gebrek aan deelname deur belanghebbende en betrokke partye sowel as gebruik van die deskundigheid van kundiges. Al die uitdagings is geïdentifiseer en toe teruggekoppel na die literatuur waaruit die uitdagings aanvanklik afgelei is. Die hoofdoel van die navorsing is dus suksesvol bereik deur ‘n aanvanklike identifisering van die uitdagings waarvoor stofbestuur in goudmynstreke te staan kom, gevolg deur ‘n kritiese evaluering daarvan en aanbevelings daaroor.

Sleutelwoorde: Stof, klimaatstoestande, goudmyn, neerslag, monitering, neerslagstandaarde, uitdagings, stofbestuur.

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DECLARATION

I certify that the report is my own work and all references used are accurately reported and that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification at this or any other university or other institution of higher learning.

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JACOBUS JOHANNES MARTINS

Date:

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V. List of Abbreviations

AIRs- Atmospheric Impact Reports

APPA- Atmospheric Pollution Prevention Act

AQFD- Air Quality Framework Directive

AQMP- Air Quality Management plan

AQR- Air Quality Regulations

AQSR- Air Quality Standards Regulations

AS- Australian Standards

ASTM- American Standard for Testing and Materials

BSI-	**British Standard Institution**
BS-	**British Standard**
DEA-	**Department of Environment Affairs**
DEAT-	**Department of Environmental Affairs and Tourism**
DME-	**Department of Minerals and Energy**
DMP-	**Dust-Management Plan**
DMR-	**Department of Minerals and Resources**
DWAF-	**Department of Water Affairs and Forestry**
EA-	**Environment Act**
EC-	**European Commission**
EIA-	**Environmental Impact Assessment**
EP-	**Environmental Protection**
EPA-	**Environmental Protection Agency**
EPA-	**Environmental Protection Authority**
EMIs-	**Environmental Management Inspectors**
EMP-	**Environmental Management Plan**
EPPs-	**Environmental Protection Policies**
EPR-	**Environmental Permitting Regulations**
EU-	**European Union**
IDP-	**Integrated Development Plan**
IPPC-	**Integrated Pollution Prevention and Control**

ISO-	**International Organization for Standardization**
LAQM-	**Local Air Quality Management**
Ltd-	**Limited**
MEC-	**Member of the Executive Council**
MIRO-	**Mineral Industry Research Organisation**
NAAQS-	**National Ambient Air Quality Standards**
NAQS-	**National Air Quality Strategy**
NEMA-	**National Environmental Management Act**
NEM: AQA-	**National Environmental Management Air Quality Act**
NGO-	**Non-Governmental Organization**
NILU-	**Norsk Institutt for Luftforsking**
NZS-	**New Zealand Standards**
Ph.D-	**Philosophiae Doctor**
PM-	**Particle Matter**
PPC-	**Pollution Prevention and Control**
PPPs-	**Pollution Prevention Plans**
RCEP-	**Royal Commission on Environmental Pollution**
SANS-	**South African National Standard**
SEPs-	**State Environmental Policies**
SP	**Suspended Particulate**
SPCC-	**Spill Prevention, Control and Countermeasure**

SPM- **Suspended Particulate Matter**

TCPA- **Town and Country Planning Act**

TSF- **Tailings Storage Facilities**

TSP- **Total Suspended Particles**

UK- **United Kingdom**

USA- **United States of America**

US-EPA- **United States Environmental Protection Agency**

VDI- **Verein Deutscher Ingenieure**

WHO- World Health Organization

WMO- World Meteorological Organization

CHAPTER 1

Introduction

This chapter deals with the motivation and relevancy of this research from both an international and a South African perspective. The importance of an effective dust-management plan with regards to dust management is also briefly discussed followed by the regionally specific nature of dust within mining regions increasing the potential of the persistency of dust problems in South Africa. This chapter starts by setting out the main problem statement and subsequent research objectives.

1.1 Problem statement

Pollution control strategies and management programmes play a critical role in conforming to regional, national and local regulations that control air quality by setting emissions standards which limit pollutants considered to be harmful to public health and the environment (Haq et al., 2002). Up till now very few countries have recommended national standards or guidelines for deposition (fall-out) dust, meaning that few management practices are in place or enforced by regulators to reduce dust deposition.

There could be many reasons for this which generally includes the following. Firstly, the fact is that most countries only consider dust deposition as a nuisance although it has many environmental impacts as well as human health influences. Secondly, the main factors contributing to dust problems like climate, sources and meteorological conditions are not strong enough in some countries to result in persistent dust problems. South Africa, though, with its vast mineral processing industries and surface waste generation as well as the predominant semi-arid climatic conditions has persistent dust problems. Currently, the only guidance for the management of dust deposition is the SANS 1929 dust-fall guideline and the only standards the ones within the newly-drafted National Dust Control Regulation. This hypothetically should have solved any dust deposition problems South Africa might have had. This, however, is not true and can only be true if the guidelines, regulation standards and dust management plans and programmes in place are adequate.

The main aim of this research is to identify and critically assess the challenges for dust management within gold-mining regions of South Africa. In order to achieve this research aim the following research objectives are addressed:

i. To investigate the sources of regional dust within gold mining regions of South Africa and identify potential challenges relating to the management thereof.

ii. To investigate the dust deposition guidelines, standards and monitoring techniques used within dust management and identify potential challenges.

iii. To investigate the key elements required of a successful dust-management plan and programme in order to identify potential challenges which would restrict the plans or programmes of dust management from solving persistent dust problems.

iv. To test the identified challenges through purposefully designed questionnaires distributed to the district municipalities, gold-mining companies, interested and affected parties and specialists involved with dust management within the identified gold-mining regions of South Africa.

v. To critically evaluate the relevant challenges.

1.2 Motivation for the research from an international perspective

Windblown dust storms are an international phenomenon with escalating health and environmental implications (Ekhtesasi & Sepehr, 2008; Jamalizadeh et al., 2008; Miri et al., 2007; Qian et al., 2004; Saxton et al., 1999 and Wang et al., 2006). Windblown dust originating in the desert regions of Africa, Mongolia, Central Asia and China can affect air quality and the health of populations in remote areas (Confalonieri et al., 2007). Despite deposited (fall-out) dust being one of the main causes of complaints about air pollution, no international recommendations for standards or guidelines currently exist. The reason for this may be that deposited ambient dust is mainly considered important as a source of nuisance (Vallack & Shillito., 1998). The nuisance element of dust as well as various other complications involved in defining a nuisance level for deposited dust has militated against the use of general standards or guidelines for the management of dust. The fact that dust deposition is ad hoc and site-specific also makes it difficult to develop general guidelines or standards for its management (Vallack & Shillito, 1998). However, a need clearly exists for guidelines or standards with a wider relevance.

There is therefore an international need for guidance to manage deposition dust in countries where dust problems are persistent. This has proven to be difficult, as many factors prohibit the development of a general guideline or standard for dust management. These factors include the control and frequency of dust sources as well as local meteorological conditions. Regardless of the specificity of dust and its subsequent management, it should nevertheless be possible to determine minimum requirements as guidance for the general improvement of dust-related problems. There is therefore a need for an investigation into international guidance for dust management which will provide the key or minimum elements required in order to improve dust management. This will not only assist this research in accomplishing its main objectives but give guidance to a wider audience.

1.3 Motivation for the research from a South African perspective

Deserts, arid and semi-arid environments (covering 40% of the world land surface) are perennial sources of aeolian dust (Chen et al., 2004; Cook et al., 2005; Ekhtesasi & Sepehr, 2008; Garrison et al., 2003; Haq et al., 2009; Middleton & Goudie, 2001; Parrington et al., 1983). Windblown dust is often a major nuisance problem faced in South African urban and peri-urban areas due to the prevailing dry climatic conditions, extensive surface mining and mineral processing (Held et al., 1996). Gold-mining waste has been estimated as accounting for 221 million tons or 47 % of all mineral waste produced in South Africa, making it the largest single source of waste and pollution (DWAF, 2001). These mine residues (or waste) usually occupy large areas on the land surface and represent significant sources of dust even if under rehabilitation. Operational gold mines further encompass and operate tailings dams, waste rock dumps and ore stockpiles which are all major sources of dust emissions in areas where they occur, especially during the late winter and early spring months, when wind speeds peak (Annegarn pers. comm., 2008).

Apart from the natural background dust attributed to climatic conditions and the surrounding environment in South Africa, a number of additional sources of dust emissions exist due to mining activities. It can therefore be assumed that South Africa will have an increased risk of dust-related problems. There will therefore also be a great need for guidance in effecting general improvements of dust-related problems in South Africa. An investigation into international guidelines for the management of dust will help this research to establish the adequacy status of dust management in South Africa and help identify the challenges within it as South African conditions are considered favourable for extensive and persistent dust problems. An investigation into the challenges of dust management will not only assist this research in accomplishing its objectives but indicate to South Africa and any other audiences the complexities relevant to dust management in regions where various sources and conditions favour persistent problems.

South Africa is currently one of the few countries to have deposition (fall-out) dust monitoring as guidelines in their environmental legislation for the management of dust deposition. Despite this South Africa still has a persistent dust problem which is assumed to be a direct result of the guidance government gives relating to waste sources and dust. Current legislation in South Africa has led to much confusion with regards to the roles and responsibilities of the Department of Minerals and Energy (DME) now Department of Minerals and Resources (“DMR”) and Department of Environmental Affairs and Tourism (DEAT) (now called the Department of Environmental Affairs “DEA”) with respect to the management of mining waste (Godfrey et al., 2007). Mining waste (single largest source of waste and pollution) is currently only regulated by a compulsory Environmental Management Plan (EMP) of which the DMR is the lead agent (Pulles et al., 2005). This has now changed, as the Minister of Water and Environmental Affairs, Edna Molewa, had given notice of draft National Dust Control Regulations on 27 May 2011 (Government Gazette, 2011). This sets forth regulations enabling Air Quality Officers of DEA to enforce dust-deposition regulations and the conviction of offenders.

Despite the regulation and its deposition standard as well as management guidelines, persistent dust problems in South Africa still exist (Held et al., 1996). The reason for this is that there could potentially be problems with the guideline or regulations themselves which would restrict them from being effective with dust management. These challenges could include the validity of standards and monitoring methods under South African conditions. There is consequently a need to investigate the validity of the dust limitation standard and monitoring method under South African conditions. This research will identify the special requirements for dust management under South African conditions which will be site-specific.

1.4 Motivation for the research from a management perspective

Dust influences many aspects of Earth's biophysical systems and dust deposition has a list of significant environmental effects which are discussed in later chapters. Wind-blown dust also poses a health risk as it acts as a secondary pathway for the inhalation of toxic metals (Combes & Warren, 2005). The deposition of dust hence has a variety of significant impacts and there will always be a need for effectively managing dust deposition in order to reduce or eliminate its impacts. It is also common knowledge that the state of the air quality of a region is usually judged by visibility and aesthetics, to which dust usually contributes significantly (Ministry for the Environment, 2001). The potential impact of dust on the surrounding environment will in the end depend on the adequacy of many factors within dust management including the deposition standard, regulations, monitoring methods as well as the management plan and programme.

As noted in preceding paragraphs very few countries have recommended national standards or guidelines for dust deposition, meaning that few management plans and programmes are in place to reduce dust deposition. This will among other things significantly contribute to the generally poor management of dust at the international level. Currently the only guidance for the management of dust deposition in South Africa is the SANS 1929 dust deposition (fall-out) guideline which does not give specific guidance for action or remediation (Government Notice, 2009).However, the guideline was not intended to give specific guidance for action and remediation as dust management is adhoc and site-specific (Vallack & Shillito, 1998). However, this is a clear indication that there is a need for dust-management guidance in South Africa.

Dust management issues should be formally addressed within a comprehensive Dust Management Plan (DMP). A DMP would generally be structured within an Air Quality Management Plan (AQMP). In countries like the UK and USA air quality has improved since the implementation of AQMP’s (Engelbrecht, 2006). An official DMP will generally form a crucial part of any AQMP. It can therefore be accepted that the same management strategies and policies used within an AQMP will be relevant to a DMP. This research, though, does not intend to develop a DMP or guideline as dust problems are region specific. It is, however, possible from literature to identify the key elements required for a successful AQMP and a general improvement of air quality (Engelbrecht, 2006).

There is currently an international and South African need for an improvement in dust management as described in preceding paragraphs. Based on international success of AQMPs as well as challenges identified within South African AQMPs (Engelbrecht, 2006), this research will determine the key elements required of a successful dust management plan. The research intends to use the identified elements for a successful dust-management plan to test the relevancy of the challenges within dust-management programmes in South Africa. Once the identified elements of dust management in South Africa have been tested, the relevant challenges restricting effective dust management in South Africa can be identified and critically evaluated. This will not only assist this research in accomplishing its main objectives but also give guidance to both industry and government in terms of areas which they can improve in order to ensure effective dust management.

1.5 Motivation for the research from a regional perspective

As previously described the nature of dust deposition is ad hoc and site-specific mostly due to the frequency of dust sources as well as the local meteorological conditions of regions. In 1981 the largest area of land occupied by mine residues in South Africa (10 700 hectares) was within the Gauteng, Mpumalanga, North West and Free State Provinces (Fuggle & Rabie, 1992; Anglo-Gold Ashanti, 2004). The mining industry, which generates 70% of all solid waste and residue, takes up large areas of land mostly in the form of tailings storage facilities (TSF) but also including rock dumps. Gold-mining activities are also mostly concentrated in certain regions of South Africa and as mentioned in Paragraph 1.3 major sources of dust emissions within those regions.

It has also been proved that TSFs are constant contributors to the ambient aerosol loading of surrounding atmosphere (Annegarn et al., 2000; Annegarn, 2006; Blight, 1989; Blight &Smith, 1996; Dolgopolova et al., 2006; Moreno et al., 2007; Wray, 1998). According to the research of Ojelede et al. (2012) on tailings facilities, they contribute more to regional ambient particulate loading than sand. The vast amount and different types of dust sources as well as the favourable climate and meteorological conditions within such a mining district region will result in increased and more intense dust-deposition episodes. All these factors will contribute to a rather complex regional distribution and composition of dust which will make the management of it very difficult. It can therefore be expected that in order to improve dust management in South Africa, regardless of the guidelines, regulation standards or management plans or programmes one needs to address the challenges where dust problems and management are most difficult. This research will therefore investigate the challenges of dust management relevant to the site-specific nature of the sources of dust within gold-mining regions of South Africa.

1.6 Chapter layout

Chapter 1 deals with the relevancy of this research from an international and South African perspective. Most importantly Chapter 1 introduces the research aim and objectives which guide the rest of the chapters. Chapter 2 provides a detailed characterization of deposited dust, it sources, health and environmental impacts as well as frameworks, guidelines and standards necessary to manage it. Chapter 2 completes objectives i. to iii by gathering and comparing the necessary information needed for identification of dust-management challenges within the gold-mining regions of South Africa. Chapter 3 describes the methodology followed for the research which relied mainly on questionnaires used to test and critically evaluate the challenges for dust management within gold-mining regions of South Africa. Chapter 4 presents the resulting data of the questionnaires as well as the identification and critical evaluation of the relevant challenges. Chapter 5describes the research results in relation to the overall research aim and the specific research objectives described in the previous section. It concludes by highlighting areas of future research.

CHAPTER 2

Characterization and management of dust

This chapter initially deals with the importance of deposition dust management by characterising deposition dust as an important atmospheric pollutant and discussing its sources and various impacts on human health and the environment. The legal frameworks, guidelines, standards and dust deposition monitoring techniques necessary for the effective management of dust deposition globally are addressed through a comprehensive literature survey including the NEM: AQA requirements of South Africa. This chapter subsequently focuses on and discusses the nature of dust specific to a prevalent mining District/region in South Africa in order to access and identify all potential challenges contributing to the difficulties in the management thereof. This chapter then continues to identify the possible challenges facing dust deposition management in South Africa by analysing the capacity of the management strategies and systems in place. All the identified challenges within this chapter are then used within the context of the research methodology of the next chapter.

2. Characterisation and management of dust internationally

In order to fully appreciate the need for proper control and management of dust deposition globally, we first need to understand the importance of dust as an atmospheric pollutant as well as its impacts and sources globally. The quickest way to do this is by characterizing dust as an atmospheric pollutant and the management thereof.

2.1 Characterization of deposited dust

In order to characterize dust as an atmospheric pollutant we need to classify deposited dust and/or nuisance dust according to size, emission factors, main sources, as well as its most significant impacts on human health and the environment. The following paragraphs will address all these factors.

2.1.1 Classification of dust as atmospheric pollutant

2.1.1.1 Size classification

Deposition or nuisance dust forms part of SPM within the atmosphere. The World Meteorological Organization (WMO) defines Suspended Particulate Matter (SPM) as particulate matter suspended in air which includes: Total Suspended Particles (TSP), Particle Matter (PM_{10}), $PM_{2.5}$, fine and ultrafine particles, diesel exhaust, coal fly-ash, mineral dusts (e.g. coal, asbestos, limestone, cement), metal dusts and fumes (e.g. zinc, copper, iron, lead), acid mists (e.g. sulphuric acid), fluoride particles, paint pigments, pesticide mists, carbon black, oil smoke and many others (The World Health Organization (WHO), 2000). Vallack and Shillito, 1998, describe deposited particles (dust) as a nuisance due to its size fraction which is generally around aerodynamic diameters > 10-20 µm (Vallack & Shillito, 1998). The EPA classifies particles ranging from 0.1 to 30 µm in diameter size as TSP which refers to the fraction of particles relevant to deposition. TSP does, however, include a broad range of particle sizes including fine, coarse, and super coarse particles as seen in Fig.2.1 (EPA, 2012). This will additionally include particle sizes from 30 µm to beyond 100 µm (Fig. 2.1). It is thus clear from the preceding statements that nuisance or deposition dust in fact includes all size fractions of SPM ranging from 0.1 µm to beyond 100 µm as described for TSP. This presents a problem as the size classification is not only relevant to the standards to be regulated but also specific to the monitoring techniques to be used. This becomes clear as the EPA's TSP was the basis for the previous primary NAAQS for PM and is still the basis of the secondary standard. However, for TSP, as measured by the standard high-volume ("hi-vol.") air sampler, an effective cut-off point of 30 µm aerodynamic diameter is frequently assigned to the standard high volume sampler (EPA, 1998).This in fact means that although TSP includes the sampling of particles ranging from < 10 µm to 100 µm, only particles up to 30 µm will in fact be effectively monitored with the EPA prescribed high-volume sampler. The current EPA standard for TSP therefore only applies to particles up to 30 µm. We can thus assume that the standards of dust deposition which will include the smaller size fractions will only apply to particles larger than 30 µm for which the EPA does not have a regulation standard or method. It can also be assumed that the fraction > 30 µm will in reality be the nuisance or deposited (fall-out) dust fraction. However, no clear guidance is given in literature with reference to the size fraction to what nuisance dust or deposition dust actually is. The only indication regarding size when it comes to nuisance dust is that it is not respirable. For this reason this study will refer to deposition dust or nuisance dust as suspended particles (SP) > 10 µm.

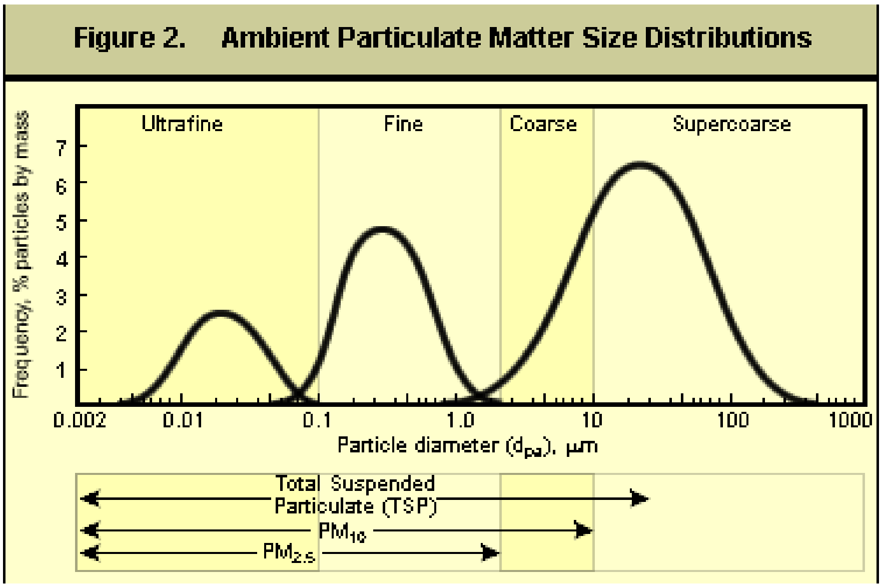

Figure 2.1*: Ambient particulate matter size distribution (EPA, 2012)*

Although Figure 2.1 represents the average frequency and percentage distribution of particulate matter of an urban environment it is clear that deposition dust accounts for a large portion of particulate matter in any geographical region. The portion of particulate matter will increase for semi-arid to arid regions.

2.1.1.2 Emission factors

Following ejection or liberation from surfaces, dust particles are susceptible to turbulent fluctuations and thus usually enter the atmosphere in the short-term (for particulate sizes between 20 - 70 µm in diameter) or the long-term (for particulate sizes smaller than 20 µm in diameter) suspension. The transport of soil or mineral particles by wind can thus be crudely separated into several physical regimes: long-term suspension (< ~20 µm diameter), short-term suspension (~20 – 70 µm), saltation (~70 – 500 µm), and reptation and creep (> ~500 µm) (Kok et al., 2012). Nuisance or deposited dust consists mainly of coarse mineral or dust particulates and usually enters the atmosphere for short-term suspension and thus has relatively short travel distances. Gomitz states that mineral particles with median dust particle radii around 30-50 µm can usually be found close to the source regions (Gomitz, 2009). Large dust particles that usually settle near the source often create a local nuisance problem (EPA, 1998). The impact of a fugitive dust source on air pollution depends on the quantity and drift potential of the dust particles injected into the atmosphere. The potential drift distance of particles is governed by the initial injection height of the particle, the terminal settling velocity of the particle, and the degree of atmospheric turbulence. Theoretical drift distance, as a function of particle diameter and mean wind speed, has been computed for fugitive dust emissions. Results indicate that, for a typical mean wind speed of 16 km/hr (10 mph), particles larger than about 100 μm are likely to settle within 6 to 9 metres (20 to 30 feet [ft]) from the point of emission. Particles that are in the 30 to 100 μm diameter range are likely to undergo impeded settling. These particles, depending on the extent of atmospheric turbulence, are likely to settle within a few hundred feet from the source (EPA, 1998).

2.1.2 Main sources of dust

Local particulate matter emissions near industrial sources mostly comprise primary particulate matter composed of carbonaceous materials, metals and soil constituents (The Ontario Ministry of the Environment, 1999). Deposition dust or nuisance dust is classified as a primary particulate material. Primary particulate material is defined by Pöschl as material which can either be emitted as liquids or solids from natural sources: biogenic materials (pollens, spores, micro-organisms, insects and needle-shaped particles), volcanic eruptions, biomass burning, sea salt, mineral dust and soil or anthropogenic sources: incomplete combustion of fossil/biofuel, wind-driven or traffic-related suspension of roads (Pöschl, 2005). Industry, especially those industries involving the mining of minerals , is responsible for anthropogenic aerosols emitted directly into the atmosphere(Brimblecombe, 1996) in the form of primary particulate material as large mineral dust aerosols (coarse mode). Concentrations of dust in air are also highly variable and very high levels can occur naturally in some areas due to wind-blown dust from arid soils. Human activities, such as fires, overgrazing, agricultural practices and mining, can increase dust concentrations in air in remote areas. The source strength of dust emissions can vary on a daily, weekly or seasonal basis (MIRO, 2011). Nuisance dust can usually arise from a wide variety of anthropogenic sources, including the following:

- wind-blown dust from exposed surfaces such as bare land and construction sites;

- wind-blown dust from stockpiles of dusty materials such as sawdust, coal, fertiliser, sand and other minerals;
- dust caused by vehicle movements on sealed or unsealed roads;
- agriculture and forestry activities;
- mines and quarries;
- road works and road construction;
- housing developments; and
- municipal landfills and other waste handling facilities; dry abrasive blasting; numerous industrial operations, including grain drying and storage, timber mills, stonemasons, mineral processing, cement handling and batching, and fertiliser storage and processing (Ministry for the Environment, 2001).

Large quantities of dust can also be generated from natural sources, such as dry river beds, pollen from plants and volcanic eruptions (Ministry for the Environment, 2001).

In the past few decades process-based research on dust entrainment, transport, deposition, and accumulation has indicated that the potential for aeolian entrainment and suspension of fine-textured sediment is enhanced by low moisture availability and sparse vegetation cover (Goudie & Middleton, 2006).

2.1.3 Impacts on human health

A large number of epidemiological studies have been conducted globally over the last two decades and associations between ambient particulate matter and excesses in daily mortality and morbidity were observed (Dockery et al., 1992; Touloumi et al., 1994; Lighty et al., 2000). The potential health effects of dust are closely related to particle size. Human health effects of airborne dust are mainly associated with particles less than about 10 µm in size (PM_{10}), while nuisance effects are caused by particles of any size, especially those larger than 20 µm. Wind-blown dust does pose a health risk as it acts as a secondary pathway for the ingestion of toxic metals (Combes & Warren, 2005). Many forms of dust are considered to be biologically inert, and hence the primary effects on people relate to our sense of aesthetics. Airborne dust can have effects on visibility, although visibility effects from dust are usually only a concern in the immediate vicinity of a specific source (Ministry for the Environment, 2001). Dust may have minor health effects, such as eye irritations when the dust is airborne. Indirect stress-related health effects could also arise, especially if dust problems are allowed to persist for an unreasonable length of time (Ministry for the Environment, 2001). Some nuisance dust may have the potential to cause other types of health effects because of the presence of specific biologically active materials. Loss of visibility due to dust is also a safety concern to human health under extreme conditions, especially for road traffic or aircraft. Suspended particulate pollutants provoke respiratory diseases, and can cause cancers, corrosion, destruction to plant life, etc. (Ministry for the Environment, 2001).

2.1.4 Impacts on the environment

Dust may affect ocean productivity (Blain, et al., 2007; Kawahata et al., 2000), control terrestrial nutrient cycling (Chadwick et al., 1999) and alter regional and global climate (Tegen et al., 1996; Yoshioka et al., 2005).This particulate matter also interferes with sunlight (e.g. light scattering from smog and haze) and acts as catalytic surfaces for reaction of adsorbed chemicals (WHO, 2000). In addition to the impact of aerosols/particulate matter on human health, climate, atmospheric chemistry and visibility, atmospheric particles may have significant effects on ecosystems and the soiling of buildings. Deposition of acidic pollutants (e.g., acid rain, nitrate and sulphate aerosols) damages forests and aquatic ecosystems (e.g., lakes) and also affects agriculture as a consequence of soil acidification (Baker et al., 2003). However, the most common areas of concern from public regarding nuisance dust will include: the visual soiling of clean surfaces, such as cars, window ledges, and household washing; dust deposits on flowers, fruit or vegetables; and the potential for contamination of roof-collected water supplies. Dust deposits inside the house are often the impact of greatest concern in residential areas, followed by soiling of the outside of the house and the effects on paintwork. Dusty conditions can also affect people’s ability to enjoy their outdoor environment, making activities such as barbecues and sports events unpleasant and unappealing. For most people, a major effect of a dust nuisance problem is annoyance at the increased requirement for cleaning (Ministry for the Environment, 2001). Conversely, this can also involve a financial aspect, through the increased use of cleaning materials, water, and possibly paid labour. It was estimated that the cost differential for maintaining a house in an area of heavy dust deposition compared with a less polluted area of the Hunter Valley, New South Wales, was $90 per annum. An equivalent figure in today’s terms could be about $500–$1000, which is significant (Narayanan & Lancaster, 1973).

Dust deposits can have significant effects on plant life mainly at high dust loadings, which can include:

- reduced photosynthesis due to reduced light penetration through the leaves. This can cause 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 incidences of plant pests and diseases. Dust deposits can act as a medium for the growth of fungal diseases. In addition, it appears that sucking and chewing insects are not affected by dust deposits to any great extent, whereas their natural predators are affected
- reduced effectiveness of pesticide sprays due to reduced penetration; rejection and downgrading of produce. Once again, this is a particular issue for horticultural crops.

The detailed effects of dust on plants were given in a report by the Agricultural Engineering Institute (McCrea, 1984). This report gives estimates of the potential losses in crop productivity for various rates of dust deposition. The main focus of the report is on horticultural crops grown alongside unsealed roads, and in this case the losses were shown to be significant within about 200 metres of the source. The effects of dusts on the agriculture and ecology of an area are determined by the concentration of dust particles in the ambient air, their size distribution, the deposition rate as well as the chemistry. These factors can influence the chemistry of the soil and health of surrounding plants, the meteorological and local microclimate conditions, and the penetration rate of dust into vegetation (Arup Environmental, 1995). Apart from vegetation, dust deposition can affect animal communities and woodlands (Balkau, 1993). Dust can also minimise productivity and cause product damage. It adheres to machinery and products, reducing the life cycle of equipment and modifying the properties of the commodities. Dust fall may also impact negatively on sensitive industries, e.g. bakeries or textile industries. Certain elements in dust may damage materials. For instance it was found that sulphur and chlorine if present in dust may cause damage to copper (Maeda et al., 2001). In the urban environment, aerosol particles can damage paints and building materials and the deterioration of monument surfaces results in costly reconstruction. Deterioration through dust is mostly caused by the reaction of acidic species with stone (e.g., limestone) but closely followed by the soiling of surfaces as well as blackening to a lesser extent as a result of soot deposition (Pio et al., 1998).

2.2 Dust deposition management internationally

The system responsible for ensuring the effective management of dust deposition is very important as it will mitigate or limit the various impacts of dust as discussed in the preceding paragraphs. The control measures such as legal frameworks, guidelines, monitoring techniques and standards considered important for an effective dust management system globally as well as the NEM: AQA requirements for South Africa will now briefly be discussed.

2.2.1 Legal frameworks, guidelines and standards for managing dust deposition internationally

The effectiveness of standards in reducing dust pollution is dependent on the methods used to implement and regulate them, especially where there is a government compliance monitoring presence (RCEP, 1998). Over the past twenty years, there has been a considerable expansion in the environmental regulation of industry through both mandatory regulations and voluntary initiatives. Voluntary initiatives, commonly used in the UK in the 1980s, have not proved any more or less effective in achieving environmental objectives than the more adversarial and regulatory approach adopted by the U.S. Measures used to regulate have included the imposition of emission limits, efficiency standards and the requirement of best available end-of-pipe technologies. Despite the provisions made by the air-quality policies and acts in most of the developed countries, few to no regulations currently exist for regulating deposition or nuisance dust. For this reason only the countries of Australia, UK, Ireland and South Africa were included in this investigation as these countries all have made some provisions within their Environmental Protection Act to give guidance for deposition-dust monitoring and management. Apart from these countries some other countries also do have dust-fall guidance standards. The majority of countries use dust-deposition standards to practise best means of reaching their air quality objectives. All environmental issues globally are usually protected by an Environmental Protection or Management Act that contains the legal framework for regulating and mitigating all environmental impacts including air quality. In the countries of Australia, UK, Ireland and South Africa, air quality are regulated in a separate but interrelated Act which has its own set of requirements and objectives and will include management guidelines for deposition dust which will be described below.

2.2.1.1 Australia

In Australia air quality is legally regulated within the EP Act (Environmental Protection Act, 1986) with the EPA as regulator. Part II of the Act enables the development of State Environmental Policies (SEPs) which are a non-statutory government policy position on a particular aspect of the environment that can include ambient air. SEPs can include the scope to develop Environmental Quality Objectives and can identify a framework for implementation using existing statutory mechanisms such as EPPs, EIA, licensing and regulation (Department of Environment and Conservation, 2008). Part III of the EP Act authorises the EPA to prepare and publish EPPs, which following Parliamentary approval and gazetting, have the force of law. EPPs set environmental values, objectives, standards and/or targets that Natural Resource Management agencies must adopt when carrying out their environmental responsibilities. Conditions imposed under Part IV of the EP Act are legally enforceable, as are proponent commitments that appear in Ministerial Statements. The EPA Guidance Statement No. 18: Prevention of air quality impacts from land development sites (EPA, 2000) makes provision for activities that can generate dust and give guidance on the control of dust and smoke from land development sites. This dust guideline is specifically aimed at providing practical advice for the development and documentation of management strategies, plans and programs aimed at controlling impacts of dust. Part V of the EP Act provides general pollution prevention provisions which apply to all pollution or harm caused by dust generation and refers to compliance with emission standards and taking all practical measures to prevent or minimise emissions (Department of Environment and Conservation, 2008).There are no single standards or limits applied universally throughout Australia. As an example, the EPP of Kwinana Atmospheric Wastes, 1992 (EPP, 1992) has specified levels of pollutants (including particulates) in defined zones around the Kwinana (Martinick Bosch Sell, 2006). Managing deposition dust in Australia has always been guided by the recommendations made by the EPA. In the past the EPA has determined that residential areas would begin to experience dust-related nuisance impacts when annual average dust (insoluble solids) deposition levels exceeded 4 g/m^2/month. The dust impacts would be at unacceptable levels when they reached 10 g/m^2/month

(SPCC, 1983). This is then also the guideline upon which authorities and industry based their deposition-dust management programmes. Recently, the EPA (Dean et al.,1990) refined these criteria. Table 2.1 shows the maximum acceptable increases in dust deposition over the existing dust levels.

Table 2.1: *Environment Protection Authority Criteria for Dust Fallout*

Existing dust fallout level- (g/m^2/month)	Maximum acceptable increase over existing fallout levels - (g/m^2/month)	
	Residential	Other
2	2	2
3	1	2
4	0	1

(Dean et al.,1990)

For example, in rural/semi-rural areas with annual average deposition levels of between 1 and 2 g/m^2/month an increase of up to 2 g/m^2/month would be permitted before it was considered that a significant degradation of air quality had occurred. The above criteria dust fallout levels are set to protect against nuisance impacts. These criteria are not relevant for interpreting the significance of dust in mining working areas, where the concept of dust deposition level becomes meaningless (Nigel Holmes and Associates, 1995). Where compliance monitoring is required, the monitoring methods selected should be in accordance with Australian Standard methods and where they are not available, USEPA or equivalent methods should be used. Standards Australia has developed the following standard for dust monitoring methodology: AS 3580.10.1: 2003 (Department of Environment and Conservation, 2008).

2.2.1.2 United Kingdom (UK)

In the UK the control of air quality from mining and related activities is legally regulated by the: TCPA, 1990 (TCPA, 1990); EPR (England and Wales), 2010 (EPR, 2010); and The Environmental Protection Act, 1990 - Part III (EPA, 1990). The TCPA, 1990 (TCPA 1990) sets out the regulatory framework within which mining and related activities need to operate. This includes planning conditions for dust control especially for mining applications which is not controlled under the Environmental Permitting system (MIRO, 2011). The EPR (England and Wales) Regulations, 2010 (EPR 2010, as amended) were created to standardise environmental permitting and compliance. The regulations affect all regulated facilities that are included in Schedule 1 of listed activities. The Environment Agency and Local Authorities are the main regulators of air quality in the UK. They integrated PPC regimes through the PPC Act, 1999 (PPC, 1999) and the PPC Regulations (PPC, 2000). The IPPC system also makes Local Authorities responsible for regulating emissions (including dust) from scheduled installations. Nuisance caused by dust are regulated by the statutory nuisance provisions under Part III of the EPA 1990. Under Part IV of the Environment Act, 1995 (EA, 1995) the Government produced a NAQS in 1997 which was revised in 2007. The NAQS provides air quality objectives for airborne PM_{10} but not for dust. The control of local air quality via LAQM regulations was invoked by the Environmental Agency in 1990. This enabled statutory limits to be set for instances where there is a risk of the statutory objectives contained within in the AQR 2007 being exceeded (MIRO, 2011). Currently no statutory nuisance dust limit exists in the UK. Dust management is guided by the "Best Practicable Means" which applies custom and practice thresholds. At this time dust deposition is measured alongside criteria like: annoyance, the frequency of occurrence, location and loss of amenities. This is undertaken to provide a balanced and objective view of the level of annoyance caused and identifying of a statutory nuisance. Custom and practice thresholds for dust mass deposition are in the order of 80 to 200 mg. m^{-2} .day^{-1} averaged over the period of a month. The lower threshold of 80 mg. m^{-2} .day^{-1} (Bate & Coppin, 1990) is applicable to darker, high contrast dust, e.g., coal. 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 the standard Frisbee dust deposition gauge and no other (MIRO, 2011) as different deposition samplers have different dust collection efficiencies. The perpetrator of the alleged nuisance has a defence of best practicable means (BPM) which provides a way of balancing the interests of industry and residents. It also provides for a list of criteria which can be found in the BPM criteria set out in s.79 of the EPA. Difficulty arises when the polluter has taken all reasonable steps to reduce the dust emissions, but the problem remains. This constitutes a nuisance in the eyes of the Local Authority. Although the operator will have prima facie grounds for successful appeal to the local authority, the authority is still obliged to serve an abatement notice (MIRO, 2011).

2.2.1.3 Ireland

Ireland currently operates within the EC which has formally adopted the AQFD (Council Directive, 1996). The first daughter directive, 99/30/EC (Council Directive, 1999), set specific limits for four air pollutants: nitrogen dioxide, sulphur dioxide, PM_{10} and lead. These directives have been transposed into Irish legislation by the AQSR, 2002 (Irish Statute Book, 2002). The original Air Quality Directives have been replaced by one over-riding European Directive (European Parliament and Council Directive, 2008) in May 2008, although the specified limits for the protection of human health remain unchanged from those specified in SI No. 271 of 2002 (Irish Statute Book,2002). Due to its subjectivity there are no statutory limits on dust deposition and the focus is on the prevention of nuisance and minimising air-borne dust emissions where practicable. A number of rule of thumb measures exist to identify whether the potential for deposition can cause dust problems. These are based on two different types of measure, namely mass deposition rate and effective area coverage (TOBIN Consulting Engineers, 2010). The main method of assessment used is the one of mass deposition rate for which the set guidelines will be discussed now. Mass deposition rates determine the quantity of material deposited per unit area over a given reference period. Two commonly applied guidelines include a UK-based rule of thumb of 200 mg/m^2/day (expressed over a 30 day average) and the German (TA Luft, 2001) guideline of 350 mg/m^2/day. Below these thresholds dust problems are considered less likely. The EU Air Framework Directive requires of member states to categorise geographic areas, in terms of Zones and Agglomerations for Air Quality and practise the respective region’s guidelines. The EPA requires Bergerhoff Dust gauges to be used as standard method for determining dust deposition. The German (TA Luft, 2001) threshold of 350mg/m^2/day (in line with the statutory limits in the Waste Licence of 350mg/m^2/day) was selected to be used as guideline to control and manage deposition dust.

2.2.1.4 South Africa

In South Africa air quality is regulated by the NEM: AQA, 2004, which is the main air quality legislation of South Africa and commenced in September 2005. This Act reflects the overarching principles of the NEMA (1998) and environmental policy and brings legislation in line with local and international good practices as they pertain to air quality management. Schedule 2 of the AQA provides ambient air quality standards (Government Notice, 2009) and is based on the SANS 1929:2005 and more in line with international trends (Airshed Planning Professionals, 2009). The DEA proposed the Draft National Dust Control Regulations (Government Gazette, 2011) for the control of dust in all areas in May 2011 which does contain prescribed collection and measurement of dust deposition (Van Nierop, 2012). Currently South Africa is guided by the SANS 1929 (2005) guidelines for managing and controlling dust deposition (Table 2.2 and Table 2.3) within its air-quality framework. The framework does require the measuring and monitoring of deposition dust to be carried out according to the ASTM D1739, 2004. In terms of the guideline no industry may operate within the fourth band (alert band) as specified in Table 2.2. Industry may operate within the third band (action band) for a limited period of time provided they have received written authorisation from the relevant authorities. This authorisation may, however, only be granted by the authorities if it is deemed essential in terms of practical operational reasons and provided that an appropriate dust suppression technology is applied for the duration of the required operation.

Table 2.2: *Four-band scale evaluation criteria for dust deposition (SANS 1929)*

Band No.	**Band Description**	**Dust Fall Rate (D)**	**Comment Label ($mg/m^2/day$), 30-day average)**
1	Residential	D < 600	Permissible for residential and light commercial
2	Industrial	600 < D < 1200	Permissible for heavy commercial and industrial
3	Action	1200 < D < 2400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year
4	Alert	2400 < D	Immediate action and remediation required following the first exceedance, incident report to be submitted to the relevant authority

Dust deposition that exceeds the specified guidelines may be discounted by the authorities for enforcement and control purposes if they are shown to be the result of an extreme weather or geological event. Such an extreme event may be characterised by excessive dust deposition over an entire metropolitan area and not be localised to a particular operation. Natural seasonal variations will not be considered as extreme events and will not be discounted (Van Nierop, 2012).

Table 2.3: *Target, action and alert threshold for ambient dust-fall (SANS 1929)*

Level	Dust Fall Rate (D) (mg/m^2/day), 30-day average)	Averaging Period	Permitted frequency of Exceedance
Target	300	Annual	-
Action Residential	600	30 days	Three within any year, not in two sequential months
Action Industrial	1200	30 days	Three within any year, not in sequential months
Alert Threshold	2400	30 days	None, first exceedance requires remediation and compulsory report to the authorities

2.3 Dust-deposition monitoring techniques

The control measures such as legal frameworks, guidelines and standards considered important for an effective dust management system globally can only be as effective as the dust-monitoring techniques used to determine the level of compliance. Monitoring is conducted for both health and nuisance purposes and the different monitoring methods can be divided into active systems and passive systems (Colls, 1997). For nuisance dust and those concerned with secondary pathways it is usually either deposition to the ground or the flux of particles past a point that is of interest (Colls, 1997). Deposit gauges have a horizontal opening and flux gauges a vertical opening (US-EPA, 1998). Deposit gauges give information on local rates of deposition to the ground, whereas flux gauges indicate the passage of material past a sampling point. Flux gauges can also possess natural directional properties, which can be used to identify the source direction of wind-blown material (Hall, 1994). Other monitoring techniques and methods in use for nuisance dust include measurement of airborne dust concentrations using gauges which sample air volumes or by using light scattering devices that measure attenuation of light (Environmental Agency, 2003); examining the progressive soiling by dust; and visual monitoring which is subjective and qualitative (Environmental Agency, 2003). The duration of sampling must be long enough to allow the results to be expressed as an average over the specified period. The choice of suitable averaging periods is usually strongly influenced by the expected short-time variability in emission levels (Environmental Agency, 2003). Passive systems focus on the soiling aspect of dust with the monitoring periods of days, weeks and months (Colls, 1997). Passive samplers have the advantage of giving a good overall picture of average pollutant concentrations. They normally give long averaging periods (typically 1-4 weeks) (US-EPA, 1998). Examples of passive samplers include single and double bucket deposition monitors (US-EPA, 1998). Passive samplers are further divided into non-directional and directional monitors. Non-directional methods provide nuisance monitoring using either dust deposition or surface soiling. Deposit gauges are designed to collect material deposited over a given monitoring period, typically one week to one month and are based on the principle that course particulates suspended in the air will precipitate out either under the influence of gravity (dry deposition) or in contact with water droplets (wet deposition). The most frequently used types of standard deposit gauges are described in Table 2.4 (Environment Agency, 2003).

Table 2.4: *Description of different standard deposit gauges*

Standard	Shape	Diameter	Depth	Extra
UK BSI 1969	Funnel	300mm	200mm	
German (VDI 1990)	Glass jar	100mm	200mm	
US (ASTM, 1990)	Cylindrical	150mm	300mm	Surrounded by a wind deflector at angle 45^0
Irish	Plastic funnel	200 & 250mm		
ISO 1991	Cylindrical	200m	400mm	
Norwegian NILU	Cylindrical	200mm	400mm	

2.3.1 Internationally accepted dust-monitoring techniques

As only the countries of Australia, UK, Ireland and South Africa have made some provisions within their Environmental Protection Act to give guidance for deposition-dust monitoring and management, only the dust-monitoring techniques required by their respective guidelines will be included in this investigation.

2.3.1.1 Australia

Australia developed the AS 3580.10.1: 2003 standard for deposition-dust monitoring (Department of Environment and Conservation, 2008). This method is set out in ‘Australian/New Zealand Standard: Methods for sampling and analysis of ambient air: Method 10.1: Determination of particulate matter – deposited matter – gravimetric method (AS/NZS 3580). In this method a deposit gauge, which comprises a 150 ± 10mm diameter funnel inserted into a glass bottle (at least 4 litres in size) through a rubber stopper (see Figure 2.2) is mounted on a stand approximately 2m tall within a canister which holds the glass bottle and protects it from sunlight.

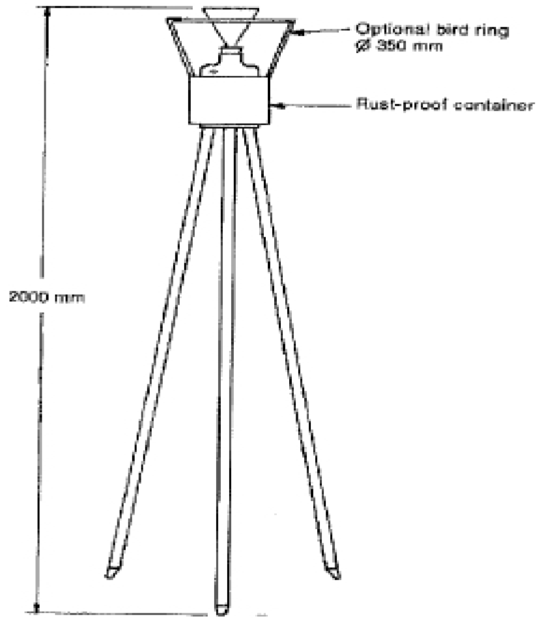

Figure 2.2*: Stand with deposit gauge based on the AS/NZS 3580. 10.1: 2003 method*

The bottle should be cleaned prior to use and rinsed with 10 ml of copper sulphate solution to prevent algal growth. The glass bottle may also collect rainwater and other material such as bugs and leaf litter, etc. This does not contaminate the sample and should not be removed in the field. However, it is recommended that the type of any contamination be noted for each sample on a piece of paper at the time of collection (for example, note the presence of bird droppings, leaf litter, sticks, spider webs, Christmas beetles, etc. or whether the bottle was broken). This record may help explain unusual results (such as high insoluble matter) during laboratory analysis. After 30 days ± 2 days, wash any deposited matter in the funnel into the glass bottle using distilled water. Remove the funnel and seal the glass bottle with a lid, identify the glass bottle with a label and transported to the laboratory for analysis. When using the AS/NZS 3580. 10.1: 2003 standard method, along with the 2g/m^2/month criteria it is important to note that the standard criteria refer to the total insoluble matter, and not total solids (this is the matter that does not dissolve in water, and is determined in a laboratory).The criteria refer to all sources of deposited matter (including sources from mines, agriculture, unsealed roads, etc.) and cumulative impacts.

2.3.1.2 United Kingdom (UK)

The standards and thresholds for dust mass deposition measured in the UK only applies to the standard Frisbee dust deposition gauge and no other (MIRO, 2011). The Frisbee dry foam deposition gauge consists of an inverted Frisbee-type plate mounted horizontally at 1.75 m above the ground (see figure 2.3).

Figure 2.3: *A dry foam Frisbee dust-deposit gauge.*

The shape has superior collecting efficiency and aerodynamic characteristics that make it suitable for short-term sampling periods of about a week (Environment Agency, 2003).The matter deposited on the collection surface and the insoluble matter in the collection bottle are removed and separated by gentle vacuum filtration. The insoluble matter is dried and determined gravitationally. The gauge requires an additional guard to reduce bird-strike, and polyester foam inserts to improve collection efficiency and reduce contamination by leaves (Environmental Agency, 2003).The gravimetric assessment of the insoluble material deposited is on a mass of material deposited per unit area per day (mg m^{-2} day^{-1}). This is derived by water extraction of the material captured on the collection plate over the period of a month. The Frisbee Gauge is specifically designed to be aerodynamically efficient, reducing the effect of eddies on particle collection thereby minimising airflow disturbance and maximising particle collection. The collection efficiency of the Frisbee gauge is 1.36 times greater than that of BS 1747: Part 1deposition gauge (Vallack & Shillito, 1995).

2.3.1.3 Ireland

The Ireland EPA requires Bergerhoff Dust gauges to be used as standard method for determining dust deposition. There are a number of methods to measure dust deposition but only the German TA Luft Air Quality Standards (TA Luft, 1986) specify a method of measuring dust deposition – The Bergerhoff Method (German Standard VDI 2119, 1972) – with dust nuisance. It is the only enforceable method available. The Bergerhoff Dust Deposition Gauge consists of a plastic collecting vessel and a stand with a protective cage (see Figure 2.4).

Figure 2.4: *Bergerhoff Dust Deposition Gauge*

The vessel is placed in the metal basket which is positioned at a height of between 1.5 and 2 metres above ground level according to the German Standard Method VDI 2119 (Measurement of Dust-fall, Determination of Dust-fall using Bergerhoff Instrument [Standard Method] German Engineering Institute).Prior to sampling, the collecting vessels will be carefully cleaned with laboratory detergent and then deionised water and allowed to dry. Sampling will involve placing the labelled containers in the protecting cages. Following exposure for a specific number of days, the sampling bottles will be securely capped and returned to the laboratory for analysis. All samples returned to the laboratory will be stored at 2-8°C (Oxigen Environmental Ltd., 2004). Subsequent analysis of all samples will be carried out gravimetrically for dust and strictly follow the standard VDI 2119. The results will be expressed in $mg/m^2/day$.

2.3.1.4 South Africa

In South Africa dust deposition is guided by the SANS 1929 (2005) guidelines which require the measuring and monitoring of deposition dust to be carried out according to the ASTM D1739, 2004. Single bucket fallout monitors are deployed following the American Society for Testing and Materials standard method for collection and analysis of dust-fall (US-EPA, 1998). The bucket stand comprises a ring that is raised above the rim of the bucket to prevent contamination from perching birds (see figure 2.5). The cylindrical container is supported on a metal stand, 2 m above the ground.

Figure 2.5: *ASTM D1739 based Dust Deposition Gauge used in South Africa*

This method employs a simple device consisting of a cylindrical container half-filled with de-ionised water exposed for one calendar month (~30 days). The water is treated with an inorganic biocide (copper sulphate) to prevent algal growth in the bucket (Sibanda, 2009).The dust falls into the bucket vertically, as either dry deposition or wet deposition. The particulate in the atmosphere deposits into the container which is returned to the laboratory, where the contents of the container is filtered and the residue dried before the insoluble dust is weighed to report the results as milligrams per square meter per day (mg/m^2/day).

2.4 NEM: AQA requirements for deposition dust management in South Africa

In South Africa the National Environmental Management Air Quality Act (NEM: AQA), 2004 (Act 39 of 2004) governs all aspects of air quality legislation in South Africa under the NEMA framework legislation (NEMA, 1998). The AQA of 2004 is the new and improved version of the previous air-quality legislation of the APPA (APPA, 1965). This Act provides for a whole list of requirements and legal aspects regarding air quality and subsequent dust management in South Africa. The main themes within NEM: AQA will be briefly described with specific reference to dust management (NEM: AQA, 2004).

Chapter 1: Interpretation and fundamental principles

This Act binds all organs of state in the national and local spheres of government as well as in the provincial sphere of government, subject to Section 146 of the Constitution. This Act must be read with any applicable provisions of the National Environmental Management Act. A key issue to understand is that AQA itself makes no provision for the compliance monitoring and enforcement of its own provision which are located in NEMA as framework legislation. NEMA makes provision for the statutory designation of EMIs to monitor compliance with and enforce AQA (NEMA, 1998). Only EMIs can monitor compliance with and enforcement of AQA. In the event of any conflict between a section of this Act and provincial legislation, the conflict must be resolved in terms of Section 146 of the Constitution. If in conflict with a municipal by-law, the section of this Act prevails.

Chapter 2: National framework and national, provincial and local standards

The Minister must, within two years of the date on which this section took effect, by notice in the Gazette, establish a national framework for achieving the object of this Act. This must include: mechanisms, systems and procedures to attain compliance with ambient air quality standards; obligations in terms of international agreements; national norms and standards for the control of emissions, air-quality monitoring, air-quality management planning as well as air-quality information management. The national framework must establish national standards for municipalities and provinces for monitoring ambient air quality and the collection and management of data. The data are necessary to assess compliance with this Act as well as compliance with ambient air quality and emission standards. The MEC may establish provincial standards for ambient air quality. The MEC may not alter any such national standards except by establishing stricter standards for the province or for any geographical area within the province. A municipality may in terms of a by-law establish local standards for emissions from point, non-point or mobile sources in the municipality. It may not alter any such national or provincial standards except by establishing stricter standards for the municipality or any part of the municipality. Though the Department of Environmental Affairs is in the process of promulgating dust deposition standards, the SANS 1929: 2005 (Tables 2.2 and 2.3, paragraph 2.2.1.4) prescribes guidelines to manage dust deposition to guide South Africa to attain national air-quality objectives.

Chapter 3: Institutional planning matters

The Minister may establish a National Air Quality Advisory Committee as a sub-committee of the National Environmental Advisory Forum established in terms of the National Environmental Management Act. This committee can advise the Minister on the implementation of this Act. The Minister must designate air-quality officers responsible for co-ordinating matters pertaining to air-quality management at the national, provincial and municipal levels. In terms of Section 15(1) of AQA, each national department or province responsible for preparing an environmental implementation plan as required by Chapter 3 of NEMA must include an AQMP as part of that plan. In the local government sphere, Section 15(2) of the AQA requires each municipality to include an AQMP in its IDP plan required in terms of Chapter 5 of the Municipal Systems Act (Government Gazette, 2000). The National departments responsible for their own AQMP as referenced in the Act of 2004 includes: Environmental Affairs and Tourism; Minerals and Energy, Health, Agriculture; Labour, Water Affairs and Forestry, Transport, Land Affairs, Provincial and Local government, Trade and Industry, Housing, Defence, Public Enterprises and Trade and Industry. This AQMP must as prescribed in terms of section 16(1) of the NEM: AQA as a minimum contain the following components:

- to improve air quality;
- to identify and reduce the negative impact of poor air quality on human health and the environment;
- to address the effects of emissions from industrial sources;

- to address the effects of emissions from any point or non-point source of air pollution other than those listed; and
- to effect best practice in air-quality management which should require some form of dust management

The annual report which an organ of state must submit in terms of Section 16(1) (b) of the NEMA must contain information on the implementation of its air-quality management plan. This must include air-quality management initiatives and the level of its compliance with ambient air-quality standards should subsequently include the deposition-dust standards as set by the SANS 1929 guidelines in order for it to be relevant. In addition, any effective AQMP would require dust deposition to be formally addressed within it as dust related issues will always affect air quality in a significant way.

Chapter 4: Air-quality management measures

The declaration, management and regulations for implementing and enforcing air quality management plans in priority areas are covered in this chapter. Priority areas are proclaimed if air-quality standards are constantly not met within the area. Priority areas may include various municipalities and extend across provincial borders. This chapter also includes listed activities published by the Minister, consisting of a list of activities with atmospheric emissions which may have a detrimental effect on the environment. No person may without a provisional atmospheric emission licence or an atmospheric emission licence conduct an activity listed on the national list anywhere in the Republic or listed on the list applicable in a province anywhere in that province. Due to the nature of deposition dust which would generally not be part of the main production activity of any industry, a listed activity is not generally listed due to its dust emissions. Thus no ambient air-quality emission standard currently exists for deposition dust. However, in Section 29 (1) the Minister or MEC may declare any substance contributing to air pollution as a priority air pollutant and require approval of, and implement pollution prevention plans in respect of that substance. Section 32 of Chapter 4 makes provision for the Minister or MEC to prescribe:

- measures for the control of dust in specified places or areas, either in general or by specified machinery or in specified instances;
- steps that must be taken to prevent nuisance by dust; or

- other measures aimed at the control of dust.

Chapter 5: Licensing of listed activities

Owners of listed activities are required to apply for an atmospheric emission licence. All the procedures and factors licensing authorities will take into account are described in Chapter 5. The chapter also gives details on the issuing of such licences. Not all activities or sources of deposition dust are listed as activities within Section 21 of NEM: AQA and can therefore be regulated as it should be.

Chapter 6: International air quality management

In this chapter the requirements and responsibilities of the Minister are specified as:

- the identification of trans-boundary air pollution;
- the investigation procedure, publication of regulations; and
- compulsory consultation by the Minister.

Although deposition dust is usually large particles it does contain all TSP size fractions of which the smaller size fractions can travel long distances in the air.

Chapter 7: Offences and penalties

This chapter defines the offences in terms of which any person is guilty by contravening any of the provisions made in this act. A person convicted of an offence is liable to a fine, ortoimprisonment for aperiod not exceeding ten years, or to both a fine and such imprisonment. A fine contemplated may not exceed an amount prescribed in terms of legislation regulating maximum fines for criminal offences. Currently deposition dust does not have an ambient air-quality emission standard nor does it have a listing schedule within NEM: AQA. Although it has guideline standards it does not constitute an offence that can be contravened and subsequently convicted. This situation will change drastically once the draft regulations for dust control are accepted and implemented.

Chapter 8: General matters

The Minister may make regulations that are not in conflict with this Act, on any matter necessary to give effect to the Republic's obligations in terms of improving air quality and concerns. The MEC may make regulations for the province concerned, not inconsistent with this Act, in respect of any matter for which the MEC may or must make regulations in terms of this Act. Before exercising a power the Minister or MEC must follow the prescribed consultative process as considered appropriate in the circumstances. Before exercising a power, the Minister or MEC must give notice and follow the prescribed public participation process. Any person or organs of state may in writing apply for exemption from the application of a provision of this Act to the Minister with exemption of provisions of section 9, 22 or 25. As of May 2011 regulations regarding dust control is in a drafted format, as the Minister proposed a draft for national dust-control regulations by invoking provisions of Section 53 (o) of Chapter 8.

Chapter 9: Miscellaneous

Transitional arrangements to ensure smooth transition between APPA and NEM: AQA are described in this Chapter. As deposition dust is still not formally part of NEM: AQA as it is not regulated nor was it in the past - this therefore has no significant influence on dust management.

2.5 Region-specific dust: Sources and management challenges

It is very difficult to develop a general guideline for dust management as previously stated (Chapter 1). This is mainly due to the distribution, frequency and intensity of SP (which will result in deposition or nuisance dust as previously described) in the lower atmosphere which depends on both the sources of SP and the meteorological conditions (see Paragraph 2.1) which are both regionally and area-specific. This should and usually does determine the dust deposition standards applicable within each guideline. It is should therefore not even be possible to adequately control dust from a nuisance point of view with a single (national) dust deposition standard averaged over a month period. The deposition standards subsequently determine the monitoring techniques, methods and guidelines of the management programme for dust deposition. In order to fully appreciate this statement the following paragraphs will analyse the sources, composition, distribution, and frequency of dust with specific reference to districts in South Africa where gold mining is prevalent.

2.5.1 Analysing dust sources and identifying challenges

The impact of dust deposition as well as its nuisance factor within any region will largely depend on its sources, composition, distribution, and frequency of dust which all depend on and are influenced by the meteorological conditions and the sources within the region itself. The impact of dust deposition in a prevalent gold-mining region will increase and be more severe due to the sources, composition, distribution, and frequency of dust characterized within these regions. To justify this statement the following paragraphs will characterise deposition dust in a gold-mining district of South Africa by discussing each of the preceding factors, contributions and impacts within the gold-mining region. It will use this assessment to identify all the potential challenges for dust management relevant to the specific nature of dust within districts and regions of South Africa where gold mining is prevalent.

2.5.1.1 Sources and challenges

South Africa is semi-arid country which experiences catastrophic droughts. Only about 13,5% of South Africa is arable and still 80% of the land is used for agriculture, which generally leads to even more rapid land degradation. Global climate change also threatens to worsen desertification in some parts of the country, as does further land degradation which includes loss of plant cover, alien plants, bush encroachment and deforestation (Hoffman & Ashwell, 2012). This only adds to the persistent dust problems faced in South Africa, since arid and semi-arid environments are perennial sources of aeolian dust (see Chapter 1) and windblown dust is a major source of dust in South African due to the prevailing dry climatic conditions, extensive surface mining and mineral processing (Held et al., 1996). Climate, land use and meteorological conditions, intensify already existing sources of SP within any region and will drastically increase dust deposition within regions of South Africa. In addition to all the preceding sources of dust there are also industrial sources as a result of industrial activities which significantly increase regional SP. These industries are usually responsible for large amounts of dust which are usually concentrated within certain regions. The strong gold mining industry is such an industry in South Africa. The contributions of gold mining to the regional SP currently in South Africa are considerable and significantly add to the already existing background contributions of regional South African SP as discussed in the preceding paragraph. The regional contribution of gold mining sources includes the large areas of land occupied by gold mine residues in the Gauteng, Mpumalanga, North West and Free State Provinces (see Chapter 1). Operational mines also make use of tailings dams for waste deposits; waste rock dumps for material not intended for processing; and ore stockpiles for material designated for processing. However, many non-operational mines also exist, which were left un-rehabilitated with exposed tailings dams and waste rock dumps. All of the preceding sources are major contributors to dust emissions and resulting dust deposition within the areas they occur. The rate of emissions of these sources also increases as winds increase and liberate dust at a higher rate from the large surfaces of tailings facilities and rock dumps. This also significantly increases not only dust deposition but the nuisance factor that comes with it. It is clear that regions where gold mining is concentrated in South Africa will have considerably more sources (natural and man-made) and a general variety of dust sources than regions where there is no mining. This together with the fact that the meteorological conditions like wind will affect the impact of different sources in different ways will all contribute to the added challenges in managing dust deposition within these regions.

2.5.1.2 Composition and challenges

Particulate matter in the lower atmosphere (suspended) is composed of highly water soluble inorganic salts (anthropogenic species of sulphates, nitrates and ammonium), insoluble mineral dust (metal oxides and silicates, and clay minerals derived from soil dust), and carbonaceous material which includes organic compounds ranging from very soluble to insoluble, plus elemental carbon (Jacobson et al., 2000). Heintzenberg recorded the major chemical components of the coarse mode (larger fraction) of particulate matter over central Europe during the winter and summer periods. According to Heintzenberg the coarse particle fraction in the summer consists of 47% insoluble dust and water, 19% organic material and 31% water soluble inorganic salts. During winter the coarse particle fraction consists of 63% insoluble dust and water, 23% organic material, 11% water soluble inorganic salts (Heintzenberg, 2003). This means that on average between 47 and 63 % of coarse particulate matter in the lower atmosphere over central Europe will in fact be insoluble dust all year around. This percentage for insoluble dust will even be higher for larger particle size fractions (coarser particles) as well as be higher during dust storms especially in arid and semi-arid environments as the sources of dust increase. This potentially bestows on insoluble dust the status of the single most important component within SP within any region. This study will use the average composition of coarse particles over central Europe as a guideline for the average composition of coarse particles as background SP over regions in South Africa. This is acceptable as the composition element for purposes of this study is only used to indicate the importance of insoluble dust within any atmospheric SP. The insoluble dust component can in fact only increase within the South African climate and environment. In South Africa Piketh, 1999 demonstrated the importance of soil dust in South Africa with research which shows that aerosols consist of a soil component up to 90% in the coarse fraction of the detected inorganic component of the aerosol (Piketh et al., 1999). This indicates that soil dust also plays a very significant role in aerosol loading in South Africa.

The preceding paragraph dealt with the average inorganic, organic and mineral dust composition associated with the averaged background SP within the lower atmosphere of any region in South Africa. This will, however, change for the composition of SP within a prevalent mining region as the composition of SP in the lower atmosphere of a region is largely determined by its surrounding sources as previously discussed. The composition of SP in a mining-prevalent region will then largely be influenced by the gold-mining sources. The research done by Ojelede on tailings facilities or TSF (the biggest gold-mining source) shows the minimum and maximum levels slimes component within the PM_{10} fraction of suspended particulate matter to be 24-38 vol.% for recent slimes and 17-26 vol.% for older slimes (Ojelede et al., 2012). This is a real indication of how significant the tailings facilities' particle contribution in fact is to the SP of that region which will only increase with particle size > 10 µm (will be explained in the following paragraphs). The impact of the resulting deposition of the SP will then also be more severe than the average background SP. The fact that the slimes on the TSF of gold mines undergo a chemical treatment process not only decreases particle sizes but results in particles containing concentrated harmful chemical substances as well as heavy metals and silica. This will result in many more environmental and health impacts as described earlier. This will also mean that a greater variety of size fractions for particles will exist for sources within gold-mining districts and regions which will travel various distances until impact. This will then also contribute to more challenges in the management of dust.

2.5.1.3 Distribution and challenges

Following emission from sources, dust particles are distributed within the lower atmosphere either in the short-term (for particulate sizes between 20 - 70 µm in diameter) or the long-term (for particulate sizes smaller than 20 µm in diameter) suspension where they make up a most of the fraction of SP (see Paragraph 2.1.1.1). The size of the particulate matter liberated from sources, whether industrial or natural, is one of the most important factors when characterising the area-specificity of dust. This can be seen by the fact that an average dust particle with a diameter size larger than 30 microns will mainly deposit within 100 metres of the source while intermediate sized particles (10 to 30 microns) are likely to travel 200 to 500 metres from the source (Goodquarry.com, 2005). This travel distance, however, can be influenced by both wind speed and the height at which the dust was liberated from the source. The average background deposited or nuisance dust of a region will consist mainly of the larger fraction of particulates as it is mainly originates from mechanically formed dust (dusts usually originate from larger masses of the same material, through a mechanical breakdown process such as grinding, cutting, drilling, crushing). This means that natural windblown background dust would usually travel only within a 100 metres from its source. This substantiates the fact that natural background dust is bound to a specific region in close proximity to its sources.

This change to some extent accounts for deposition of nuisance dust for regions where gold mining is prevalent. This is due to the fact that when the sources and composition of deposition or nuisance dust change so will its distribution distance. The waste rock dumps and reef stockpiles will still be classified as emitting SP of the size fraction > 30 µm and its distribution treated as such. However, the biggest source of deposition or nuisance dust as well as SP resulting from mining activities would be TSF. The particulates from TSF are formed chemically and could have size fractions < 30 µm and result in increased distribution distances. This can be assumed from the statement that milling equipment within the gold-mining industry was continuously refined to achieve a more homogeneous particle size of around 30 microns and smaller before the material is sent for the gold extraction (Handley,2004; Adamson,1972). This though is an ultimate size for gold recovery which is not generally achievable as different plant processes have different conditions and factors to deal with. It is, however, a standard that 80% of the particles must be < 70 microns for gold recovery to be economically viable. The deposition of material on a tailings (or sand) dam would be followed by its gradual drying out. Critical to facilitating and speeding up the process of drying out was the increasingly homogeneous particle size of more than 75% smaller than 30 microns. Once the material has dried out, it was this homogeneity that makes it more susceptible to wind and water erosion (Reichardt, 2012). If we consider the previous statements together with the fact that there is a chemical treatment of particles after the crushing and milling process which includes leaching and dissolving the gold we can assume the particle size will reduce even more. It is also common practice in South Africa where entire inactive TSFs are frequently reprocessed for gold and undergo a second chemical treatment and extraction process. It is thus potentially possible that any specific TSF in South Africa could contain less than 25% of particulate matter larger than 30 microns which means the rest of the slime residue would be of particle sizes from 10 to 30 microns and can be potentially emitted as such.

This will have significant consequences to the prediction of deposition distances and subsequent management thereof. It can be therefore be deduced that a large percentage of particulate matter emitted from TSF could potentially be in the size fraction of 10-30 µm. The dynamics of an isolated airborne particle of tailings blown by wind were furthermore extensively researched by Blight. According to Blight the travel distance of a particle can be calculated through calculating its falling velocity using Stokes equation: $v = 360\ d^2$ (with d the particle diameter in mm). Using this equation Blight determined the travel distance for tailings dust particles through re-suspension. He then determined that if tailings particles of 60 and 6 micron are projected one metre into the air by a wind with a velocity of 13.9 $m.s^{-1}$ it will travel a distance of 38 and 3800 metres respectively before it is deposited on a surface (Blight, 2007). Using the same method of calculation and the relative high wind speed of a 13.9 $m.s^{-1}$ the travel distances for tailings dust particles with diameters of 70, 60, 30, 20, 15 and 12µ m can be calculated to be 28, 38, 154, 347, 617 and 965 m respectively. This indicates that the SP released from TSF > 10µm will fall-out as deposition or nuisance dust at distances which will most probably exceed a 1000 m from the TSF source. These distances can also be much further depending on the height that the TSF is emitted from. The preceding paragraphs thus estimate that the travel distances of all the SP of importance relevant to deposition or nuisance dust within a regional gold mining region which would impact from any distance to 1000 m and beyond. This will mean that although deposition or nuisance dust within a prevalent mining district/region is still considered to be regionally bound and specific it will have more varying distribution distances for dust than an average region with no mining sources. This will mean that there are certain management challenges when considering the various impact distances of the various sources. An additional challenge is that TSF in South Africa has historically always been situated within the 1000 m boundary and in some cases much closer to residential areas. This will have significant challenges relevant to monitoring and subsequent management of deposition or nuisance dust with the current guidelines and standards available.

2.5.1.4 Frequency and challenges

The impact of climatic conditions on the persistent SP concentrations in the lower atmosphere is decisive and the factors determining climatic conditions include: rainfall (drought), wind speed and the time periods with little or no wind. The meteorology characteristics of a site or region significantly influence the rate of emissions from fugitive sources, and govern the dispersion (distribution), transformation and eventual removal of pollutants (deposition) from the atmosphere (Godish, 1990). Fugitive dust emission rates are predominantly a function of the wind speed, and the intensity and duration of the activity generating the dust (Godish, 1990). Meso-scale factors are very important as they control the dispersion of atmospheric pollution and include factors such as regionally induced topographic winds, urban heat island effects and atmospheric stability (Held et al., 1994 a, b; Tyson et al., 1988). It is thus apparent that the climatic conditions of a regional area will determine the concentration of SP in the regional atmosphere as well as the rate of the deposition and removal of SP. It is also common knowledge that the climatic conditions of a region are seasonal and will fluctuate on a monthly basis which will result in the concentration of SP in the lower atmosphere as well as the quantity of its deposition to fluctuate.

This was demonstrated by Vallack and Shillito who asserted that seasonal effects usually lead to significant monthly variations even at background deposition monitoring sites where peaks in monthly mean are often higher than annual mean (Vallack & Shillito, 1998). Dust or SP emissions can also be episodic (dust storms) and this usually intensifies - which can occur on a daily basis (dust events) which will drastically influence the average monthly deposition rate but can to some extent be controlled. This is stated by Schofield and Shillito who state that in terms of monthly dust-fall results in the UK, for BS deposit gauges, that when dealing with insoluble deposits, deposition rates exceeding 200 $mg.m^{-2}$ d^{-1} on a monthly average will generally cause nuisance to residential properties at peak periods within that month. Schofield and Shillito, 1983 also state that even though the dust deposition standard of 200 $mg.m^{-2}$ d^{-1} is not exceeded, nuisance dust complaints from the public were received (Schofield, C. and Shillito, D., 1983). This clearly indicates that even a monthly deposition standard may not be enough to manage the nuisance factor of dust deposition. The reason for this is that due to frequency factors of dust distribution, which are controlled by climatic conditions, matters will differ so drastically on a daily and monthly basis that nuisance complaints would not be limited by a single annual or even a second monthly standard. This is mainly a result of the fact that the nuisance factor of deposition dust cannot be defined by a standard in the legal sense. The frequency of deposition or nuisance dust of a prevalent mining region will even be more intense as described in the preceding paragraph when the climatic conditions are favourable due to all the additional sources. It is therefore important that the correct monitoring technique and methods are used when measuring the dust deposition in order to validate a true reflection of the region's deposition or nuisance dust. This could potentially contribute to more challenges for dust management in a predominantly gold mining region.

2.6 Challenges facing the dust-deposition monitoring method

Now that we have established through Paragraph 2.5 how important the regional characteristics of SP and resulting deposition or nuisance dust are to the management thereof, we can start to focus on specific challenges within the management programme. It is apparent from Paragraph 2.5 that the dust-monitoring techniques and methods used in dust deposition management will be very important for effective dust management in districts/regions where gold mining is concentrated. Dust monitoring is also essential for the regulation and control of dust deposition. The dust deposition monitoring methods reliability and accuracy will ensure the effectiveness and efficiency of the regulation standard to control and manage dust deposition. It is thus of utmost importance that the best suited method is used for monitoring dust deposition. The suitability of the dust-deposition monitoring method will depend on the sources, composition, distribution and frequency of dust as described in Paragraph 2.5. We will now consider these factors in relation to the current monitoring techniques used in Australia, the UK, Ireland and South Africa (as described in Paragraph 2.3) in order to identify specific challenges relating to each one within a mining region.

2.6.1 Sources and challenges

Sources, although they influences every aspect of dust and its subsequent monitoring technique, will for this specific paragraph only be addressed in terms of their relevance to the monitoring method that comes with the technique. What the author implies with this is that the sources of dust determine the distance of impact which it turn is determined by the size of the particulates of the source. This means that the different monitoring technique is not so important here as the distance where the deposition gauge is placed as part of the monitoring method with relevance to the source being managed. If we now consider the sources contributing to dust deposition within the selected mining district regions (Paragraph 2.5.1.3) it shows that all the sources of dust deposition will impact at varying distances which may exceed a 1000 m from all the sources identified within the selected gold mining district regions. This becomes an important part of the dust-deposition monitoring method as you can only manage dust deposition if you know the highest point of impact which will be specific to each individual source. It is also important to note that nuisance dust can be any SP fraction between 10-100 µm, which could mean that due to the number of different sources a number of different measuring methods should be used within mining district regions. The implementation of monitoring methods specifically designed for individual sources could present a potential challenge.

2.6.2 Composition and challenges

The currently used techniques of AS/NZS 3580.10.1:2003 method, Frisbee method, Bergerhoff method, and the ASTM D1739 method all measure the total insoluble SP fraction with regards to dust composition which will include organic as well as inorganic insoluble particulates. This could potentially be a challenge as it will have an effect on the control of dust depositions as the insoluble organic fractions will not be separated during gravimetric determination of filters (used in all deposition monitoring methods). This could be misleading to the actual insoluble inorganic fractions mass which is the actual dust fraction being regulated by the standard. Another potential challenge of the ASTM D1739 monitoring method is that it prescribes half-filling the bucket with de-ionised water. This together with the fact that one of the biggest sources of dust deposition within gold-mining district regions are tailings facilities which consist almost entirely of inorganic material, which all is potentially soluble and leachable by water. Even if large parts of insoluble quartz are present in mine-waste deposits a potentially significant amount of deposited inorganic material within the bucket will be leached through the filter in solution during the analytical process. The preceding factors are important when determining maximum allowed dust deposition standards which should be relevant to the surrounding region. In district regions where gold mining is prevalent the organic fraction contribution to coarse fraction of the SP would normally be less than 50 % (see Paragraph 2.5.1.2) which means the maximum standards should compensate for organic content as well as potential loss of collected dust through leaching accordingly to ensure that standards is relevant to the inorganic content of the district region.

2.6.3 Frequency and distribution and their challenges

One of the most important factors for monitoring dust deposition is the frequency or period of monitoring as described in paragraph 2.5.1.4. The period of monitoring is also determined by the monitoring technique itself. This has a drastic influence on the measured dust deposition as each monitoring technique has its own collecting method as well as expressing its result per specific time period. This becomes a huge factor in validity of results as monitoring data are usually averaged out over a statistical period of one day. The Frisbee, Bergerhoff and the ASTM D1739 monitoring methods all express their results as an average per day, although the period of sampling is for 30 days. Only the AS/NZS 3580.10.1:2003 method expresses its results as an average per month, which correlates with their sampling period of 30 days. This poses a challenge as dust deposition exceeds or causes nuisance per month due to daily events, but cannot be measured by one of these techniques per day. In addition dust problems can peak on a daily basis as well as during different months in different seasons of the year. The AS/NZS 3580.10.1:2003 and ASTM D1739 monitoring methods require a minimum monitoring period of 30 days or calendar month while the Bergerhoff method does not specify 30 days but speaks of a specific number of days. The only method indicating a number of days less than 30 is the Frisbee method which advocates short-term sampling periods of about a week. The shorter the sampling period the more the chance of preventing and regulating daily dust events as averaging it out to $mg.m^{-2}.day^{-1}$ for a month period will increase the chances of exceedances. Despite being difficult, it is possible to control dust deposition with the monitoring techniques currently available within regions where the seasonal and daily events of dust emissions are not too intense. This, however, becomes more difficult or even impossible and a subsequent major challenge in regions where favourable climatic conditions and availability of sources contribute to intense dust events like in prevalent gold-mining district regions.

2.7 Challenges facing dust-deposition standards

Except for the challenges facing the validity of the deposition techniques and methods monitoring dust deposition as described in Paragraph 2.6, it is futile to try and manage deposition or nuisance dust without an adequate deposition or nuisance dust standard which will be discussed in the following paragraphs. To illustrate this, we will briefly discuss the background of deposition standards from an international perspective and then compare it to South Africa's deposition standards and relevancy to its surrounding environment.

2.7.1 International dust deposition standards

Despite all the environmental and health effects deposition or nuisance dust might have, the biggest concern and main reason for deposition-dust regulation remains to be its subjective nature in respect of humans. This will include all human concerns ranging from personal annoyance, financial loss, product loss and health to aesthetics and dust visibility due to deposition on private property. These concerns are mostly the reason and main purpose for the existing international regulation standards to manage dust deposition within countries practising it through environmental legislation. These standards usually form part of pollution-control strategies aimed at reducing dust emissions and improving air quality in general and are usually based on WHO guidelines (Haq et al., 2002). There has, however, been no clear evidence of any overall systematic and significant change in TSP levels as seen from data collected through the 1990s which show increasing as well as decreasing trends in a similar number of cities (WHO, 2000). This could possibly be due to the fact that the regulation and control of dust deposition are generally poorly practised at the international level. This, we can presume, is partly due to the fact that although several countries and states have introduced standards for deposited dust (Table 2.5) no international organisations have produced recommendations (Vallack & Shillito, 1998).

Table 2.5: *International dust deposition standards ($mg.m^{-2}.d^{-1}$)*

Argentina	Annual average	333
Australia (W. Australia)	Loss of amenity first perceived	133
	Unacceptable reduction in air quality	333
Canada		
Alberta	Annual average	180
Manitoba	Annual average	153
	(maximum acceptable)	266
	(maximum desirable)	200
Newfoundland	Annual average	153
	Monthly average	233
Ontario	Annual average	170
	Monthly average	200
Finland	Annual average	333
Germany	Long-term average	350[a]
	Short-term average	650[a]
Spain	Annual average	200
U.S.A.		
Kentucky	Annual average	196
Louisiana	Annual average	262
Maryland	Annual average	183
Mississippi	Monthly average (above background)	175
Montana	Annual average (residential areas)	196
New York	During any 12 months no more than 5% of 30 d values to exceed	100
	and 84% to be below	130
North Dakota	3 Monthly average	196
Pennsylvania	Annual average	267
	Monthly average	500
Washington	Annual average	183
Wyoming	Monthly average	170
UK	Monthly average	200
Malaysia		133

[a] *Combined weight of dissolved and un-dissolved deposits*

In fact even the EPA which is an international leader in setting standards for regulating air quality does not regulate particles larger than 10 µm (EPA, 2012). The only progress in the monitoring dust deposition and regulation continues in countries where dust deposition monitoring is included in their environmental legislation. Australia, the UK, Ireland and South Africa are among the countries that have included deposition (fall-out) dust monitoring as guidelines in their environmental legislation with appropriate deposition-dust limits and action levels. Adding to the challenges in reducing dust deposition is that the SP leading to dust deposition consists of the entire size fraction of TSP as previously stated, yet only ambient concentration of $PM_{2.5}$, PM_{10} and TSP (10-30 µm) is strictly regulated. The possible problems facing TSP control internationally and in South Africa can potentially be all related to dust-deposition management and the proper definition of the relevant size fraction. If we consider the fact that the dust-deposition fraction might globally potentially be interpreted as SP> 30µm due to the nuisance factor and quick deposition rate, we can then assume from previous paragraphs that generally accepted sources of deposition or nuisance dust in certain regions such as mining areas can add significantly to TSP < 30µm. These sources, however, are not considered as continuous (e.g. burning processes) or emitting TSP < 30µm and thus regulated as such. The mere fact that deposition dust cannot effectively control nuisance complaints through all the current attempts of standards, monitoring techniques and guidelines available internationally is an important vindication of this statement.

2.7.2 Challenges facing the South African dust-deposition standard

Currently South Africa is guided by the SANS 1929 (2005) guidelines and drafted national dust control regulations for managing and controlling dust deposition. The best practice guideline specifies the targets allowable for deposition dust according to the standard is 600 $mg.m^{-2}.day^{-1}$ for residential and light commercial and 1200 $mg.m^{-2}.day^{-1}$ for industrial areas averaged over 30 days (Government Notice, 2009). The Draft National Dust Control Regulations (27 May 2011) specified that the deposition-dust standards will in fact will remain 600 $mg.m^{-2}.day^{-1}$ for residential areas and 1200 $mg.m^{-2}.day^{-1}$ for industrial areas. These standards will in the following paragraphs be compared to international standards to see whether the standards of South Africa could be adequate to regulate and control dust deposition to an acceptable level for all interested and affected parties. There currently exist two dust-deposition standards for

South Africa, separating industrial areas from residential areas. Internationally only one dust-deposition standard exists and has reference to the public and its concerns which relates back to the main reasons for which dust regulation was indented. To compare the same standards with each other is vital for this study to justify the conclusions to be made. This study will therefore only compare the residential standard of South Africa with the international standard expressed in $mg.m^{-2}.d^{-1}$ which is average over a month period and therefore be would generally be higher than annual averages due to seasonal variations. The following comparisons were made:

The South African standard of 600 $mg.m^{-2}.day^{-1}$is according to Table 2.5 in fact 4.5 times higher than West Australia, three times higher than UK, 2.6 times higher than Newfoundland, three times higher than Ontario, 3.4 higher than Mississippi and 3.5 times higher than Wyoming. Only the short-term average standard of Germany (650 $mg.m^{-2}.day^{-1}$) and the monthly average standard of Pennsylvania (500 $mg.m^{-2}.day^{-1}$) even closely resemble the South African standard. As previously stated dust complaints were received in the UK during a month where the 200 $mg.m^{-2}.day^{-1}$was not breached. It is thus clear that the South African standard value seems very high in comparison with other countries which mean it is easier achievable by industry which usually results in a lower standard of air quality. Although we also have to consider that South Africa mainly consists of semi-arid landscapes and because of its climate and environment is very prone to dust. This, however, cannot be justifiable as Australia has all the same environmental factors which in most cases are even worse and they implement a standard 4.5 times less than South Africa. In addition to this a dust-deposition rate of $4g/m^2$/month (133 $mg.m^{-2}.day^{-1}$) already equates to a visible layer of dust on outdoor furniture or on a clean car. It is thus apparent and also the view of the author that the residential standard of dust deposition in South Africa as it is now, is incapable of regulating dust deposition to a level that is acceptable to all interested and affected parties. It is also a fact that due to historical mining activities TSF and waste rock dumps are frequently situated within residential areas or in very close proximity of them. It is thus not possible to separate or apply industrial and residential area deposition dust standards when considering districts/regions where gold mining is concentrated. It is therefore apparent that the South African deposition dust standards will also be insufficient managing dust while having this separation of standards. It can therefore be concluded that there are major challenges within the South African deposition dust standards.

2.8 Challenges facing an effective dust-management programme

The preceding paragraphs investigated and considered all the potential challenges facing the management of dust deposition as a direct result of the complexities of dust and its specificity in terms of regions. It also identified potential challenges for dust management due to the monitoring methods and the adequacy of the prescribed standards to solve regional nuisance or dust problems. The only major challenge left within the management of dust is the management plans and programmes themselves. Due to a lack of dust management at international level, not many DMPs are currently available. The management of dust, however, should normally be included as part of any air-quality management programme and impose the same principles. The failure or success of any AQMP as well as its implementation can be measured with respect to the resulting air quality of the country or region it was implemented in. It is therefore then possible from literature to identify the key elements within an AQMP which ultimately contribute to the failure or success of the plan. This methodology was used by Engelbrecht during his research in completion of his Ph.D, where he identified key elements required to illustrate successes and failures in the implementation of AQMPs. This was done through an international and national literature survey (Engelbrecht, 2006). Since an official DMP will generally form a crucial part of any AQMP, it can hence be assumed that the same strategies for management used within an AQMP will be relevant to a DMP. This study will use the same method and most of the literature results as obtained by Engelbrecht to identify the key elements required for successful dust management. These required elements will then also present the potential challenges of dust management in South Africa in areas where they are not present. This study, however, focuses on the management elements identified within an AQMP which overlap with the challenges identified during this study from the resulting specificity of dust and the management thereof.

2.8.1 Identifying challenges within dust-management plans

A literature survey on the status quo of AQMPs in five countries around the world was conducted to provide the basis for the compilation of challenges facing the successful management of air quality around the world. Two countries, the UK and USA, were selected because of improvement in air quality due to the implementation of AQMPs (Engelbrecht, 2006). Two other countries, namely China and Mexico, where air quality has deteriorated despite the implementation of air-quality management measures, were also included in the literature study. A study of the status quo of AQMPs in the RSA was conducted to conclude the literature study. Four AQMP's from the Metropolitan Councils of Tshwane, Johannesburg, Ekurhuleni and Cape Town respectively were assessed (Engelbrecht, 2006). Table 2.6 represents a summary of the critical elements identified for an effective AQMP, and it also specifies which of these critical elements are present in the AQMPs of the UK, USA, RSA, China and Mexico.

Table 2.6: *Critical elements of an AQMP and their presence in the UK, USA, RSA, China (*Engelbrecht, 2006)

Element	**UK**	**USA**	**RSA**	**China**	**Mexico**
Air-quality goals and objectives	√	–	√	–	√
Source inventories and emission quantification	√	–	√	√	–
Air-quality monitoring	√	√	–	–	√
Air-quality standards and guidelines	√	√	√	–	√
Simulation (dispersion) modelling	√	√	√	–	–
Public information and dissemination	√	√	–	–	–
Air-quality alert	√	–	–	–	–
Planning and air-quality management	√	√	–	–	–
Enforcement programme	–	√	–	√	√
Source control (national and international)	–	√	√	–	–
Staffing, funding and authority confirmation	–	√	√	–	–
Plan revision process	–	√	√	–	–
Energy conservation	–	–	–	√	–

Using the summary of critical elements of an AQMP (Table 2.6) Engelbrecht then continued to identify elements absent from AQMP's of China and/or Mexico and present in the AQMPs of both the UK and the USA. These elements could therefore then be regarded as imperative to ensure air quality improvement knowing that the air quality of China and Mexico is poor when compared to the UK and USA (Engelbrecht, 2006). These elements are:

- Air-quality monitoring;
- Air-quality standards and guidelines;
- Simulation (dispersion) modelling
- Public information and dissemination; and
- Planning and air-quality management.

Engelbrecht concluded from his study that enforcement programmes, although present in both Mexico and China, but absent in the UK and the USA, didn't have any positive impact on air quality. When Engelbrecht considered the critical elements present in both the UK and the USA the following elements, which are critical success factors to an AQMP (as clear from Table 2.6) the following elements absent from South Africa's AQMP were identified:

- Air-quality monitoring;
- public information and dissemination; and
- planning and air-quality management.

Engelbrecht concluded that these three factors need to receive priority attention in order to obtain success of South African air-quality management in the future while not negating other elements identified in Table 2.6. In addition he concluded that proper source inventory and emission quantification as well as air quality standards and guidelines seem to be the most important elements that were implemented by "successful" countries.

Table 2.7: *Management challenges identified in the AQMPs of UK, USA, RSA, China (*Engelbrecht, 2006)

Element	**China**	**Mexico**	**UK**	**USA**	**RSA**
Political impracticability	√	–	–	–	√
Legislative and institutional barriers	√	–	√	√	–
Perception barriers	√	√	–	–	–
Local analytical / technical capability	√	√	–	–	–
Limited rule of law	√	√	–	–	–
Reactive control	–	√	–	–	√
Absence of public participation	√	√	–	–	√

Management of point sources only	√	√	–	–	–
Absence of prioritization	–	√	–	–	√
Air-quality standards not met	√	√	√	√	√

Table 2.7 provides a summary of the reasons for air quality management planning in the countries investigated not achieving positive results as derived by Engelbrecht during his research. The blank spaces (-) presented in Table 2.7 indicate that no specific indication was present in the literature survey to conclude that it was seen as a problem. It should be noted that not one of the countries investigated demonstrated full compliance with air-quality standards. In the UK and USA, this can be attributed to legislative and institutional barriers, since this is the only limiting parameter present in both the "successful" countries. However, elements that contributed to the failure of AQMP's to achieve the required results in Mexico and China are the following:

- Perception barriers;
- Local analytical / technical capability;
- Limited rule of law;
- Absence of public participation; and
- Management of point sources only.

These factors were identified by Engelbrecht as priorities to be noted by South African air-quality managers and avoided if an improvement in air quality is to be achieved. These priority factors identified will then be used as identified challenges facing managers with regard to dust management and planning within South Africa. The AQMP elements of air quality monitoring as well as standards and guidelines were found to overlap as the same challenges were identified during this study for dust management (Paragraph 2.6 and 2.7). This in fact deals with the specificity of dust and will be focussed on during development of questions testing the challenges of dust management. Special reference will also be made to prioritisation which has reference to the classification of nuisance dust and its subsequent regulation.

CHAPTER 3

Research methodology

This chapter reflects on the research methodology and justifies the research methods in relation to achieving the main research objective. The section deals with a description of the process and development of the questionnaires as part of the research methodology.

3.1 Introduction

The research for this study was conducted in three phases. The first phase consisted of a literature study of the current literature on the importance and management of dust as global atmospheric pollutant. This phase was followed by a second literature survey on the management of dust as a regional specific atmospheric pollutant within gold mining districts of South Africa and the complicating factors influencing the management thereof. The first two phases were supplemented by phase three, a quantitative survey to investigate and test the importance of: regional specificity, monitoring methods and standards as well as the planning and management of dust within the selected Districts/Regions within South Africa. Information was gathered by means of a survey methodology from individuals working in the relevant field, members of the public as well as specialists. This study has been limited to selected districts in South Africa where the gold mining industry is prevalent and dust management known to be problematic.

3.2 Description of the research methodology

This section deals with the methods that have been used in this research to derive information and present the data. Different methods were used to collect data, including a literature survey and a quantitative survey including both closed and open-ended questionnaires. The focus of this section is on the literature studies that were conducted as well as the quantitative survey (including the questionnaire design and layout, validity, selection of target population and sampling, distribution, data analysis and ethics).

3.2.1 Literature review

The literature review process in reality consisted of three separate but intertwined reviews. The first review was a thorough literature study conducted on the existing global dust management information with the specific emphasis on legal frameworks, guidelines, standards and monitoring techniques. The second literature review included additional site and dust-specific information of gold-mining regions, including comparisons to dust management globally. The second review also scrutinized dust management in South Africa with specific reference to regional and area specificity of dust by identifying the potential challenges resulting from the restricting factors within standards and monitoring. The third review included an investigation and identification of the key elements within the planning and management of dust within South Africa required for the effective management of dust.

The main aim of the literature study was to identify the reasons (challenges) preventing effective dust management in South Africa by identifying the daily challenges facing both regulators and gold-mining companies within districts where mining is prevalent. The identified challenges will mainly include factors which are relevant to the nature of dust and its sources. The literature basis has provided insights into all the factors making dust management problematic for both regulator and gold-mining companies within gold-mining prevalent district regions.

The literature study included:

- Relevant publications in accredited academic journals.
- Information on dust regulation, standards and classification from internationally recognized organisations.
- International dust management controls and regulations from environmental government departments.
- Authoritative books on dust categorization and behaviour.
- Relevant industry publications on gold-mining waste and pollution.
- Specialist publications on gold-mining waste and pollution.

The preceding literature review aimed to provide an intimate knowledge of the nature of dust as well as a perspective on the current capacity of the dust-management constitution of South Africa, in order to develop the necessary insights with regards to the study objectives.

3.2.2 Quantitative survey

In quantitative research, the research design is considered crucial in determining the most appropriate technique for the measurement of perceptions of respondents. While a number of techniques are available for the collection of primary data such as surveys, experiments, or observations, the survey method was selected for this research. The survey method was selected because it allows descriptive reporting and makes use of questionnaires where respondents provide information on their attitudes and perceptions.

3.2.2.1 Questionnaire design

Structured questionnaires were used to gather information from the participants. The questionnaires is designed to help determine how well the organization or person being researched is functioning in a related area. To cater for all the participants of this study closed structured questions as well as open structured questions were used. The standard participants (employees of government and industry) were catered for with the closed (structured) questions. The most important participants' (specialist, managers and public) opinions were assessed by open-ended questions in which respondents would have been required to answer in their own words. The advantages of closed questions are:

- They simplify questionnaire completion and hence encourage respondents to take part.
- Coding for data analysis is simplified.
- The questionnaire can be completed in a relatively short period of time
- The amount of probing needed is reduced (van Wyk, 2009)

The Likert scale is the most common variation of the summated rating scale (Cooper & Schindler, 2003). The questionnaires were constructed to include a Likert scale with responses on a four-point scale. The respondents were asked to agree or disagree with each statement and the level of agreement or disagreement could then be assigned a numerical score that can be totalled to measure attitudes. This type of scale helps in the comparison of one person's score with a distribution of scores from well-defined samples. The questionnaire used in this research study was designed to test and assess the challenges identified within the dust management constitution in

South Africa (see Chapter 2). The questionnaires were therefore designed to incorporate all components considered to be important for successful dust management which is controlled mainly within three areas (see Table 3.1). The first area within the questionnaire captured data relating to the network responsible for monitoring dust; the second area collected data on the competence of the planning and dust management itself, while the last part gathered information on the sharing of information and participation of all affected and interested parties to dust management. These three main areas were then separated into the separate components (Table 3.1) needed for successful dust management as identified within Chapter 2 and were questioned as such. The questions and statements related to each component are different for both closed and open-ended questions to industry, authority, specialists and interested and affected parties. The three main areas of focus and their numbered separate components can be seen in Table 3.1, which also gives the statements' numbering as per questionnaire.

Table 3.1: *Indexing of components in the main three focus areas*

Area	Statement No.	Component	Component No.
Dust monitoring	1-12	Dust monitoring network and receiving environment	A1
		Dust monitoring techniques and guideline	A2
		Dust sources	A3
		Nuisance dust standard	A4
Planning and dust management	13-33	Dust management capacity	B1
		Technical capacity and financial resources	B2
		Dust management policy and framework	B3
		Dust management planning	B4
		Reactive control, perception and absence of priority	B5
		Limited management, enforcement and regulation	B6
		Dust management strategies and reporting	B7
Information and participation	33-42	Cooperative governance information and participation	C1
		Public information and participation	C2
		Specialist information and participation	C3

Open-ended questionnaires were also constructed to be completed through interviews by specialists, managers and interested and affected parties. These questionnaires included questions relating to the main focus areas and their separate components, except that it was more probing and specialised.

3.2.2.2 Validity of research method

Validity and reliability are pre-requisites and fundamental characteristics of quality scientific research. This study used questionnaires as the main research method. Although this method has been proven to be reliable to some extent there are many influences that can affect its reliability that need to be controlled as best as possible. When it comes to validity, any research should be able to measure what it is supposed to measure. For this study all measures were taken into account to ensure the internal validity of the research in relation to its objectives. Leading questions were avoided and the wording of each question is simple and clear-cut. The questionnaires were designed to be answered easily and correctly. The content validity of the survey has been evaluated by means of a pre-test survey with a number of knowledgeable individuals on the subject.

3.2.2.3 Selection of population and sampling

The populations selected for the sampling of the study were defined by their potential for solving dust management problems. The local government sphere is legally responsible for AQMP's according to Section 15(2) of the AQA which requires each municipality to include an AQMP within its IDP required in terms of Chapter 5 of the Municipal Systems Act (Government Gazette, 2000). The study ascertained that dust problems are regional and area-specific. This means that dust problems are generally restricted to a specific area or region, which means that dust problems will not be solved within one municipal area. It was therefore decided to use district authorities which include more than one municipality and are usually responsible for AQMP of priority areas.

The main aim of the research has been to test and critically evaluate the challenges identified within dust management of gold-mining regions of South Africa. The target population therefore is environmental managers and air quality officers at functional level at selected gold-mining companies and district municipalities within selected areas of concern in South Africa. This includes specialists as well as other interested and affected parties.

Districts

District municipalities were selected as target population as it is a NEM: AQA requirement for district municipalities to submit AQMPs of which dust management initiatives would be an essential part-off. District municipalities will also then be held accountable for district regions air quality and thus subsequent dust control.

The gold-mining industry

Although it is not a legal requirement for industries to submit AQMPs, which would include dust management, they are an integral part of air quality management in any municipal or district areas due to their significant contribution to air and dust pollution. Gold-mining companies were selected as industry as they are the largest sources of dust problems within the selected districts. Industries like gold-mining companies may also be required by National and Provincial Government to submit PPPs in terms of NEM: AQA (Section 29 1-3) as well as AIRs in terms of NEM:AQA (Section 30 a & b).

Interested and affected parties

Interested and affected parties were selected as part of the target population. These parties were selected to ascertain the view of people concerned with regional dust problems and to get perspectives other than the normal legal compliance issues. This is important as one of the key challenges facing dust management is the nuisance factor of it which is cannot be defined by a law.

Specialists

The target population also included specialists in the field of dust with no relation to government, industry or public opinion to test concerns of the dust management constitution of South Africa. This was also an important target population as dust deposition and distribution are very complex issues as discussed during the literature surveys. Due to the relatively small number of participants within each selected population, each of the selected participants was individually targeted for survey, rather than sampling being used.

The planned sample size was approximately 37 individuals which consisted of individuals employed by the two selected District Municipalities, seven gold-mining companies, concerned citizens of both districts as well as specialist in the field of dust and monitoring methods. All the respondents except the concerned citizens were knowledgeable in the field of air quality/dust management.

3.2.2.4 Distribution of closed structured questionnaire to District Municipalities

The closed structured questionnaire to district municipalities is presented in Appendix 1 and was developed from the construct specified in Appendix 6 before it was sent to the selected district municipalities. The questionnaires were addressed to district municipalities to gather important information from the role players responsible for dust management. The questionnaires were distributed to air quality officers at functional levels. Respondents were asked to assess each statement and then mark their level of agreement or disagreement with each statement. The questionnaire consisted of three pages and included a total of 42 statements (Appendix 1). Approximately 10-20 minutes were required to complete the questionnaire. The data were collected by sending out the questionnaire in the form of an e-mail to each individual with a preceding phone call and in some cases also a visit notifying them of the e-mail and confirming the brief of the study. A short cover letter attached to the questionnaire explained the purpose of the study in more detail with clear instructions on how the questionnaire should be completed. The participants were asked to fill out the questionnaire on the basis of their experience with their current employer. Anonymity was also guaranteed for all participants.

3.2.2.5 Distribution of the closed-structured questionnaire to gold-mining companies

The closed structured questionnaire to gold mining companies is presented in Appendix 2 and was developed from the construct specified in Appendix 7 before it was sent to the selected gold-mining companies. The questionnaire was sent to the air quality officers or employee(s) responsible for dust management at the functional level of the selected gold mining companies. Respondents were asked to assess each statement and then mark their level of agreement or disagreement with each statement. The questionnaire consisted of three pages and included a total of 42 statements (Appendix 2). Approximately 10-20 minutes were required to complete the questionnaire. The data were collected by sending out the questionnaire in the form of an e-mail to each individual with a preceding phone call and in some cases also a visit notifying them of the e-mail and confirming the brief of the study. A short cover letter attached to the questionnaire explained the purpose of the study in more detail with clear instructions on how the questionnaire should be completed. The participants were asked to fill out the questionnaire on the basis of their experience with their current employer. Anonymity was also guaranteed for all participants.

3.2.2.6 Distribution of open-ended questionnaire to managers

The open structured questionnaire to managers is presented in Appendix 3 and was developed based on questions relating to the components identified in Table 3.1. The questionnaire was sent to the managers responsible for dust management at the functional level of the selected district municipalities and gold-mining companies. Managers were asked to carefully consider each question before answering the questionnaire on the basis of their experience with their current employer. The questionnaire consisted of three pages and was completed as interviews. A total of 14 questions were included in the questionnaire. Approximately 10-30 minutes were required to complete the questionnaire. The data were collected by conducting individual interviews with the targeted persons. This adds value to the study by including additional information regarding the day to day challenges faced by mangers.

3.2.2.7 Distribution of open-ended questionnaire to concerned citizens and dust specialists

The open structured questionnaire to specialists and interested and affected parties as presented in Appendix 4 and 5 respectively was developed based on questions relating to the components identified in Table 3.1. It was subsequently sent to the selected specialists and interested and affected parties within the district municipalities. The specialists and citizens were asked to carefully consider each question before answering the questionnaire on the basis of their experience with dust and the district region respectfully. The questionnaire consisted of four and two pages to specialists and concerned citizens respectively. A total of 15 questions for the specialist and 12 questions for the citizens were included in the questionnaire. Approximately 10-30 minutes were required to complete the questionnaire. The data for the citizens were collected by identifying concerned interested and affected parties at district air quality forums and then conducting individual interviews with them. The data for the specialists were collected by identifying specialists in South Africa through the literature survey and then conducting individual interviews with them. The open-ended questionnaires to concerned citizens will add value to the study as the need of interested and affected parties is usually more than what is required by law. The open-ended questionnaires to specialists will add value to the study by providing technical information on all the complexion factors regarding dust. The interview with specialist included more probing and specialised open-ended questions relating to specific areas and their individual components of Table 3.1.

3.3 Data analysis

Where the Likert scale was used to generate data within this research, the distinction of data between the levels of agreeing or disagreeing was not used to make any conclusions. The author thus believes that the data gathered through the different levels of agreeing and disagreeing can be grouped as just *agree* and *disagree* as it will have no effect on the final outcome or conclusions made. Grouping this data together will only increase the confidence of the final assessments to be made.The raw data from each of the questionnaires were then imported into the Microsoft Excel software programme and plotted to find patterns and make conclusions. The raw data of the interviews were individually assessed and conclusions made.

3.4 Ethics

Individuals were asked to complete questionnaires in their personal capacity and consent was always sought. The purpose and aim of the completion of the questionnaire were explained beforehand, in a covering letter attached to each questionnaire. The participants completing questionnaires were not expected to identify themselves on the questionnaires. Participation was voluntary and participants were free to withdraw from the process at any time without giving a reason. There was an open invitation in each of the covering letters inviting respondents to contact the researcher for clarification on any of the aspects of the questionnaire. The next Chapter will report on and discuss the results of each of the surveys.

CHAPTER 4

Results and evaluation

This chapter presents the results attained through the distributed questionnaires and interviews. The first part of the chapter deals with the participants and collection process as well as the response rate to the questionnaires. The data obtained from the questionnaires and interviews are then considered and interpreted with regard to the focus areas as well as the individual stakeholders.

4.1 Introduction

This chapter presents the results obtained from the structured questionnaires relevant to each of the relevant stakeholders included within this research study. This presentation of results includes the distribution and collection process, the efficiency of retrieving data and subsequent response rate as well as the difficulties experienced during the collection process. The results of a total of five questionnaires sent to district municipalities, gold-mining companies, interested and affected parties as well as specialists are presented within this chapter. The results are presented mostly in the form of graphically illustrated data as obtained from the Likert scale method (Chapter 3) of structured questionnaires. The results also include the answers provided by respondents to the open-ended questions which will be integrated and critically evaluated according to the various focus areas and components as discussed in Chapter 3.

4.2 Distribution and response to questionnaires

The draft questionnaire was pre-tested with colleagues who have been involved at all levels of environmental management on gold mines. Once their feedback had been received, the questionnaire was edited and finalized to be reviewed by the research supervisor before distribution. A list of potential participants was drafted and their contact details were gathered. After the final questionnaire had been approved by the study supervisor, it was sent together with a cover letter via e-mail on the 1st of July 2013 to all selected participants including all relevant stakeholders of this study. The self-imposed deadline for responses was set to be August 30th 2013. The first questionnaire was received back on the second day after it was sent out whilst the remainder of the responses were gathered over the remainder of the allowed response time. The initial letter with the attached questionnaire was sent on up to four occasions to the potential participants not responding. A courtesy phone call was also made to participants considered important contributors to the study as well as reminders and explanatory information regarding the study. A response summary is presented in Table 4.1.

Table 4.1: *Response summary for the total population size tested.*

Stakeholder	Distribution and Collection of data		
Correspondence	Distributed	Received	% Response
District Municipality officers	**6**	**5**	**83.3**
Gold-mining company officers	**7**	**6**	**85.7**
Interested and affected parties	**10**	**10**	**100**
Specialists of dust management	**5**	**4**	**80**
Managers of districts & gold mines	**9**	**4**	**44.4**
Total	**37**	**30**	**81.1**

A total of 37 questionnaires were sent out of which 31 were returned, a response rate of 81.1%. The gold mining company's response rate was the poorest with only 8 out of 14 questionnaires being returned. The quickest response was given by the interested and affected parties of whom all the selected respondents participated in the study. The district municipalities were second with their response and all participated except one, although more time and persuasion was needed for responses. The gold-mining companies, although reflected as 85.7% response in Table 4.1 did not respond to the open-ended questionnaires sent to management. This resulted in an overall response of 57.1% which contributed to the 44.4% response for managers of both district and gold mines reflected in Table 4.1. This was then also the poorest response rate of the entire collection process. The questionnaires to specialists which also had an 80%response rate, shared second place for response rates with district municipalities, although it had its own complexities which will be discussed later within this chapter.

It is important to note that the sample population of this study was never going to be very large due to various factors including the stakeholders and the nature of this study. One of the biggest reasons from a stakeholder perspective was found to be that only three air quality officers are appointed per district region and the nature of this study was bound to gold mining and subsequently mainly two district regions were included. Another big factor reducing the population size is the fact that within these two district regions mainly three big mining companies owned almost all the mining lease areas (shafts and tailing facilities) relevant to gold mining. This also meant that only one dust management programme, of which one person is held responsible for the actual programme, was in place per mining company. This meant that much effort was made to distribute the questionnaires to this reduced sample population and retrieve them again. The response rate to the sample population of the gold-mining industry, although presented as 85.7% in Table 4.1 can never be perceived as true results representative of the entire gold-mining industry. This is due to the reality of the relevant size and surface areas of these industries within the selected districts compared to the amount of participants responsible for these areas. In totality the response of the targeted populations presented adequate response rates to derive representative data. Employees and managers from a total of seven gold-mining companies, two district municipalities, dust monitoring and management specialists as well as the interested and affected parties in both districts, were defined for inclusion in this study. The response ratio for this study can be deemed as adequate as more than 80% of the individuals who received questionnaires responded. The data-gathering effort for the purpose can therefore be considered to be satisfactory, and the conclusions drawn from the sample can be said to be a fair reflection of the sample population. The researcher strongly believes that all reasonable measures were taken to elicit responses from the sample, and that this is an excellent response rate. The researcher can therefore conclude that the data obtained from the sample are a fair reflection of the intended populations.

4.3 Interpretation of data

The closed-ended questionnaires used to gather information comprised 42 questions that tested 14 components relating to the main focus areas identified during the study which also links up with the main research objectives. A total of three questions each for every component of each focus area was presented to the respondents within the district municipalities as well as the gold-mining companies. The responses to the different components are discussed per component within each of the main focus areas. The indexing of questions into the separate components of the main three focus areas (constructs) as well as the blank closed-ended questionnaires for both the district municipalities and gold mining companies as used during questionnaire development in Chapter 3 are presented as Appendices 6-7 and Appendices 1-2 respectively and should be used for reference. Apart from the closed-ended questionnaires, open-ended questionnaires were also used in the form of interviews to gather additional information on the 14 components deemed important in relation to the main focus areas identified during the study. These open-ended questionnaires were more in-depth and targeted the managerial level of both the districts and the gold-mining companies. Open-ended questionnaires were also used for dust specialists as well as interested and affected parties to get the maximum available information on potential dust challenges which might not be reflected by parties directly involved with dust management. The blank open-ended questionnaires to managers, specialists and interested and affected parties are presented in Appendices 3, 4 and 5 and should be used as reference.

The chapter initially deals with and interprets the results per main focus area and target population, before interpreting the results in their entirety. The following results will further separate the main focus areas into the individually components considered important elements for successful dust management and discussed as such. Each component is individually analysed in depth to test its relevancy in order to confirm or reject the challenges within the selected sample of stakeholders. The open-ended questions to the managerial levels, specialists and interested and affected parties are analysed to provide information to either validate, rate or nullify identified patterns from operational level of both district municipalities and gold mining companies. As anonymity was guaranteed to the respondents, no names are mentioned and only the industry and district municipality as entity will be mentioned. Where Likert scale data are used within this research, *strongly agree* and *agree* as well as *strongly disagree* and *disagree* data will be grouped and represented only as two data sets of *agree* and *disagree*. The author believes that the level of agreeing or disagreeing will have no effect on the final outcome and by grouping it together will only strengthen and substantiate the final assessments of the research results.

4.3.1 Dust monitoring

One of the most important factors or focus area necessary for successful and effective dust management and the first of the three areas which will be evaluated during the following results is the monitoring function of the dust fall-out itself. It is crucial for an effective dust management plan or programme that reliable data for the initial baseline and continuous monitoring are provided. It must also be the basis for decision-making as far as the identification and management of priority areas. It can therefore be said that if there are challenges regarding dust monitoring, there will be challenges in managing dust deposition successfully. To access and test these potential challenges within dust-management of district municipalities and gold-mining companies, 12 questions were presented to 11 participants within the two District regions and the results are given in Figure 4.1.

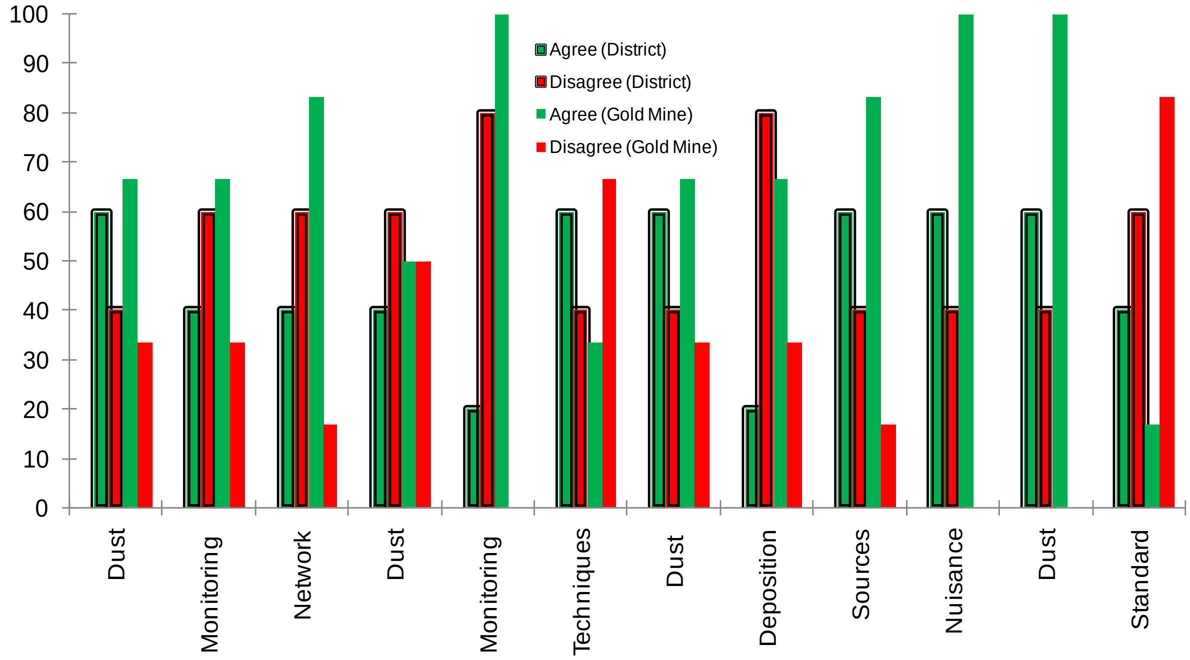

Figure 4.1: *Potential challenges of dust monitoring*

The first three columns of Figure 4.1 represent the responses of district as well as gold mining employees with regards to the regional development of their dust-monitoring network. The air quality officers of district municipalities indicated with 60% agreement that their dust-monitoring network was relevant to their sources and region. They did, however, indicate with 60% disagreement that neither climate nor regional source inventories were used for developing their dust monitoring network. The air quality officers of all the gold mining companies indicated with 70% agreement that their dust-management network was specifically developed for their sources and region as well as their regional climatic conditions. Gold mines also agreed with 83.3% that their dust monitoring network was designed according to their source inventories.

By using the preceding data we can now make the following conclusions about the dust monitoring and climate component:

- The district indicated a definite challenge when it comes to designing dust-monitoring networks, specifically in accordance with different sources and including regional climatic conditions; and
- The gold mines indicated no challenge when it comes to designing dust-monitoring networks.

Columns four to six of Figure 4.1 represent the responses of district as well as gold-mining employees with regards to the effectiveness of the dust deposition guidelines, draft regulations as well as the ASTM D739 monitoring method. The air quality officers of district municipalities indicated with 60% disagreement the statement that they think that both the SANS 1929 guidelines or draft regulations are sufficient for managing dust with their district region. They also indicated with 80% disagreement that complying with the guidelines or draft regulations will reduce public complaints due to dust deposition. They did, however, agree with 60% that the ASTM D739 monitoring method was the best method to ensure effective dust management within their district. The air quality officers of gold mining companies within both districts felt 50% confident that complying with both the SANS 1929 guidelines or draft regulations is sufficient for managing their dust within the district region. They did, however, with a 100% agreement indicate that they do believe that complying with the guidelines or draft regulations will reduce public complaints due to dust deposition. Gold mines officers disagreed with 66.7% that the ASTM D739 monitoring method is the best method to ensure effective dust management within their company. By using the preceding data we can now make the following conclusions about the dust monitoring techniques and guidelines component:

- The district indicated a definite challenge regarding the SANS 1929 guideline or draft of dust control regulations standard potential for effective management of dust deposition as well as reducing dust complaints. They do, however, see no challenges regarding the ASTM D1739 monitoring method to ensure effective management.
- Gold mines were inconclusive regarding the challenges within the SANS 1929 guideline or draft of dust-control regulations' standard potential for effective

management of dust deposition. They do, however, see no challenges regarding the current regulations ability to reduce public complaints. They did however indicate possible challenges regarding the ASTM D1739 monitoring method to ensure the best effective dust management.

The columns from seven to nine in Figure 4.1 represent the responses of district as well as gold mining employees with regards to their dust sources and deposition data. The district municipalities were 60% in agreement that they had listed all the sources of dust deposition within their districts. The officers of the districts also indicated with 80% disagreement that they do not manage dust deposition by source-specific monitoring methods. The districts also indicated with 60% agreement that their regional sources contributions to visible daily dust events were not adequately reflected within the district's monthly dust-deposition data. The gold-mining companies agreed with 66.7% that they had a complete list of all the dust sources of their company. The gold mines also agreed with 66.7% that they managed dust deposition with source-specific monitoring methods. There is also an 83.3% agreement that the companies' sources contributions to visible daily dust events are not reflected within monthly dust-deposition data. By using the preceding data we can now make the following conclusions about the dust-source component:

- The district indicated possible challenges within the monthly deposition monitoring data as well as source-specific dust-monitoring methods as part of their management programme. The district sees no challenge for source identification within their district.
- Gold mines identified no challenges regarding identification of dust sources or using source-specific monitoring methods as part of their dust management. They did, however, indicate a possible challenge within the monthly dust-deposition data.

The last three columns in Figure 4.1 represent the responses of the district as well as gold-mining employees with regards to nuisance dust and the deposition standard itself. The district municipalities indicated with 60% agreement that they considered all the dust of surface mining activities to be nuisance or deposition dust and that they did comply as a district with the monthly deposition standard of the SANS 1929 guideline. They then disagreed with 60% that a single deposition standard would be sufficient to manage the seasonal effect of dust deposition. The gold-mining companies agreed with 100% that they considered all the dust of surface mining activities to be nuisance or deposition dust and that they do comply as company with the monthly deposition standard of the SANS1929 guideline. They then disagreed with 83.3% that a single deposition standard will be sufficient to manage the seasonal effect of dust deposition. By using the preceding data we can now make the following conclusions about the nuisance dust-standard component:

- The district indicated that there was no challenge in complying with the monthly dust-fall standard of the SANS 1929 guideline. The district indicated that there was no challenge in how they classify dust emissions from surface mining activities. The district also indicated possible challenges with the adequacy of a single dust-fall standard.
- The gold mines indicated that there was no challenge in complying with the monthly dust-fall standard of the SANS 1929 guideline. The gold mines indicated that there was no challenge in how they classify dust emissions from their surface mining activities. The gold mines also indicated possible challenges with the adequacy of a single dust-fall standard.

4.3.2 Planning and dust management

The most important factor or focus area necessary for successful and effective dust management will always be the dust management system itself which will include planning in each of its facets. This is then the second factor or focus area which will be evaluated through the gathered results in this chapter. The efficiency and success of dust management will consequently depend on many factors like the capacity to plan, manage, enforce and maintain good dust management practices. Dust management is also multi-disciplinary in nature and a certain level of technical and scientific skills is necessary for proper management. It is thus essential that certain technical skills and capacities are available for effective management. It is therefore clear that if there are challenges regarding dust management and planning, there will be challenges in managing dust deposition successfully. To access and test these potential challenges within dust management of district municipalities and gold mining companies, 21 questions were presented to 11 participants within the two districts and the results are given in Figures 4.2 and 4.3.

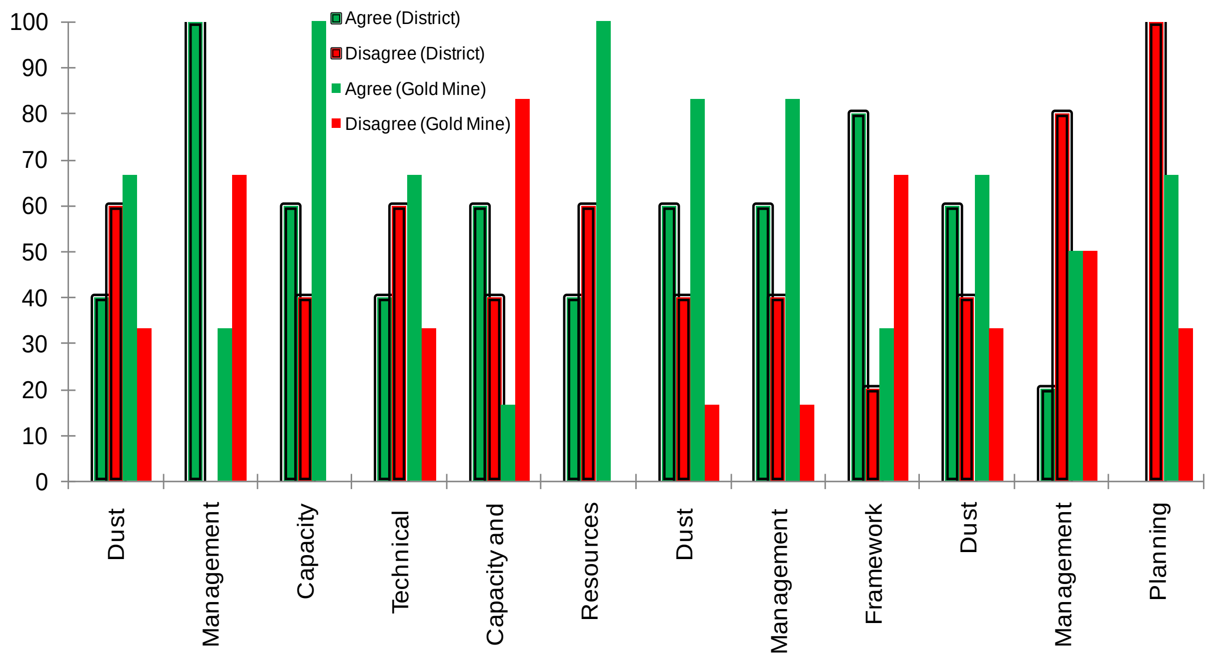

Figure 4.2: *Potential challenges in planning and dust management*

Columns one to three of Figure 4.2 represent the answers of the district and gold-mine employees concerning their capacity to carry out dust management successfully. About 60% of the district municipalities disagreed with the statement that air quality officers are being appointed for dust management while 66.7% of gold mines agreed that air pollution officers are being appointed to do their dust management. When it comes to a dedicated air quality department responsible for dust management, the districts agreed 100% that they did have a dedicated department whereas the gold mines disagreed with 66.7% to not having a dedicated department. The district agreed with 60% that their districts possessed the technical skills to maintain and implement a dust-management programme while the gold-mining officers agreed 100% that their companies possessed all the necessary technical skills. By using the preceding data we can now make the following conclusions about the dust-management capacity component:

- The district indicated that there was no challenge in skills for maintaining and implementing dust management, and neither was there a lack of a dedicated department. There is a potential challenge in the fact that there are no formally appointed air quality officers within the department.
- Gold mines indicated that there was no challenge for them in either skill or in appointed pollution control officers to maintain and implement dust-

management programmes. There is, though, a potential challenge as there is no dedicated air quality department.

Columns four to six of Figure 4.2 indicate the response of the district and gold-mine employees concerning their technical capacity to develop a dust-management plan as well as financial capacity to ensure that an effective dust-management plan is developed, implemented and maintained. The district disagreed with 60% that they possessed the technical skills necessary to develop a dust-management plan, whereas the gold mines officers agreed 66.7% that they possessed the technical skills necessary to develop a dust-management plan. The district municipality agreed with 60% that they had their own budget and financial provision to develop, implement and maintain a dust-management plan. The district municipality disagreed with 60%that they used any financial provisions from outside the district. The gold mines on the other hand disagreed with 83.3% that they had the financial resources available to develop, implement and maintain a dust management plan and agreed with 100% that they used specialists from outside the company for this function. By using the preceding data we can now make the following conclusions about the technical capacity and financial resources component:

- The district indicated a challenge in terms of the necessary in-house technical skills to develop a dust-management plan. There was also no indication of in-house challenges regarding financial provision to develop, implement and maintain a dust-management plan.
- Gold mines indicated that there were no challenges regarding their technical skills for developing a dust management plan. They did indicate that they had challenges in terms of the financial provision to develop, implement and maintain dust management.

Columns seven to nine of Figure 4.2 indicate the response of the district and gold mines regarding the relevancy of their dust management policies and objectives. The district agreed that they had a vision, mission and objectives for dust management and that their objectives relating to the dust standard were different from the SANS 1929 guideline and draft of national dust control regulation with 60% each respectively. The gold mines agreed that they had their own vision, mission and objectives for dust management and that their objectives relating to the dust standard were different from the SANS 1929 guideline with 83.3% each respectively. The district municipality agreed with 80% that their dust management objectives were included within an AQMP, while the gold mines disagreed with 66.7% that their objectives were included within an AQMP. By using the preceding data we can now make the following conclusions about the dust-management policies and frameworks component:

- The districts revealed that there was no challenge regarding vision, mission and objectives for dust management per district. There was also no challenge with dust-management objectives not being planned and included within an AQMP.
- Gold mines revealed that there was no challenge regarding vision, mission and objectives for dust management and that it was specific for each gold mine. There was, however, a challenge regarding planning as there are no dust-management objectives included within their AQMP.

Columns 10-12 of Figure 4.2 reflect the position of the district and gold mine on dust-management planning. The districts agreed with 60% that they had their AQMP submitted within an IDP and disagreed with 80% that their AQMP was approved or included specific dust-management plans. The district by 100% disagreed with the statement that an approved AQMP with specific DMP would improve air quality and potentially solve dust-related problems. The gold mines agreed with 66.7% that they had an AQMP with specific dust-management plans but only agreed 50% that these were based on ISO management principals. The gold mines agreed with 66.7% with the statement that an approved AQMP with specific DMP would improve dust-related problems within their company. By using the preceding data we can now make the following conclusions about the dust management planning component:

- The district indicated that the submission of AQMP within their IDP presented no challenge. There was, however, a challenge in the fact that they revealed that the AQMP has not been approved nor did it contain specific dust-management plans as well as that they did not believe that it would make a difference.
- Gold mines indicated no challenges in dust management planning as they did have an AQMP with specific DMP and also believed that an approved plan would improve dust problems. The potential challenge they revealed was that

they were not confident that their plan was based on ISO management principles.

Figure 4.3 represents the second part of the planning and dust management focus area and includes the rest of the question statements to reflect the rest of the response data.

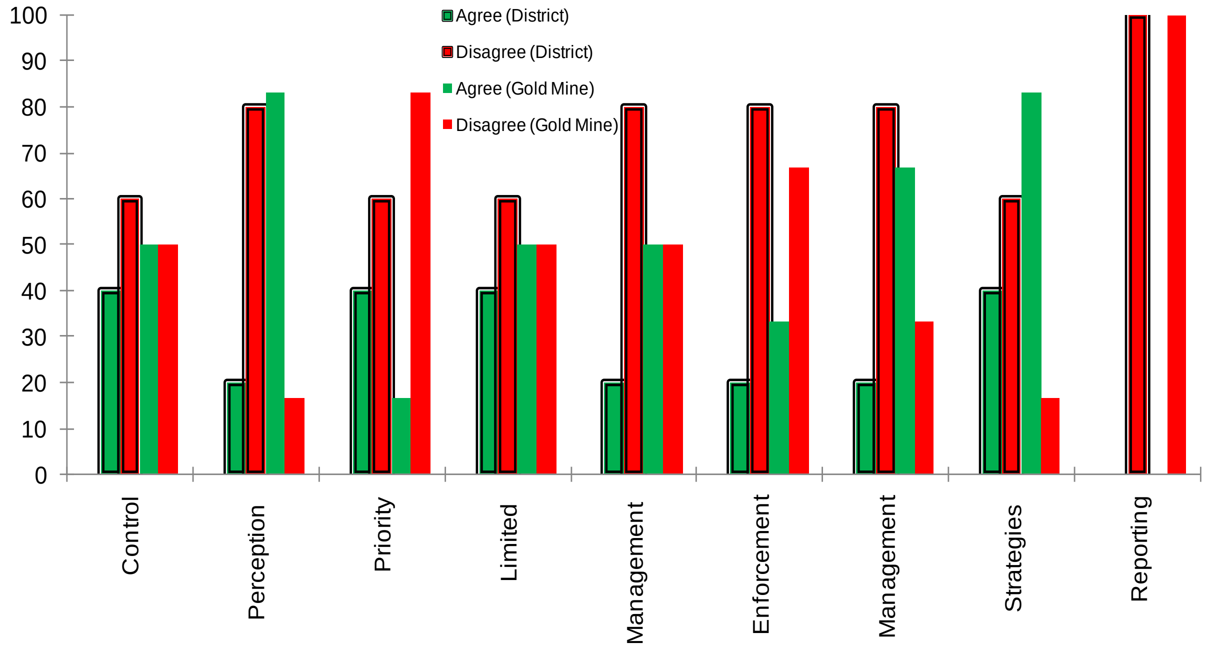

Figure 4.3: *Potential challenges of planning and dust management*

The first three columns of Figure 4.3 represent the responses of both district and gold mines with regard to the manner in which they treat and react to dust challenges. The air quality officers of the district municipalities disagreed with 60% that they only managed dust problems after these got reported and disagreed with 80% that they recognized dust deposition only as a nuisance problem reported by the public. The district also disagreed with 60% to the statement that they treated dust complaints and compliance as no real priority. The officers of gold mines only agreed with 50% that they only manage dust problems after it gets reported and agreed with 83.3% that they only see dust deposition as a nuisance problem reported by the public. The gold mines also disagreed 83.3% with the statement that they treat dust complaints and compliance with no real priority. By using the preceding data we can now make the following conclusions about the reactive control, perception and absence of priority component:

- The district indicated that there were no challenges regarding their perception of deposition dust or the priority with which they treated deposition dust-related problems.
- Gold mines indicated that there are no challenges regarding the priority they place on dust-related issues. There is, however, an indication of a possible challenge in the reactive way they manage dust problems.

Columns four to six of Figure 4.3 represent the approach of the district as well as gold-mining employees with regards to the their principles with regard to enforcing and regulating dust deposition. The air quality officers of the district disagreed with 60% that they did have a formal reporting line for dust-deposition exceedances. They then disagreed 80% with the statement that they did not enforce the dust-deposition standards and also disagreed with 80% that they had issued warnings to industries that did not comply with the SANS guidelines for dust deposition. The officers of gold mines agreed with 50% that they did not have a formal reporting line for dust-deposition exceedances and also agreed 50% that they did not enforce the dust-deposition standards as per guideline. They then disagreed 66.7% that they did issue warnings to employees whose actions resulted in deposition exceedances. By using the preceding data we can now make the following conclusions about the limited management, enforcement and regulation component:

- The districts revealed that there were no challenges in the reporting of dust-deposition exceedances or enforcing of compliance. The districts, however, indicated a possible challenge as no warnings for industries had ever been issued warnings for not complying with the SANS 1929 guideline.
- Gold mines revealed that there were possible challenges regarding their reporting line for dust-deposition exceedances and enforcement of compliance as well as issuing warnings to employees whose actions led to deposition exceedances.

The columns from seven to nine in Figure 4.3 represent the responses of the district and gold mines with regard to their dust management strategies and reporting. The officers of the district disagreed with 80% with the statement that they do have intervention plans to implement if necessary to reduce dust-deposition and also disagreed with 60% that they had a quality review process for dust management. The districts disagreed 100% that they reported to provincial government on an annual basis regarding the status and compliance of dust management within their region. The officers of the gold mining companies were 66.7% in agreement that they did have intervention plans to implement if necessary to reduce dust deposition and additionally agreed with 83.3% that they had a quality review process for dust management. The gold mines also disagreed 100% that they report to the district regarding the status and compliance of their dust management plans. By using the preceding data we can now make the following conclusions about the dust management strategies and reporting component:

- The districts indicated challenges due to the lack of intervention plans, quality review processes for dust management as well as reporting to provincial government on the status of dust management.
- The gold mines indicated no challenges regarding intervention plans or quality review processes for dust management. They indicated possible challenges due to the lack of reporting to district municipalities on their dust management status.

4.3.3 Information and participation

The final factor or focus area deemed necessary for successful and effective dust management within this research is the use of all available information as well as participation of all the stakeholders. This is the last of the three factors and although there are environmental laws, including the NEM: AQA which require compulsory community participation processes, the importance of the public and specialists cannot be denied. It can for example be a counter-bias and provide information to ensure continuous improvement practices. If there are challenges relevant to the availability of information and participation, there could potentially be challenges within dust management. To access and test these potential challenges within the information and participation processes of district municipalities and gold mining companies, nine questions were presented to 11 participants within the two district regions and the results are given in Figure 4.4.

Columns one to three of Figure 4.4 represent the answers of the district and gold mine employees concerning the amount of information and participation they use from government as part of their dust management plan. The districts disagreed with 80% that they rely on information from local municipalities or provincial government to improve or develop their dust management plan and furthermore disagreed with 80% that they do discuss dust problems within the district with any of the preceding parties on a regular basis. They also disagreed with 80% that they do receive continuous training and capacity building relevant to dust management from national or provincial government.

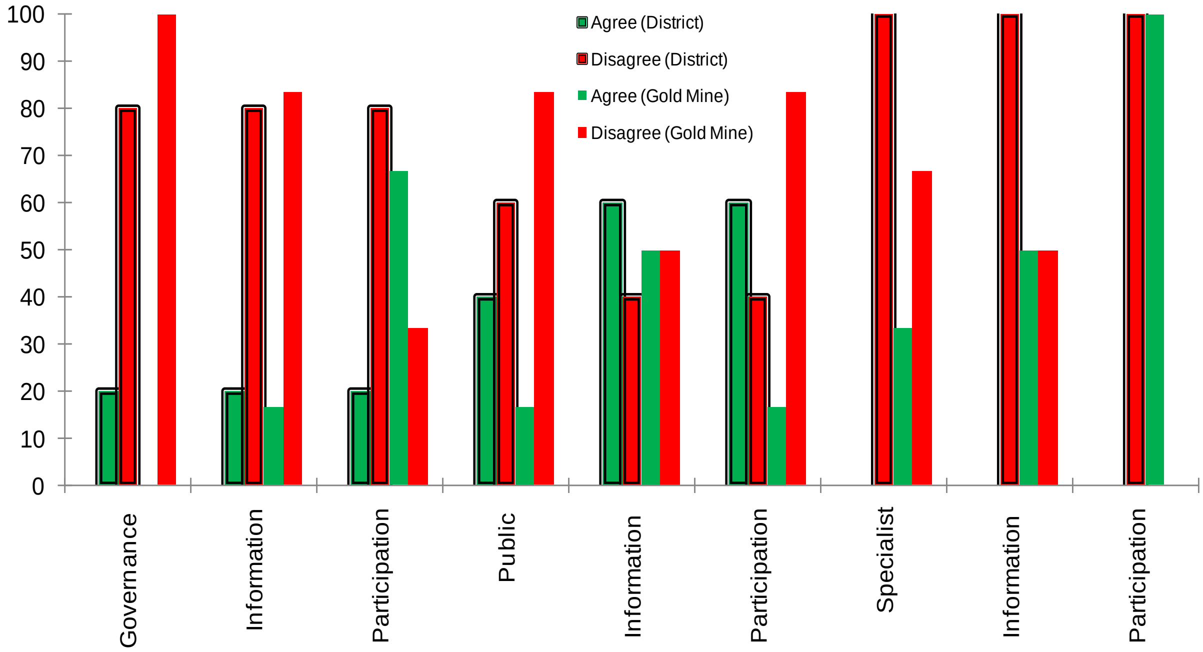

Figure 4.4: *Potential challenges of information and participation processes*

The gold mines disagreed totally (100%) that they relied on information from local municipalities or provincial government to improve or develop their dust management plan. The gold mines also disagreed with 83.3% that they discuss dust problems within the district or company with local or district municipalities. The gold mining officers then agreed with 66.7% that they did receive continuous training and capacity building relevant to dust management from local and district municipalities. By using the preceding data we can now make the following conclusions about the governance, information and participation component:

- The district revealed challenges regarding the lack of input from local municipalities and provincial government concerning dust management plans as well as inputs regarding dust problems. There are also potential challenges as a result of lack of training or capacity building from national and provincial government.

- Gold mines revealed challenges regarding the lack of input from local and district municipalities concerning the development and improvement of dust-management plans as well as inputs regarding persistent dust problems. Gold mines did, however, reveal no challenges regarding the continuous training and capacity-building they receive from local and district municipalities.

Columns four to six of Figure 4.4 indicate the approach the district and gold mine employees had towards including the public within their dust management process. The district disagreed with 60% that they included information of interested and affected parties when developing and improving their dust management plan. They agreed with 60%about discussing dust problems within the district with interested and affected parties on a regular basis. They also agreed with 60% that they provide continuous awareness campaigns, training and capacity-building for the public and workforce regarding dust and the management thereof. The gold mines on the other hand disagreed with 83.3% that they include information of interested and affected parties when developing and improving the dust management plan of the company. They only agreed with 50% that they do discuss dust problems within the district and company with interested and affected parties on a regular basis. They disagreed with 83.3% that they provide continuous awareness campaigns, training and capacity-building for the public and workforce regarding dust and the management thereof. By using the preceding data we can now make the following conclusions about the public information and participation component:

- The district indicated no challenges about receiving inputs from the public regarding dust problems or providing them with awareness campaigns, training and capacity building programmes. A challenge identified is that the district does not use any information of interested and affected parties to help develop and improve their dust management plan.
- Gold mines identified challenges regarding the lack of input from interested and affected parties within their dust management plan as well as facilitating awareness campaigns, training and capacity building to public and workforce regarding all matters of dust. Gold mines also indicated potential challenges due to the lack of input from the public regarding persistent dust problems.

Columns 7-9 of Figure 4.4 reflect the district and gold mine approach to the use of specialists as part of their dust-management process. The district disagreed with

100% that they use or include information of specialists in developing or improving dust-management plans and also disagreed with 100% that they discussed district dust problems with specialists. They furthermore disagreed with 100% that they contracted them for providing training and capacity building of air-quality officers regarding dust. The gold mines disagreed with 66.7% that they included information of specialists in developing or improving their dust management plan. The gold mines only agreed with 50% that they discussed dust problems with specialists while they agreed with 100% that they contracted specialists for providing training and capacity building of their officers regarding dust and the management thereof. By using the preceding data we can now make the following conclusions about the specialist information and participation component:

- The districts indicated challenges regarding the lack of specialists' input concerning their dust-management plan and all potential dust problems. The districts also indicated challenges due to a lack of specialists' input during continuous training and capacity building of air-quality officers.
- Gold mines indicated challenges regarding the input of specialists' information within their dust management plan and also challenges due to the lack of input regarding all potential dust problems. Gold mines indicated no challenges due to the lack of specialists' input during continuous training and capacity building of their pollution officers.

4.3.4 Dust challenges from a management perspective

In addition to the data generated from the officer level and thus operational part of dust-management plans and programmes, this research also collected data from a management level to test challenges that relate more to decision-making and planning activities. These data were generated by using open-ended questions conducted as interviews in which the target population could express themselves in a more adequate way. This additional information will not only confirm or contradict the patterns and responses from the closed-ended surveys but also add additional information in order to identify more challenges. The open-ended questionnaires used to gather information comprised 14 questions that tested 14 components relating to the main focus areas identified during the study. These following paragraphs will discuss the collected data for the district municipalities and gold mines separately.

4.3.4.1 District municipalities

To access and test the challenges within management level in the district municipalities, 14 questions were presented to two participants within the two districts of which the results will now be discussed per question.

The first question related to problems within their dust-monitoring network component and the responses indicated that not one of the districts have their own dust monitoring network in place. The second question related to the dust-monitoring techniques and guideline component of which the response ranged from the guidelines not being adequate to not knowing what the guideline was. The third question related to the dust-sources component and both districts acknowledged that they did receive dust complaints of which one district said it was in months during which they did comply with the dust fall-out standards. Question four had relevance to the nuisance dust-standard component and both districts responded that the same source of dust could be managed and restricted by enforcing two different standards. Question five had reference to the dust management capacity component the districts responded with an honours degree in environmental management and a degree in environmental science as qualifications of the highest-qualified employees responsible for implementing and maintaining a dust management network. Question six related to the financial resources component and the districts responded from not having funding to even acquiring their own dust-monitoring equipment to have funding but not be able to get it allocated. The inadequate funds allocated to their programme are a result of government believing the polluter must pay and thus monitor its own deposition. The seventh question was relevant to the dust management policy and framework component and the district responded that they are held responsible for dust deposition with higher priority in terms of nuisance complaints. Question eight had reference to the dust management planning component and the districts indicated that government should centralize funding and in general more resources should be allocated for monitoring. The national government should be stricter on polluters and locate specialists to the districts to help with the programme.

Question nine was relevant to reactive control, perception and absence of priority components and the districts indicated that they did not have a dust management system in response to its effectiveness. Question ten was in reference to the limited management, enforcement and regulation component and the district response included enforcement and regulations and for the dust management function to be blamed for persistent dust problems and complaints within the district as well as the dust fall-out standard itself. Question eleven had relevance to the dust management strategies and reporting component and the districts indicated that they had no programme in place in response to what part of one's programme received the least attention. We can note that a response of no dedicated department was also made. Question twelve was relevant to the co-operative governance information and participation component and the districts' responses ranged from no contribution of government to dust management programme to subsidizing three monitoring stations for the district. The second last question related to the public information and participation component and the district indicated that no real contribution was made, but just complaints were received. The last question has reference to the specialist information and participation component and the districts indicated that they did not use any contribution of specialists within their dust management programme. By using the preceding data we can now make the following conclusions about challenges within each focus area tested:

- **Dust-monitoring area**: The response from the districts to the potential challenges tested indicates a major challenge within this focus area primarily due to the fact that none of the districts have their own dust-monitoring network. This presented a problem as the rest of the questions tested all relate to a dust-monitoring network which is absent. Despite this the response to tested challenges will be of great value due to operational knowledge and experience of industrial data. Districts indicated a definite challenge relating to the current guidelines and standards as well as operational understanding of it, although no challenge was identified in using two different dust standards for managing dust sources.
- **Planning and dust-management area**: The district indicated no challenge regarding the technical capacity for the operation of dust management. Definite challenges were identified for financial resources, dust-management policy, dust-management assistance, dust management systems, enforcement and regulation as well as dust management strategies.
- **Information and participation area**: The districts revealed major challenges within this focus area as the tested components indicated

challenges for information and participation of government, public and specialists leaving the district virtually isolated regarding assistance on all matters relating to dust management.

4.3.4.2 Gold mines

To access and test the challenges within the management levels of gold mines, 14 questions were presented to two participants within two of the major gold mining companies of the selected regions of which the results will now be discussed per question.

The first question related to problems within their dust-monitoring network component and the responses indicated that the biggest challenge relates to the dust-monitoring equipment itself being stolen, damaged as well as the placement and availability of right equipment. The second question related to the dust-monitoring techniques and guideline component of which the response ranged from the guidelines being adequate to not being adequate as climatic factors are not considered within the guidelines. The third question related to the dust-sources component and everyone agreed that they did receive dust complaints in the months in which they did comply with the dust fall-out standards. Question four had relevance to the nuisance dust-standard component and gold mines' responses ranged from yes to no with regards to the same sources of dust that can be managed and restricted by enforcing two different standards. Question five had reference to the dust management capacity component and gold mines responded with information ranging from no graduate qualifications in science or environmental management of employees responsible for implementing and maintaining a dust-management network, although the networks were mostly contracted out to consultants. Question six related to the financial resources component and gold mines responded from not having any funding due to the current state of gold mines in South Africa to needing to convince top management that it is necessary in order to achieve the SANS 1929 guidelines. The seventh question was relevant to the dust management policy and framework component and gold mines responded that they were held more responsible for nuisance dust complaints. Question eight had reference to the dust management planning component and gold mines indicated that government should monitor municipal areas and identify sources so they can differentiate between mine dust and dust from other sources.

Question nine was relevant to reactive control, perception and absence of priority components and gold mines responded that they had improved considerably on their dust fall-out and that they did comply with monthly dust fall-out standards. Question ten was in reference to limited management, enforcement and regulation component and gold mines response included enforcement and regulations and dust-management functions to be blamed for persistent dust problems and complaints. Question eleven had relevance to the dust management strategies and reporting component and gold mines indicated the control over vehicles to unauthorized sites as well as external auditing of dust management programmes to be the part of their programme that received the least attention. Question twelve was relevant to co-operative governance information and participation component and gold mines responses ranged from no contribution of government to dust management programmes to auditing of programmes by the Department of Mineral Resources (DMR). The second last question related to the public information and participation component and gold mines responded in a range from the public forming an integral part of discussions at forums to provide important information in the form of reporting, to the public not even knowing where to report or complain. The last question has reference to the specialist information and participation component and gold mines responded that they did use specialists and that they though their contribution was significant. It was also noted that some of the gold mines believe that many of the consultants rendering services as specialists are no specialists and can only provide them with the bare essentials. By using the preceding data we can now make the following conclusions about challenges within each focus area tested:

- **Dust-monitoring area**: Gold mines' response to the tested challenges indicates minor challenges within their monitoring network itself which can be mitigated. A definite challenge was identified regarding the dust-deposition standard. The response from gold mines regarding the current guidelines and two separate deposition standards was divided between being a challenge and not being a challenge and due to the uncertainty this study will recognize it as a potential challenge.

- **Planning and dust-management area**: Gold mines indicated definite challenges regarding the technical capacity, financial resources, dust-management policy, dust-management assistance, enforcement and regulation. Gold mines indicated minor challenges within their management strategies which can be easily mitigated, while no challenges were identified within their current dust-management systems.

- **Information and participation area**: Gold mines revealed a split in response to tested challenges within this focus area where information and participation of government and public were identified as both having challenges as well as not having challenges. Due to the uncertainty this study will recognize both as having potential challenges. Gold mines did not, however, identify any challenges regarding information and participation of specialists within their dust management programmes.

4.3.5 Key challenges identified for dust management within the district municipalities

Paragraphs 4.3.1-3 and 4.3.4.1 discussed in depth the responses of the operational and management levels of district municipalities to each individual question, component and focus area relevant to this study. By incorporating and assessing all of the preceding data we can now begin to validate the initial identified challenges within the district which were the following:

The district municipalities indicated a key challenge for designing a dust management network as well as source-specific dust-monitoring methods and subsequently do not have their own networks. The districts also indicated key challenges within the guidelines and standards' ability to ensure effective dust management. They further identified challenges with the accuracy of the monthly deposition data. Another key challenge is that the district does not have formally appointed air-quality officers or in-house skills to develop a DMP. The districts revealed that although they have the available financial resources to develop and maintain a dust management network it is major challenge to get the financial resources allocated. The reason for this is that government believes in the polluter-pay principle and subsequently that the industry must do their own monitoring. Another key challenge is that the district does not have an approved AQMP with specific DMP contained within it. An indirect but also key challenge identified is the fact that districts believe that having an approved AQMP with specific DMP will not make a difference to dust management. The districts revealed a possible key challenge which could implicate the deposition standard as not being adequate. This they did by acknowledging that they do not issue warnings to industries for not complying with the SANS 1929 guideline. This could either be the result of no over-exceedances or reporting failures although the district confirmed no challenges in reporting either exceedances or enforcing compliance. This would then indicate the deposition standard not to be adequate as dust complaints were conceded to still remain an issue. The district revealed key challenges regarding the availability of intervention plans and the lack of quality review process or system in place for dust management. They also indicated a key challenge as being that they did not get any assistance nor did they report to other spheres of government on any matters related to dust management. The district also identified a key challenge by not using any information, knowledge or assistance from interested and affected parties or specialists within their DMP or programme.

4.3.6 Key challenges identified for dust management within gold mines

Paragraphs 4.3.1-3 and 4.3.4.2 discussed in depth the responses of the operational and management levels of gold mines to each individual question, component and focus area relevant to this study. By incorporating and assessing all the preceding data we can now begin to validate the initial identified challenges within gold mines which were the following:

Gold mines indicated only minor challenges within the maintenance of the dust-monitoring network. Gold mines indicated a key challenge with the deposition-dust standard which is confirmed with the identified key challenge of dust complaints received in the months when they comply with the standards. Gold mines also identified a key challenge by using the ASTM D1739 monitoring method within dust management and this challenge was substantiated by identified key challenges with the accuracy of monthly deposition dust data. A possible key challenge identified is the fact that gold mines do not have officers or managers maintaining and implementing dust management programmes – these would be qualified graduates of science or environmental management. Part of the challenge is the fact that gold mines have indicated that they have the technical skills to develop, maintain and implement a dust management programme. Gold mines indicated a minor challenge of not having a dedicated air-quality department as well as a key challenge for obtaining financial provision for developing and implementing a DMP. They also have a key challenge in not having dust management objectives included within their AQMP. They also have minor challenges in the reactive way in which they treat dust problems as well as key challenges within their reporting line and in-house enforcement of compliance. They also identify government's lack of enforcement and regulation as well as dust management in general as a key challenge relating to dust problems within the district. The gold mines in addition identified the lack of input from government to the development and improvement of their dust management plan and dust problems as key challenges but also admit reporting to government on their dust management status to be a challenge. Gold mines identified a lack of input from interested and affected parties within their dust management plan as a key challenge. Gold mines identified a lack of input of specialists within their dust management plan as a key challenge but admit that they do make use of them. It was also noted that gold mines felt that a lot of the air-quality consultants contracting themselves out as specialists only provide a basic service to monitoring dust deposition and could not solve dust-related problems. The facilitation of awareness campaigns, training and capacity building to public and workforce regarding all matters of dust as well as being trained by specialists also remains a key challenge.

4.3.7 Dust-management challenges from a specialist's perspective

In addition to the data generated from the stakeholders directly involved in dust management and regulation, this research also collected data from specialists to obtain information from a more technical point and certain level of objectivity. The data were generated by using open-ended questions conducted as interviews. This additional information will confirm patterns and responses from the data generated from districts and gold mines and add additional information for the identification of challenges. The open-ended questionnaires used to gather information comprised out of 15 questions testing the main focus areas identified during the study but focusing mainly on the components relating to dust monitoring network, monitoring technique and standard. It did include some questions relating to the dust management programme. To access and test potential challenges within the preceding focus areas, 15 questions were presented to four participants and their responses were used to identify the following possible challenges:

Possible challenges facing a dust-monitoring network:

- Cost of equipment and maintenance thereof;
- Technical capacity to develop networks;

- Monitoring costs;
- Accurate determination of total dust fall-out;
- Capacity needed for regional data base management and interpretation;
- Lack of effective standards;
- Support from municipalities and land owners;
- Lack of importance leads to lack of regulation and subsequent networks; and
- Lack of scientific background.

Possible challenges facing a dust-monitoring technique and methodology:

- Incorporating meteorological and geographical factors of the district/region;
- Correct placement of buckets with relevance to source;
- Correct placement of buckets with relevance to sensitive receptors;
- ASTM monitoring method could be improved;
- ASTM monitoring method is a very rudimentary method and highly inaccurate when it comes to accurate mass determination;
- Monitoring methods relevant to smaller size fractions are needed for more effective management of dust sources.

Possible challenges facing the deposition-dust standard:

- The actual size fraction considered to be either deposition or nuisance dust;
- Regional dust standards too complex to manage and implement;
- Deposition standard of 600 $mg.m^{-2}.day^{-1}$ not adequate to limit dust complaints; and
- Current dust deposition standard does not nearly resemble international standards.

Possible challenges facing the dust-deposition management programme:

- Incorporate background dust of regions during source management;
- Understanding seasonal climatically conditions and planning for them;
- Districts currently do not have the capacity or technical ability to successfully manage dust deposition within gold mining regions;
- Government not taking responsibility for managing deposition data;

- Gold mining companies not held responsible for generating deposition data;
- Gold mining companies not held responsible for not contracting specialists to facilitate dust-management strategies between government and gold mines to manage regional dust-deposition;
- The general exclusion of interested and affected parties from programmes who could provide invaluable knowledge, contributions and potential capacity once educated on dust matters;
- The use of dispersion modelling as it is highly inaccurate due to ever-changing climatic conditions and lack of real emission factors; and
- Lack of training by specialists of both gold mine and district air-quality officers in dust management.

4.3.8 Dust management challenges from a public perspective

In addition to the data generated from the stakeholders directly involved in dust management and regulation as well as specialists in the field, this research also collected data from the public and NGOs to obtain information from a more personal level. The data were generated by using open-ended questions conducted as interviews. This additional information will confirm patterns and responses from the preceding data and add additional information for the identification of more challenges. The open-ended questionnaires used to gather information comprised 12 questions testing some of the components relating to the main focus areas identified during the study. The questions did, however, focus mainly on the components relevant to dust management which affect and reflect on the effectiveness of dust management within their district. To access and test potential challenges within dust monitoring and management, 12 questions were presented to 10 participants and their response were as follows:

Possible challenges facing dust-deposition standards:

- The standard for dust-deposition should be the same for industrial as well as residential areas; and
- Dust is affecting the public both at home and work as they live too close to mining activities.

Possible challenges facing the successful management of dust within the districts:

- Managing dust emissions from mining activities;
- No enforcement by authorities;
- Districts do not have the capacity, commitment or political will to manage dust effectively;
- Both the district and gold mines are not taking responsibility for their sources;
- Visible dust in atmosphere and on surfaces as well as the effect of allergies and sinusitis during events;
- No clear evidence that district has acted on dust complaints or results of their interventions;
- Lack of public awareness of dust management regulations;
- Lack of public awareness of dust-monitoring networks or its status;
- Not effective - too much dust visible;
- Lack of public awareness of district dust management forums;
- Public inputs are rarely implemented by districts;
- Lack of public awareness of mining dust management meetings; and
- Public inputs are rarely implemented by mining companies.

4.4 Dependences and linkages

In total 37 questionnaires were distributed among two district municipalities, seven gold-mining companies, ten interested and affected parties including two NGOs, as well as five specialists. A total response rate of 81.1% was achieved with the highest and quickest response coming from the interested and affected parties followed by districts then specialists and ending with gold mines coming in at last place. The following final assessment directly relates to the main challenges of dust management in its entirety within gold mining regions of South Africa as concluded from the research study.

This study clearly showed that the single biggest challenge facing dust management within gold mining regions of South Africa has relevance to the dust monitoring itself. This includes the standard itself, the guidelines as well as the monitoring method which was confirmed (Paragraphs 4.3.5 and 4.3.6) through the questionnaires with both the district and the gold mines. The possible challenges regarding the monitoring methods ability to accurate determine the dust-deposition in gold mining regions were firstly identified in Paragraph 2.5.2.2 (Chapter 2) and confirmed not only by questionnaires distributed to gold mines and districts but also by specialists in Paragraph 4.3.7. The biggest single challenge facing dust management relevant to the monitoring of dust deposition will definitely be the dust-deposition standard itself. The challenges regarding the deposition-dust standard were initially indicated within Paragraph 2.6.2 (Chapter 2) and confirmed not only by questionnaires to gold mines and districts (Paragraphs 4.3.5 and 4.3.6) but also by specialists in Paragraph 4.3.7. The challenge to the deposition standard also relates to complicating factors such as the seasonal and daily nature of deposition of dust identified by literature in Paragraph 2.5.2.3 (Chapter 2) and confirmed by questionnaires to the district and gold mines (Paragraph 4.3.1). Another important challenge of dust management relating to deposition dust standards is the separation of industrial and residential areas and subsequent standards. This presents a definite challenge as identified in Paragraph 2.6.2 and confirmed by the questionnaires to the public in Paragraph 4.3.8. The last and most complex and potentially biggest challenge facing dust management in relevance to the monitoring of it will be the actual size fraction considered as deposition-dust. This research clearly indicates this potential challenge in Paragraph 2.6.1 (Chapter 2) which is confirmed by questionnaires to specialists in Paragraph 4.3.7.

The second area of concern and the single most important part of dust management is the planning and dust management process itself. The biggest challenges of dust management from district point of view are the challenges of financial provision for dust-monitoring networks and although the questionnaires to officers (Paragraph 4.3.2) indicated that there were enough resources available, the questionnaires to managers (Paragraph 4.3.4.1) indicated that the available resources were not allocated to the departments as government does not believe they should do any dust monitoring. The gold mines on the other hand indicated that they have challenges in allocating the financial provision for implementing effective dust management (Paragraph 4.3.6) but also indicate that they use consulting specialists- which will most probably cost more than doing it in-house. The main challenge concerning technical skills within the district showed that districts feel (Paragraph 4.3.2) that they do not have the skills to develop a dust management plan, although Paragraph 4.3.4.1 showed that they do have the necessary tertiary qualifications. This is the opposite of the challenge facing the technical skills within gold mines who believe from Paragraph 4.3.2 that they have the skills but Paragraph 4.3.4.2 showed that they have not. Another definite challenge regarding dust management is the general lack of a specific DMP within approved or unapproved AQMPs as indicated in Paragraphs 4.3.5 and 4.3.6 and the fact that districts do not believe that this would make a difference to their dust problems within the district. The general lack of regulation and enforcement of compliance standards by both district and gold mines which is confirmed in Paragraph 4.3.5 and 4.3.6 is a major challenge for dust management and directly influences the standard's ability to manage dust deposition problems.

The last area of concern for effective dust management relates to information and participation. This study confirms through Paragraphs 4.3.5 and 4.3.6 that the biggest challenge within this area is that neither districts nor gold mines receive any assistance nor do they report to government with regards to their dust management programme. This poses a challenge as it limits both the district's and gold mines' ability to enforce and improve their dust management programmes. The lack of use of information provided by interested and affected parties (Paragraph 4.3.8) within the dust management plan of both the district and gold mines is a major challenge as deposition-dust regulations were initiated to protect the public and their property (Paragraph 2.6.1) in the first place. The biggest challenge, however, as identified in the study for this focus area is the lack of specialist involvement in dust management plans and programmes of both districts and gold mines (confirmed by Paragraphs 4.3.5 and 4.3.6). There are, however, implications regarding the capacity of consultants rendering services as air-quality specialists (confirmed in Paragraph 4.3.4.2). It is the view of the author that when it comes to using consultants a clear distinction should be made between dust management and monitoring as the necessary qualifications relevant to each of the areas are totally different. It was confirmed by questionnaires to specialists (Paragraph 4.3.7) that there is a general lack of scientific knowledge within dust management. It is furthermore the author's view that to render air-quality services specifically pertaining to monitoring one should at least have a tertiary qualification in science. This will also be an advantage as it is generally accepted that if you know scientifically where and how exactly your data are generated you will be more equipped to interpret it and decide on how to properly manage it.

CHAPTER 5

Critical reflections

In this chapter, the study will be evaluated in terms of its success in achieving the study objectives.

5.1 Research objectives

The success of this study will be evaluated according to the extent that the objectives set in Chapter 1 were achieved, as well as how the overall research aim was achieved. Moreover, recommendations are made on how to take dust management forward. The initial objectives are presented in Paragraph 1.5 and the critical evaluation of each given in the same order.

5.1.1 To investigate the sources of regional dust within mining districts of South Africa and to identify potential challenges relating to the management thereof.

This was done by critically analysing the sources, composition, distribution, and frequency of dust specific to regions in South Africa where gold mining is prevalent. This was done by critically discussing the diversity of dust sources within gold mining districts and the influence of the different sources as well as the meteorological conditions on the impact of dust within the district. By documenting the individuality and behaviour of dust within a gold mining region and how it complexes its management especially from a monitoring point of view assisted the writer of this study to identify general challenges relating to the management of dust within these regions.

5.1.2 To investigate the dust-deposition guidelines, standards and monitoring techniques used within dust management and to identify potential challenges it faces.

This was done by firstly using the globally available dust-monitoring techniques and critically analysing their ability to effectively monitor the sources of dust within gold mining regions in South Africa. This was also done in respect of the complex factors of composition, distribution, and frequency of dust, specific to regions where gold mining is prevalent. This enabled the researcher to successfully identify possible challenges to be incorporated and tested within the quantitative surveys which were developed in the later chapters. Secondly, the South African dust-deposition standard was compared to international standards and critically analysed with regard to the standard's ability to effectively manage dust-deposition within gold mining districts of South Africa. This allowed the study to successfully identify challenges within the deposition standard to be incorporated and tested within the quantitative surveys which were developed in the later chapters.

5.1.3 To investigate the key elements required of a successful dust management plan and programme in order to identify potential challenges which could restrict the plans or programmes of dust management from solving persistent dust problems

This was successfully done by investigating the validated method and results as obtained by J.C. Engelbrecht (Engelbrecht, 2006) to identify the key elements required for successful air quality management around the world. This study, however, selected the elements identified within an AQMP which overlaps with the challenges identified within this study due to the specificity of dust and its management. This allowed the study to successfully identify and focus on possible challenges within the management plan and programme restricting effective dust management. The identified challenges were then successfully incorporated and tested within the quantitative surveys developed within the later chapters.

5.1.4 To test the identified challenges through purposefully designed questionnaires distributed to the district municipalities, gold mining companies, interested and affected parties and specialists involved with dust management within the identified gold mining regions of South Africa.

This was successfully done by developing appropriate questionnaires by incorporating the identified challenges of objectives i to iii. The questionnaires were then successfully distributed to all stakeholders of the research study and a response rate of 81.1 %, was obtained, which can be deemed as an adequate and a fair reflection of the sample population in order to validate the results. The results obtained were then used to successfully identify and rate the relevancy of the tested challenges.

5.1.5 To critically evaluate the relevant challenges

In terms of the objective to critically evaluate the relevant challenges, the objective was successfully realized and in this way it was possible to identify the most significant challenges to dust management as the following (in no particular order of importance):

- The monitoring networks;
- The monitoring method;
- The deposition standard;
- Financial provision;
- Technical skills and capacity;
- Specific dust management plans within an AQMP;
- Limited regulation and enforcement;
- Limited information and participation of government;
- Limited information and participation of interested and affected parties; and
- Limited information and participation of specialists.

All the preceding significant challenges were identified from the results of the questionnaires to the district municipalities, gold mining companies, interested and affected parties as well as the dust specialists and successfully linked back to the authenticated and referenced literature from which the challenges were initially identified. Additional potential challenges observed by the author and not referenced by literature were also successfully linked back to results obtained from the questionnaires. The preceding paragraphs which discussed how the objectives of one to five were successfully completed also then complete the main aim of this study as it describes how the challenges resulting in persistent dust problems were initially identified and tested in order to critically assess the challenges for dust management within the gold-mining regions of South Africa.

5.2 Areas of future research

The only real disappointment of the study was the initial response to questionnaires and the general attitude of most of the stakeholders in participating in the study. Another significant disappointment was the representation of gold mines and subsequent sample size of the gold mines in relevance to the magnitude of their operations within each of the selected districts (which was not reasonable). This could result in the loss of valuable information and a lack of interpretation of the dust management programmes within the selected regions.

It will be of value for the future to research the fraction size for classification of deposition-dust as this will determine the methods to be used to monitor its deposition which will have a significant influence on the resulting management of it. The subsequent classification of dust sources will also depend on the size fraction of the dust which will determine the importance of its regulation. There is also a need for investigating potential solutions with regards to the responsibility of dust-deposition and its impacts and the financial implications it holds for both government and industries. A further investigation into the capacity of air quality specialists and consultants should be conducted if neither government nor industry employs specialists but rather decide to use consultants who in most cases cannot solve dust-related problems. Future research on dust deposition and management within South Africa should also include the other mining sectors such as platinum, iron and coal which will provide valuable information on more regions, sources and climates of South Africa which will assist in general dust management solutions.

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APPENDIX 1

Closed structured Questionnaire to District Municipality

Statement number	Question	Strongly Disagree	Disagree	Agree	Strongly Agree
1	Our District Municipality appointed air-quality officers for dust management				
2	Our District Municipality has a dust-monitoring network specifically designed for its sources and region				
3	Our District Municipality relies on information of all relevant local municipalities as well the provincial government when developing and improving the dust management plans for the District				
4	Our District Municipality air-quality officers do report annually to provincial government regarding the status and compliance of dust management within the District				
5	Our District Municipality has the technical skills to develop a dust-management plan				
6	Our District Municipality believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations is sufficient for managing dust deposition within our District				
7	Our District Municipality relies on and includes information of all interested and affected parties when developing and improving the dust-management plan of the District				
8	Our District Municipality has issued warnings to industries which do not comply with SANS 1929 guidelines for dust deposition				
9	Our District Municipality has a vision, mission and objectives for dust management relevant and specific to our District.				
10	Our District Municipality has a list of all the major sources and contributors to dust deposition within the District				

11	Our District Municipality relies on and includes information of specialists when developing and improving the dust management plan for the District				
12	Our District Municipality treats dust complaints and compliance as no real priority				
13	Our District Municipality has an AQMP submitted within its IDP				
14	Our District Municipality considers all dust from surface mining activities to be deposition or nuisance dust				
15	Our District Municipality discusses dust problems within the District with all relevant local municipalities as well the provincial government on a regular basis				
16	Our District Municipality dust management objectives are included within an AQMP				
17	Our District Municipality only manages dust problems after they get reported				
18	Our District Municipality carefully considered our regional climatic conditions before designing our dust-monitoring network.				
19	Our District Municipality discusses dust problems within the District with all interested and affected parties on regular bases				
20	An approved AQMP including specific dust-management plans will improve air quality and potentially solve all dust-related problems within our District				
21	Our District Municipality has no formal reporting line for dust-deposition exceedances				
22	Our District Municipality believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations will reduce public complaints due to dust deposition				
23	Our District Municipality discusses dust problems within the District with specialists on a regular basis				
24	Our District Municipality makes use of financial provisions available outside the District to develop, implement and maintain a dust-management plan				
25	Our District Municipality has intervention plans available which we can implement to reduce dust deposition if necessary				
26	Our District Municipality manages dust deposition by monitoring major dust sources with methods specifically designed for each individual source of dust.				
27	Our District Municipality air quality officers receive continuous training and capacity building relevant to dust management from national and provincial government.				

28	Our District Municipality has a dedicated air-quality management section/department responsible for dust management				
29	Our District Municipality complies with the monthly deposition or dust-fall standard of the SANS 1929 guideline				
30	Our District Municipality provides continuous awareness campaigns, as well as training and capacity-building for the public, work-force and systems and structures regarding all matters relating to dust and the management thereof.				
31	Our District Municipality has an adequate budget and financial provision to develop, implement and maintain a dust-management plan				
32	Our District Municipality has a dust-monitoring network specifically designed according the region's source inventories				
33	Our District Municipality contracts specialists for continuous training and capacity-building of air-quality officers regarding dust and the management thereof.				
34	Our District Municipality's dust management objectives relating to standards are different from the SANS 1929 guideline or draft of National Dust Control Regulations.				
35	Our District Municipality believes that the ASTM D1739 dust-monitoring method is the best monitoring method to ensure the effective management of dust deposition in our District				
36	Our District Municipality has an approved AQMP with specific dust-management plans				
37	Our District Municipality only recognizes dust deposition as a nuisance reported by the public				
38	Our District Municipality source contribution to visible daily dust events is not adequately reflected in the monthly averaged dust-deposition data of the District.				
39	Our District Municipality does not enforce compliance with dust-deposition standards of SANS 1929 guidelines				
40	Our District Municipality believes that a single dust-fall or deposition standard will be sufficient to manage the seasonal effect of dust deposition in our District.				
41	Our District Municipality has a quality review process for dust management				
42	Our District Municipality has the technical skills to maintain and implement a dust-management programme				

APPENDIX 2

Closed structured Questionnaire to Gold Mines

Statement number	Question	Strongly Disagree	Disagree	Agree	Strongly Agree
1	Our Company appointed pollution control officers for dust management				
2	Our Company has a dust-monitoring network specifically designed for our sources and region				
3	Our Company relies on information of local and district municipalities for developing and improving our dust-management plan				
4	Our Companies pollution control officers do report to the District Municipality regarding the status and compliance of its dust management plan				
5	Our Company has the technical skills to develop a dust-management plan				
6	Our Company believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations is sufficient for managing our dust deposition				
7	Our Company relies on and includes information of all interested and affected parties when developing and improving the dust-management plan of the Company				
8	Our Company has issued warnings to employees whose actions resulted in dust-deposition exceedances				
9	Our Company has a vision, mission and objectives for dust management relevant and specific to our activities and requirements.				
10	Our Company has a list of all the sources of dust deposition within the Company				
11	Our Company relies on and includes information of specialists when developing and improving the dust-management plan of the company				
12	Our Company treats dust complaints and compliance with no real priority				
13	Our Company has an AQMP with specific dust-management plans				

14	Our Company considers all dust from our surface activities to be deposition or nuisance dust				
15	Our Company discusses dust problems within the company and district with local and District municipalities on a regular basis				
16	Our Company’s dust-management objectives are included within an AQMP				
17	Our Company only manages dust problems after they get reported				
18	Our Company carefully considered our regional climatic conditions before designing our dust-monitoring network.				
19	Our Company discuss dust problems within the company and the District with all interested and affected parties on regular bases				
20	An approved AQMP including specific dust-management plans will improve all dust-related problems within our Company				
21	Our Company has no formal reporting line for dust-deposition exceedances				
22	Our Company believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations will reduce public complaints due to dust deposition				
23	Our Company discusses all potential dust problems within the company with specialists on a regular basis				
24	Our Company makes use of specialists outside the company to develop, implement and maintain a dust-management plan				
25	Our Company has intervention plans available which we can implement to reduce dust deposition if necessary				
26	Our Company manages dust deposition by monitoring major dust sources with methods specifically designed for each individual source.				
27	Our pollution control officers receive continuous training and capacity-building relevant to dust management from local and district municipalities				
28	Our Company has a dedicated department responsible for dust management				
29	Our Company complies with the monthly deposition or dust-fall standard of SANS 1929 guideline				
30	Our Company provides continuous awareness campaigns, as well as training and capacity building for the public, our workforce as well as systems and structures regarding all matters relating to dust and the management thereof.				

31	Our Company has an adequate budget and financial provision to develop, implement and maintain a dust-management plan				
32	Our Company has a dust-monitoring network specifically designed according to our source inventories				
33	Our Company contracts specialists for continuous training and capacity-building of pollution control officers regarding dust and the management thereof				
34	Our Companies dust management objectives relating to standards are different from the SANS 1929 guideline				
35	Our Company believes that the ASTM D1739 dust-monitoring method is the best monitoring method to ensure the effective management of dust deposition for our Company				
36	Our Company has an AQMP based on ISO management principals				
37	Our Company only recognizes dust deposition as a nuisance reported by the public				
38	Our Company's dust sources contribution to visible daily dust events is not adequately reflected in the monthly dust-deposition data				
39	Our Company does not enforce compliance with dust deposition standards as per SANS 1929 guideline				
40	Our Company believes that a single dust-fall or deposition standard will be sufficient to manage the seasonal effect of dust deposition				
41	Our Company has a quality review process for dust management				
42	Our Company has the technical skills to maintain and implement a dust-management programme				

APPENDIX 3

Open ended questionnaire to Managers

1. What are your biggest challenges in maintaining your current dust-monitoring network?

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2. Do you think the SANS 1929 guideline on dust deposition and management is sufficient to guide you to successfully control your dust deposition to levels acceptable to all the interested and affected parties, and if not, why not?

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3. Do you still receive nuisance dust complaints in the months where you do comply with the dust fall-out standards?

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4. Do you think that the sources of dust can be effectively managed by using two different dust fall-out standards, and if not, why not?

---

5. What are the background training and qualifications of your most qualified employee responsible for implementing and maintaining a dust-management network?

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6. What are the general challenges for you as manager to acquire the necessary funding to implement or improve your dust-management programme?

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7. As manager of air quality are you held more responsible for nuisance complaints or exceeding fall-out dust standards?

8. What do you think government can do to guide you as manager to improve your ability to manage your dust deposition to an acceptable level to all interested and affected parties?

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9. To what extent do you consider your current dust-management system to be effective?

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10. If dust problems and complaints within your District persist, what out of the following four reasons would you think the reason would be: the dust fall-out standards themselves, dust fall-out guidelines, enforcement and regulations or the dust-management function?

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11. What part of your dust-management programme receives the least attention and why?

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12. What is the contribution of government to your dust-management programme?

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13. What is the contribution of interested and affected parties to your dust-management programme?

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14. What is the contribution of specialists to your dust-management programme?

APPENDIX 4

Open-ended questionnaire to Specialists

1. What do you think the biggest challenges are for developing an effective dust-monitoring network for a District?

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2. How big of a role do the dust sources play when determining the distance of a deposition-gauge monitoring site from the source to be monitored and managed? Why?

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3. Do you think the ASTM D1739 dust monitoring method is the best available dust-deposition monitoring method for the South African conditions? Why?

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4. What size fraction do you classify as deposition or nuisance dust and why?

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5. Do you think different regions within South Africa should have different dust-deposition standards, and why?

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6. Can seasonal dust deposition be managed? Why ?

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7. Do you think dust complaints as a result of dust deposition in South Africa can be limited by using the 600 $mg.m^{-2}.day^{-1}$deposition standard for residential areas? Why?

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8. Do you think part of the dust-management problem is the separation of industrial and residential dust fall-out standards? Why?

9. Do you think the District Municipalities have the capacity and technical ability to successfully manage dust deposition within Districts where gold mining is prevalent? Why?

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10. Who do you consider to be the main role player in dust-deposition monitoring and management, District Municipalities or Gold-mining companies, and why?

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11. Do you think interested and affected parties should be more involved in the dust-management programmes of District Municipalities and gold-mining companies, and why?

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12. Do you think dispersion modelling should at any point replace dust-deposition (gauge) data within baseline assessment or source inventories, and why?

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13. What is the extent of training of air-quality officers of District Municipalities and gold-mining companies with regards to dust-deposition monitoring and data interpretation with which you have been involved?

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14. Do you think dust sources could be managed more effectively by measuring their dust emissions with methods relevant to smaller size fractions than it is now? What monitoring techniques would you suggest?

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15. If you were responsible for developing a dust-deposition standard which will eliminate all potential dust complaints, what would that dust-deposition standard be for residential areas expressed in $mg.m^{-2}.day^{-1}$?

APPENDIX 5

Open-ended questionnaire to interested and affected parties

1. What do you think are the biggest sources of dust in your district?

2. How effective is dust enforcement in your District and what do you think are the reasons for the performance?

3. Where is nuisance dust affecting you the most, at home or other places, and why?

4. Do you think the level of dust pollution should be allowed to differ between your workplace and your home? Why?

5. Do you think your District Municipality is sufficiently competent and capacitated to solve the dust problems within your District? why?

6. Who do you think should be responsible for dust management in the district and why?

7. What do you consider to be the indicators alerting you to dust problems within your District?

8. To your knowledge have there been instances where the District Municipality has acted on complaints about dust?

9. Do you consider your District's current dust-management system to be effective? Why/why not?

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10. To what extent are you invited to attend District Municipalities' dust-management meetings, and to what extent do you think your inputs are considered?

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11. To what extent are you invited to attend mining companies' dust-management meetings, and to what extent do you think your inputs are considered?

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12. How effective do you consider your District's dust-monitoring network to be? Why?

APPENDIX 6

Construct for closed structured questionnaire to District municipality

Dust monitoring component

Component	Question 1	Question 2	Question 3
Dust-monitoring network and climate	Our District Municipality has a dust-monitoring network specifically designed for its sources and region	Our District Municipality carefully considered our regional climatic conditions before designing our dust-monitoring network.	Our District Municipality has a dust-monitoring network specifically designed according to the region's source inventories
Dust-monitoring techniques and guideline	Our District Municipality believes that complying with the SANS 1929 guideline or draft National Dust Control Regulations is sufficient for managing dust deposition within our District	Our District Municipality believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations will reduce public complaints due to dust deposition	Our District Municipality believes that the ASTM D1739 dust monitoring method is the best monitoring method to ensure the effective management of dust deposition in our District
Dust sources	Our District Municipality has a list of all the major sources and contributors to dust deposition within the District	Our District Municipality manages dust deposition by monitoring major dust sources with methods specifically designed for each individual source of dust.	Our District Municipality's source contribution to visible daily dust events is not adequately reflected in the monthly averaged dust-deposition data of the District/region.
Nuisance Dust standard	Our District Municipality considers all dust from surface mining activities to be deposition or nuisance dust	Our District Municipality complies with the monthly deposition or dust-fall standard of SANS 1929 guideline	Our District Municipality believes that a single dust-fall or deposition standard will be sufficient to manage the seasonal effect of dust deposition in our District/region.

Planning and dust management component

Component	Question 1	Question 2	Question 3
Dust-management capacity	Our District Municipality appointed air-quality officers for dust management	Our District Municipality has a dedicated air-quality management section/department responsible for dust management	Our District Municipality has the technical skills to maintain and implement a dust-management plan
Technical capacity and financial resources	Our District Municipality has the technical skills to develop a dust-management plan	Our District Municipality has an adequate budget and financial provision to develop, implement and maintain a dust-management plan	Our District Municipality makes use of financial provisions available outside the District to develop, implement and maintain a dust-management plan
Dust-management policies and frameworks	Our District Municipality has a vision, mission and objectives for dust management relevant and specific to our District.	Our District Municipality's dust-management objectives relating to standards are different from the SANS 1929 guideline or draft of National Dust Control Regulations.	Our District Municipality's dust-management objectives are included within an AQMP
Dust-management planning	Our District Municipality has an AQMP submitted within its IDP	Our District Municipality has an approved AQMP with specific dust-management plans	An approved AQMP including specific dust management plans will improve air quality and potentially solve all dust-related problems within our District/region.
Reactive control, perception and absence of priority	Our District Municipality only manages dust problems after they get reported	Our District Municipality only recognizes dust deposition as a nuisance reported by the public	Our District Municipality treats dust complaints and compliance asno real priority
Limited management, enforcement and regulation	Our District Municipality has no formal reporting line for dust-deposition exceedances	Our District Municipality does not enforce compliance with dust-deposition standards of SANS 1929 guidelines	Our District Municipality has issued warnings to industries which do not comply with SANS 1929 guidelines for dust deposition
Dust Management Strategies and reporting	Our District Municipality has intervention plans available which we can implement to reduce dust deposition if necessary	Our District Municipality has a quality review process for dust management	Our District Municipality's air-quality officers do report annually to provincial government regarding the status and compliance of dust management within the District.

Information and participation component

Component	Question 1	Question 2	Question 3
Governance information and participation	Our District Municipality relies on information of all relevant local municipalities as well the provincial government when developing and improving the dust management plans for the District	Our District Municipality discusses dust problems within the District with all relevant local municipalities as well the provincial government on a regular basis	Our District Municipality air quality officers receive continuous training and capacity-building relevant to dust management from national and provincial government.
Public information and participation	Our District Municipality relies on and includes information of all interested and affected parties when developing and improving the dust management plan of the District	Our District Municipality discusses dust problems within the District with all interested and affected parties on a regular basis	Our District Municipality provides continuous awareness campaigns, as well as training and capacity-building for the public, work-force and systems and structures regarding all matters relating to dust and the management thereof.
Specialist information and participation	Our District Municipality relies on and includes information of specialists when developing and improving the dust management plan for the District	Our District Municipality discusses dust problems within the District with specialists on a regular basis	Our District Municipality contracts specialists for continuous training and capacity-building of air-quality officers regarding dust and the management thereof.

APPENDIX 7

Construct for closed structured questionnaire to Gold Mines

Dust-monitoring component

Construct	Question 1	Question 2	Question 3
Dust monitoring-network and climate	Our Company has a dust-monitoring network specifically designed for our sources and region	Our Company carefully considered our regional climatic conditions before designing our dust-monitoring network.	Our Company has a dust-monitoring network specifically designed according to our source inventories
Dust-monitoring techniques and guideline	Our Company believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations is sufficient for managing our dust deposition	Our Company believes that complying with the SANS 1929 guideline or draft of National Dust Control Regulations will reduce public complaints due to dust deposition	Our Company believes that the ASTM D1739 dust-monitoring method is the best monitoring method to ensure the effective management of dust deposition for our Company
Dust sources	Our Company has a list of all the sources of dust deposition within the Company	Our Company manages dust deposition by monitoring major dust sources with methods specifically designed for each individual source.	Our Company dust sources contribution to visible daily dust events is not adequately reflected in the monthly dust-deposition data
Nuisance Dust standard	Our Company considers all dust from our surface activities to be deposition or nuisance dust	Our Company complies with the monthly deposition or dust-fall standard of SANS 1929 guideline	Our Company believes that a single dust-fall or deposition standard will be sufficient to manage the seasonal effect of dust deposition

Planning and dust-management component

Construct	Question 1	Question 2	Question 3
Dust-management capacity	Our Company appointed pollution control officers for dust management	Our Company has a dedicated department responsible for dust management	Our Company has the technical skills to maintain and implement a dust-management programme
Technical capacity and financial resources	Our Company has the technical skills to develop a dust-management plan	Our Company has an adequate budget and financial provision to develop, implement and maintain a dust-management plan	Our Company makes use of specialists outside the company to develop, implement and maintain a dust-management plan
Dust-management policies and frameworks	Our Company has a vision, mission and objectives for dust management relevant and specific to our activities and requirements.	Our Company's dust-management objectives relating to standards are different from the SANS 1929 guideline	Our Company dust-management objectives are included within an AQMP
Dust-management planning	Our Company has an AQMP with specific dust-management plans	Our Company has an AQMP based on ISO management principals	An approved AQMP including specific dust-management plans will improve all dust-related problems within our Company.
Reactive control, perception and absence of priority	Our Company only manages dust problems after they get reported	Our Company only recognizes dust deposition as a nuisance reported by the public	Our Company treats dust complaints and compliance with no real priority
Limited management, enforcement and regulation	Our Company has no formal reporting line for dust-deposition exceedances	Our Company does not enforce compliance with dust-deposition standards as per SANS 1929 guideline	Our Company has issued warnings to employees whose actions resulted in dust-deposition exceedances
Dust-management Strategies and reporting	Our Company has intervention plans available which we can implement to reduce dust deposition if necessary	Our Company has a quality review process for dust management	Our Companies pollution control officers do report to the District Municipality regarding the status and compliance of its dust-management plan

Information and participation component

Construct	Question 1	Question 2	Question 3
Governance information and participation	Our Company relies on information of local and district municipalities for developing and improving our dust-management plan	Our Company discusses dust problems within the company and district with local and the District municipalities on a regular basis	Our pollution control officers receive continuous training and capacity-building relevant to dust management from local and district municipalities
Public information and participation	Our Company relies on and includes information of all interested and affected parties when developing and improving the dust management plan of the Company	Our Company discusses dust problems within the company and the District with all interested and affected parties on a regular basis	Our Company provides continuous awareness campaigns, as well as training and capacity-building for the public, our work-force as well as systems and structures regarding all matters relating to dust and the management thereof.
Specialist information and participation	Our Company relies on and includes information of specialists when developing and improving the dust-management plan of the company	Our Company discusses all potential dust problems within the company with specialists on a regular basis	Our Company contracts specialists for continuous training and capacity-building of pollution control officers regarding dust and the management thereof.