Chapter 1

Introduction and background

1.1. Sustainable development in the mining industry

"In its latest audited figures, Anglo Platinum discloses that it pumped 12% more chemical emissions into the Rustenburg bowl last year, releasing 68 700 tons of Sulphur dioxide (SO_2) into the atmosphere. The world's largest Platinum producer is also accused of causing pollution so severe that it is making children sick. Locals have started to hit back, raising the spectre of class actions and as a last resort, threatening to force the closure of a deficient plant, in the process bringing production to a halt. At a public meeting in Rustenburg this week, local Anglo Platinum management admitted the pollution figures were "not a pretty picture of what is being done to the environment". The group's own documentation reports a staggering increase of 1 596 level one environmental incidents in the 12 months to end December" (Moneyweb, 2003a).

These words written about the world's largest Platinum producer lead to a media event with several more articles published relating the air pollution problems associated with one of South Africa's leading mining companies (Beeld, 2003; Business Day, 2003; Classic fm, 2003; e tv news, 2003; Moneyweb, 2003b; Rapport, 2003) and do not seem to indicate sustainable mining practices. The debate surrounding sustainable development in the mining industry is a drawn-out one, which has gained considerable attention from a wide range of parties and has prompted a number of academics, industrialists, and government employees to provide personal viewpoints on the applicability of sustainable development to mining (Hilson & Murck, 2000).

The World Commission on Environment and Development (also known as The Brundtland Commission) was convened by the United Nations in 1987 and laid the foundation for defining "*Sustainable Development*" in the landmark report "*Our Common Future*" presented to the UN General Assembly in 1987 (WHO, 2000). The report defined sustainable development as "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987: 43). The report, however, failed to outline effective sustainable strategies for any specific industry to follow (Hilson & Murck, 2000), suggesting that no single blueprint for sustainability exists (NRC, 1995 cited in Hilson & Murck, 2000: 227).

Every industry, in addition to generic environmental complications faces industry-specific challenges that require careful planning, tactical investment, and strategic management to overcome (Hilson & Murck, 2000). In the case of mining, the environmental problems resulting from operations are well known, particularly because the industry attracts considerable public attention with its ongoing need to obtain planning permission to change the original land use and to extract minerals (Richards, 1996 cited in Hilson & Murck, 2000: 228), as well with its nuisance effects, such as noise, dust and traffic (Hilson & Murck, 2000). Sustainable development in a mining context requires commitment to continuous environmental and socio-economic improvement through effective environmental management (Hilson & Murck, 2000). Environmental sustainability may be compromised in the mining industry by air pollution, which is a complex problem with benefits, risks, and costs being all-important parameters (Gerrans, 1993).

In order to fully investigate the effect air pollution may have on environmental sustainability (the focus area of this study), it is firstly necessary to be acquainted with and to understand the characteristics and composition of both the pollutants and the atmosphere itself.

1.2. Composition of air

Air is a mixture of gases, vapour of water and organic liquids, and particulate matter held in suspension that surrounds the earth in a relatively thin layer (Boubel *et al*., 1994; Strauss & Mainwaring, 1984). The mass of the dry atmosphere is suggested to be 5.132 x 10^{18} kg, with a mean atmospheric pressure of 982.4 mb (Trenberth & Guillemot, 1994 cited in Derwent, 1997: 61). The mean mass of water vapour in the atmosphere is 1.35 x 10^{16} kg (Derwent, 1997), while it's quantity varies greatly from almost complete dryness to super-saturation; *i.e.*, between 0% and 4% by weight (Boubel *et al*., 1994).

Most of the air (95%) is located in the first 20km of the earth's atmosphere (*i.e.* above sea level), above which it decreases in density until it merges into space several hundred kilometres higher (Strauss & Mainwaring, 1984). The lower part of the atmosphere (troposphere) is approximately 8km thick at the earth's poles, and about twice this at the equator (Strauss & Mainwaring, 1984). For the most part, human activities take place within the first 2km of the atmosphere (Strauss & Mainwaring, 1984).

The principal constituents of air (Table 1.1) do not react with one another under normal circumstances (Strauss & Mainwaring, 1984). There is little or no interaction between molecules of certain atmospheric trace components, while a number of other gases present in trace quantities are not chemically inert but interact with the biosphere, the hydrosphere and each other, and so have a limited residence time in the atmosphere and characteristically variable concentrations (Table 1.1) (Strauss & Mainwaring, 1984).

Table 1.1: Atmospheric composition (Monn (2001); Scorgie (2001a); Derwent (1997); Strauss & Mainwaring (1984))

		Chemical Symbol	Volume (%)	Concentration (%)	Concentration (ppm)	Estimated residence time
Natural atmospheric constituents						
	Pollen, fungi, spores, bacterial aerosols, endotoxins, lypposaccharides, other biological material in aerosols					
Principal gases						
	Nitrogen	N_2	78.084 ± 0.004	73.000	780.900	Continuous
	Oxygen	O_2	20.946 ± 0.002	20.900	209.400	Continuous
	Argon	A	0.934 ± 0.001	0.930	9.300	Continuous
	Carbon dioxide	CO_2	0.033 ± 0.001	0.032	315.000	20 years
Trace gases:						
A - Non reactive	Helium	He			5.200	Continuous
	Neon	Ne			18.000	Continuous
	Krypton	Kr			0.500 - 1.100	Continuous
	Xenon	Xe			0.080 - 0.086	Continuous
	Hydrogen	H_2			0.500	?
	Nitrous oxide	N_2O			0.250	8 – 10 years
B - Reactive gases	Carbon monoxide	CO			0.100	0.2 – 0.3 years
	Methane	CH_4			1.200 - 1.400	< 2 years
	Non-methane hydrocarbons	HC			0.020	?
	Nitric Oxide	NO			0.200 – 2.000 x 10^{-3}	2 – 8 days
	Nitrogen dioxide	NO_2			0.020 - 4.000 x 10^{-3}	2 – 8 days
	Ammonia	NH_3			6.000 – 20.000 x 10^{-3}	1 – 4 days
	Sulphur dioxide	SO_2			0.030 – 1.200 x 10^{-3}	1 – 6 days
	Ozone	O_3			0.000 – 0.050	?

1.3. Defining air pollution

Before enforceable laws and ordinances can be formulated to control the pollution of the air, the term air pollution must be defined (Strauss & Mainwaring, 1984; Wark & Warner, 1981). One method of defining an air pollutant is first to specify the composition of "*clean*" or "*normal*" dry atmospheric air and then to classify all other materials or increased amounts of those materials given in the composition of atmospheric air as pollutants if their presence results in damage to human beings, plants, animals or materials (Wark & Warner, 1981). According to Boubel *et al.* (1994) unpolluted air is a concept; *i.e.*, what the composition of the air would be if humans and their works were not on earth. DME (Department of Minerals and Energy) (1999) describes airborne pollutants as any toxic, harmful, corrosive, irritant or asphyxiant, or a mixture of such pollutants; *i.e.* dusts, fibres, fumes, gases, vapours, mists, aerosols or any pollutant in any other form.

Ross (1972: 19) uses the New Jersey State definition of air pollution and describes air pollution as "*the presence in the outdoor atmosphere of one or more air contaminants in such quantities and duration as are, or tend to be, injurious to human health or welfare, animal or plant life or would unreasonably interfere with the enjoyment of life and property*". Ross (1972) further states that an air pollutant does not have to be inhaled to be classified as an air pollutant; it becomes a pollutant merely by being in the air. Derwent & Hertel (1998) and Derwent (1997) defines a pollutant as a trace gas that, between the point of its emission into the atmosphere and the point of its ultimate removal, causes harm to a target (*e.g.* ecosystems, materials, humans, or climate). In this thesis, air pollution is defined as "*the presence in the outdoor atmosphere of one or more contaminants or combinations thereof in quantities, and for durations, that may be or may tend to be injurious to a receptor (e.g. human, plant, or animal life, or property) or would unreasonably interfere with the enjoyment of life or property or the conduct of businesses*" (adapted from Boubel *et al.* (1994); Strauss & Mainwaring (1984), and Wark & Warner (1981)).

Atmospheric pollution comprises a variety of forms, namely (*Anon*., 1999; Strauss & Mainwaring, 1984; Wark & Warner, 1981)

a. Particulate matter,
b. Sulphur-containing compounds,
c. Organic compounds,
d. Nitrogen-containing compounds,
e. Carbon monoxide,

Halogen compounds, and
Radioactive compounds.

The focus of discussion in this thesis is particulate matter, for which there are few data and little published material, particularly for southern Africa.

A particle can be described as consisting of a single continuous unit of solid or liquid, containing many molecules held together by intermolecular forces and primarily larger than molecular dimensions (> 0.001µm) (Burger & Scorgie (2000a). A particle may also be considered to consist of two or more such unit structures held together by interparticle adhesive forces such that it behaves as a single unit in suspension or upon deposit (Burger & Scorgie (2000a). The three major characteristics of particulate pollutants are (Boubel *et al*., 1994):

a. Total mass concentration: to determine mass concentration, all the particulates are removed from a known volume of air and their total mass is measured. The principal methods for extracting particulates from an air stream are filtration and impaction.
b. Size distribution: very important in understanding the transport and removal of particulates in the atmosphere and their deposition behaviour in the human respiratory system.

c. Chemical composition: may determine the type of effects caused by particulate matter on humans, vegetation, and materials.

1.3.1 Natural versus anthropogenic pollution

Natural sources of air pollution are defined as those not caused by human activities (*e.g.* natural veld fires, active volcanoes, decaying vegetation and dust storms) (Scorgie, 2001a; Boubel *et al*., 1994; *Anon*., 1999; Roos, 1993; Wark & Warner, 1981; Stewart, 1979). Anthropogenic sources are pollutants emitted by human activities and can be divided into three different groups (Scorgie, 2001a; *Anon*., 1999):

a. Industrial sources: Stationary sources that emit relatively consistent qualities and quantities of pollutants (*e.g.* manufacturing products from raw materials, convert products to other products).
b. Utilities: *e.g.* an electric power plant generating electricity to heat and light homes in addition to providing power for household utilities.
c. Personal sources: *e.g.* automobiles, home furnaces, home fireplaces and stoves, open burning of refuse and leaves.

The total global production of pollutants from natural sources is greater than that from anthropogenic sources, but global distribution and dispersion of those pollutants result in low average concentrations (Wark & Warner, 1981). However, the human body does not discriminate between sources of pollution (Stewart, 1979).

1.3.2 Primary versus secondary pollution

Primary pollutants are emitted directly from sources (Table 1.2), while secondary pollutants are formed in the atmosphere by chemical reactions among primary pollutants and chemical species normally found in the atmosphere (Table 1.2) (Roos, 1993; Bridgman, 1990; Strauss & Mainwaring, 1984; Wark & Warner, 1981). The global emissions of natural particulates are mainly primary, whereas, anthropogenic emissions are predominantly secondary (Querol *et al*., 2001).

The mix of pollutants in the air is never constant or straightforward and the damage observed in a particular situation is often the result of more than one pollutant acting together (Strauss & Mainwaring, 1984). A synergistic interaction can occur where the total effect is enhanced over and above the sum of the effects of the individual pollutants present (Strauss & Mainwaring, 1984).

Table 1.2: Primary and secondary pollutants (Wark & Warner (1981))

Class	Primary pollutants	Secondary pollutants
Sulphur containing compounds	SO_2, H_2S	SO_3, H_2SO_4, MSO_4
Organic compounds	$C_1 - C_5$ compounds	Ketones, aldehydes, acids
Nitrogen containing compounds	NO, NH_3	NO_2, MNO_3
Oxides of carbon	CO, (CO_2)	None
Halogen	HCL, HF	None

1.3.3 Criteria vs non-criteria pollutants

Criteria pollutants are described as "*traditional*" pollutants that are widespread, common pollutants known to be harmful to human health and welfare (Scorgie, 2001a). The term "*criteria*" was developed after legislation in various countries required authorities to evaluate the potential health effects of pollutants and to issue a criteria document at various intervals (Scorgie, 2001a). In South Africa, the term was applied by the Department of Environmental Affairs and Tourism (DEAT) to five pollutants (SO_2, CO, Pb, oxides of nitrogen, and particulate matter) (Scorgie, 2001a).

1.3.4 Scale and transport of air pollution

Problems of air pollution can be divided according to the spatial scale of the occurrence, namely (Derwent, 1997; Boubel *et al.*, 1994; Bridgman, 1990):

a. Local (up to 5km): local transport occurring from individual point or line sources out to a few kilometres; mainly associated with plumes.
b. Urban: transport occurring from individual point or line sources to 50 km.
c. Regional scale (50 – 500 km): regional scale transport occurs to distances less than a thousand kilometres. At this scale, individual plumes are merging, and the distance allows a relatively uniform profile to develop after about one or two hours.
d. Continental scales (500 to several thousand kilometres): sub-continental and continental scale transport occurs over several hundred to a few thousand kilometres. The pollution experiences several diurnal cycles and interchange of pollution between the Troposphere and Stratosphere is possible.
e. Global (worldwide): global transport extends from a few thousand kilometres to the entire atmosphere; the emission source and target ecosystem being harmed are in different continents or hemispheres.

Action to control air pollution was initially conducted only at national levels, ignoring the import or export of air pollution across national frontiers (WHO, 2000). Acid deposition, photochemical oxidants, and accidental releases of ionising radiation and toxic chemicals first became international issues during the 1970's (WHO, 2000). The recognition that air pollution does not respect national frontiers has led to considerable action, although still at an early stage, to develop international approaches to the management of air quality (principles, international agreements and treaties) (WHO, 2000).

Factors influencing the transport of air pollutants from the source to the receptor are (Boubel *et al.*, 1994; Stewart, 1979):

a. Wind velocity (wind direction and wind speed),

b. Turbulence,

c. Temperature inversions,

d. Topography,

e. Humidity, and

f. Rainfall.

1.3.5 Absorption and dispersion of pollutants in the atmosphere

The general effect of emissions on atmospheric pollution depends on the average life of pollutants in the atmosphere (Stewart, 1979; Inman *et al*, 1971 cited in Wark & Warner, 1981: 2). The mechanisms whereby pollutants are removed from the atmosphere are called scavenging mechanisms (Boubel *et al.*, 1994). Except for fine particulate matter (0.2 µm or less) that may remain airborne for long periods of time, and gases such as CO, which do not react readily, most airborne pollutants are eventually removed from the atmosphere by sedimentation (settling by gravity), reaction (transformation), dry or wet deposition and dispersion (Table 1.3) (Egenes, 1999; Boubel *et al.*, 1994).

Table 1.3: Factors affecting atmospheric dispersion (Scorgie (2001a); Preston-Whyte & Tyson (1988)).

Horizontal dispersion	Vertical dispersion
Wind speed	Mechanical turbulence
Wind direction	Thermal turbulence
	Mixing depth

The rate and means by which air pollutants disperse in the atmosphere depends on the state of the atmosphere, particularly within the earth's boundary layer where thermal (convective) and mechanical processes dominate (Turner *et al.*, 1995). Six types of plume behaviour can occur (Scorgie, 2001a; Egenes, 1999; Somers, 1971):

1.3.5.1 Looping

Looping (strong lapse condition) occurs during unstable conditions of a light wind on a hot summer afternoon, when the large-scale eddying carries portions of the plume pattern (Fig. 1.1a). The result is that very large momentary pollution concentrations can be recorded near the chimneystack with lower concentrations encountered at distances from the stack.

1.3.5.2 Fanning

Fanning is an inversion condition that occurs with the onset of a temperature inversion in the presence of light winds. With the onset of winter and towards evening, the warm ground will cool off more rapidly due to surface radiation than will the air above it. The temperature gradient reverses and the temperature rises with an increase in altitude, which results in the plume being transported intact for great distances without reaching the ground. Ground concentrations are only detected a considerable distance downwind from the stack (Fig. 1.1b).

1.3.5.3 Fumigation

On hot days with clear skies and light winds the condition known as fumigation (lapse below, inversion aloft) can occur (Fig. 1.1c). Fumigation is the most severe pollution condition where the chimney plume will reach the ground nearby causing high ground level concentrations normally towards midday. As evening approaches the ground cools off again and the whole cycle may repeat itself.

1.3.5.4 Trapping

When South Africa experiences a low-pressure condition at altitude during the winter months a second inversion or boundary layer can develop (subsidence inversion) above which pollutants will not be carried. When a pollutant is emitted into an unstable layer of air trapped between an inversion layer and the ground, trapping (lapse below, inversion aloft) occurs (Fig. 1.1d).

1.3.5.5 Coning

Coning (lapse condition) occurs with the same temperature profile conditions as looping, but under cloudy or very windy conditions which gives rise to a more elevated and concentrated pollution pattern due to the action of the wind (Fig. 1.1e).

1.3.5.6 Lofting

Lofting (inversion below, lapse aloft) occurs when the stack (above 250 metres) exhausts above an inversion and no pollution will reach the ground. This situation will occur after sunset during winter. Alternatively low level emissions from domestic fires, motor vehicles, smouldering coal discard dumps and small industry will be trapped under the ceiling caused by the inversion and not penetrate it. Pollution levels will then build up to unpleasant (Fig. 1.1f).

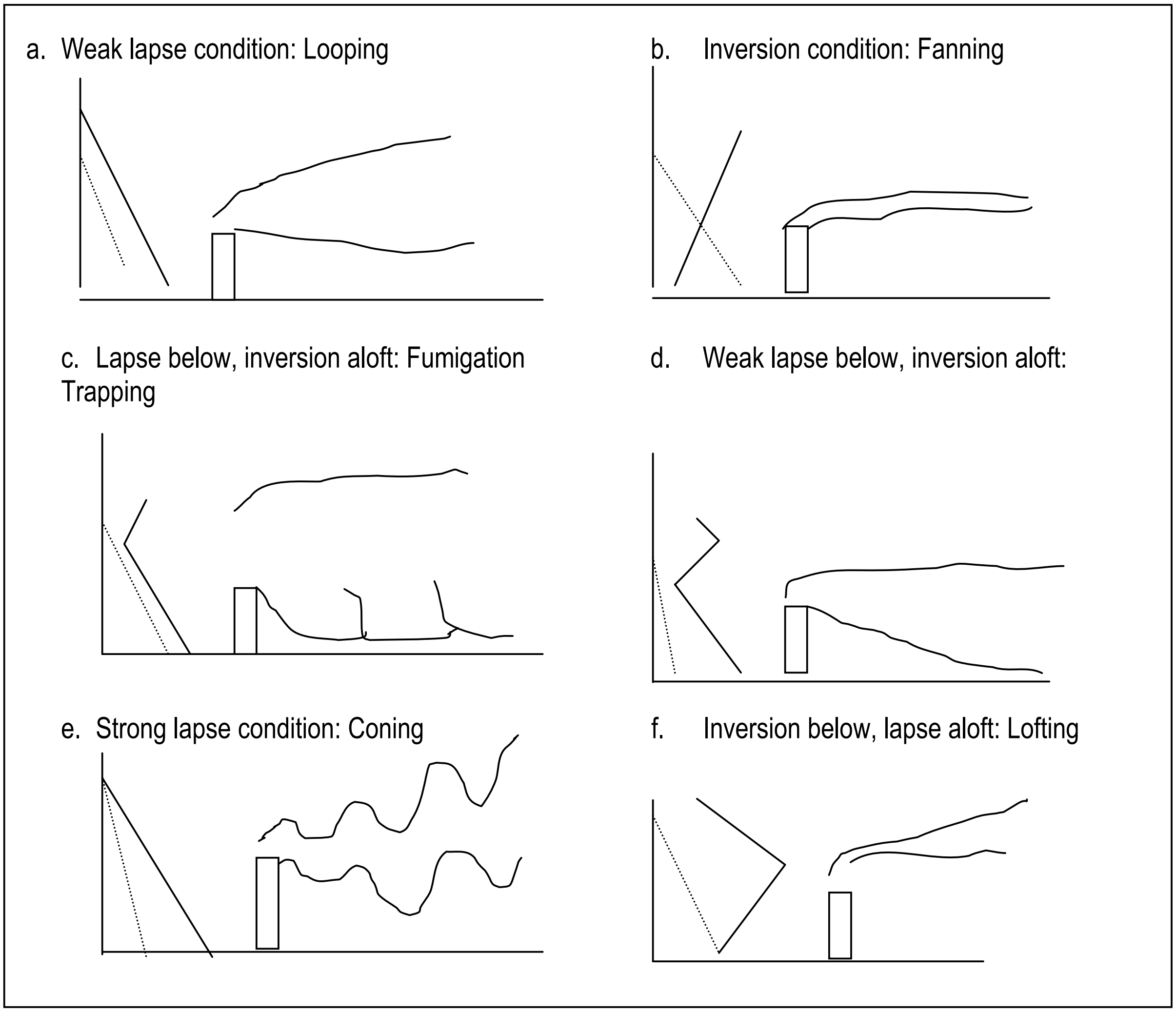


Figure 1.1: Dispersion of air pollutants in the atmosphere (*Broken lines: Dry adiabatic lapse rate; Full lines: Existing lapse rates*) (Scorgie (2001a); Boubel *et al*. (1994); Bierly & Hewson (1962))**.**

1.4. History of air pollution research

Although air pollution (as defined above) has become a very serious and prominent issue during the last part of the twentieth century, it has affected human beings long before then, as can be seen from the following discussion.

1.4.1 The global situation before the industrial revolution

From the time that early humans learned to use fire, the air inside living quarters has been filled with the products of incomplete combustion (Boubel *et al*., 1994). The principal industries associated with air pollution in the period preceding the Industrial Revolution were metallurgy, ceramics, and preservation of animal products (Boubel *et al*., 1994). One of the reasons that people of early history were nomadic was to periodically move away from the waste they generated (Boubel *et al*., 1994).

1.4.2 The Industrial Revolution

The Industrial Revolution formed the foundation of the current technological society and was the consequence of steam used to provide power for pumping water and moving machinery (Boubel *et al*., 1994; Wark & Warner, 1981). During most of the Nineteenth Century, coal was the principal fuel, although oil was used for steam generation late in the period (Boubel *et al*., 1994). In England, Richard II and later Henry V took steps to regulate and restrict the use of coal (Stern, 1968 cited in Wark & Warner, 1981: 1). One of the earliest legal attempts to control air pollution in the United States is thought to be an 1895 ordinance that criminalized visible exhaust vapour from steam automobiles (Wark & Warner, 1981).

1.4.3 The Twentieth Century

From 1900-1925, changes occurred in the technology of both the production of air pollution and its engineering control, but no significant changes took place with regard to legislation, regulations, an understanding of the problem, or public attitudes (Boubel *et al*., 1994). Although the severity of pollution increased as cities and factories grew larger, people only became aware that human activities could affect the global atmosphere during the late 1940's and early 1950's when many of the present-day air pollution problems and solutions to these problems emerged (Boubel *et al*., 1994). Only from 1950 onwards were national air pollution control legislation and regulations adopted and enacted anywhere in the world (Boubel *et al*., 1994). During the 1970's and 1980's the total environmental approach emerged with large regional to global scale air quality projects involving multidisciplinary research beginning (Derwent, 1997; Boubel *et al*., 1994; Bridgman, 1990). By 1980, mathematical models of the polluting of the atmosphere were being developed, air quality monitoring systems became operational throughout the world and a wide variety of measuring instruments became available (Boubel *et al*., 1994).

The 1990's saw the emergence of two distinct, but closely related, global environmental crises, namely uncontrolled global climate changes and stratospheric ozone depletion (Boubel *et al*., 1994). Zannetti *et al*. (1993) identified five different trends in the study of air pollution as evident during the 1990's:

a. Movement of interest from local problems to regional, continental, and global issues. Indoor air quality problems have emerged as a major issue in relation to human health.
b. Several computer revolutions have affected the way the atmosphere and environment have been studied in general (*e.g.* advanced 3D numerical models).
c. A few decades ago only industrialized countries were polluted, while today the worst air pollution problems are often found in the Third World.
d. The type of pollution of concern has changed; secondary pollutants have become the major source of concern.
e. Environmental laws and regulations have become a determining factor in the evolution of atmospheric sciences.

Good air quality is essential for the health of people and the environment, and although significant improvements have been made in many countries over the last 20 to 30 years, air quality remains a priority issue on most national environmental agendas (Mitchell *et al.*, 2000).

1.5. Air pollutants and their effects

According to Boubel *et al*. (1994), the harmful effects of air pollutants on human beings have been the major reason for efforts to understand and control the sources of air pollution. This section focuses on the impact of air pollution in general and specifically of particulate pollution on humans and the environment. Information about the effect of SO_2, Carbon monoxide, oxides of nitrogen and hydrocarbons can be found in Appendix A.

In assessing the impact of airborne particulates (>0.01 µm; <50 µm in diameter) it is necessary to distinguish between particle size fractions (Burger & Scorgie, 2000a):

a. Total suspended particulates (TSP): usually taken into account in the assessment of dust deposition potentials.
b. Inhalable particulates (PM_{10}): particulates with an aerodynamic diameter of less than 10 µm. Simulated in order to characterise health impacts.
c. Respirable particulates ($PM_{2.5}$): particulates with an aerodynamic diameter of less than 2.5 µm. Simulated in order to characterise health impacts.

Fine (<2.5 μm) and coarse (> 2.5 μm) particulates represent two different sets of pollutants with different emission sources, chemical composition and spatial and temporal behaviour (Monn, 2001).

1.5.1. Effects on human health and welfare

The health impacts of air pollutants can manifest in the respiratory system, immune system, skin and mucusal tissues, sensory system, central and peripheral nervous system and the cardiovascular system (Schwela, 1998). The impact of anthropogenic air pollution on health can be explained through three complex reactions (Stewart, 1979):

a. The relationship between pollutant emission and ambient air pollution,
b. The relationship between ambient air pollution and exposure of the population, and
c. The relationship between exposure and impacts on health.

1.5.1.1 Respiratory and lung diseases

According to Ayres (1997), lung diseases are the major area for concern regarding air pollution. Humans normally present only limited areas of skin to the atmosphere but each day inhale about 7500 litres of air so that the lungs and respiratory system are in contact with, and have the potential to retain, whatever harmful substances might be contained in that air (Strauss & Mainwaring, 1984). The receptor population in an urban location includes a wide spectrum of demographic traits with respect to age, gender, and health status (Boubel *et al*., 1994). Certain sensitive subpopulations have been identified (Boubel *et al*., 1994):

a. Very young children (respiratory and circulatory systems are still undergoing maturation),
b. The elderly (respiratory and circulatory systems function poorly), and
c. Persons with pre-existing diseases (*e.g.* asthma, emphysema and heart diseases).

A considerable body of evidence suggests that day to day changes in air pollution can cause minor changes in symptoms and lung function in both children and adults with asthma, but there is very limited evidence to suggest that individuals exposed to air pollution in the long term are more likely to become asthmatic than those that had not been so exposed (COMEOAP, 1995 cited in Ayres, 1997: 72). There are many factors that are responsible for respiratory ill health, notably cigarette smoke, allergen exposure and viral infections (Ayres, 1997). Consequently it becomes increasingly important when trying to assess the size of health effects from air pollution to ensure that all other contributory factors have been adequately assessed (Ayres, 1997). Another factor that would seem to be important is the time spent breathing indoor as opposed to outdoor air (Ayres, 1997). The vast majority, probably 80-90%, of our time is spent indoors, but penetration of air pollution from outdoors inwards is significant for many pollutants (Schwela, 1998; Ayres, 1997).

The bulk of respiratory diseases emanate from the upper respiratory tract (nasal disease, sore throats, tonsillitis) (Ayres, 1997). Health effects of air pollution on the lower respiratory tract include acute and chronic changes in pulmonary function, increased incidence and prevalence of respiratory symptoms, sensitisation of airways to allergens present in the indoor environment and exacerbation of respiratory infections such as rhinitis, sinusivitis, pneumonia, alveolitis, legionnaires disease (Schwela, 1998; Ayres, 1997; Stewart, 1979).

Nasal openings permit inhalable (larger) particulates, along with respirable (much smaller) particulates, to enter the respiratory system (Burger & Scorgie, 2000a; Boubel *et al*., 1994; Ross, 1972). Larger particulates are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages, while over 50 percent of smaller particulates pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions (Burger & Scorgie, 2000a; Boubel *et al*., 1994; Burchard, 1974 cited in Wark & Warner, 1981: 18). The respiratory system has several efficient mechanisms for removing deposited particulates from the upper airways (*e.g.* nose blowing, sneezing, coughing, swallowing, mucociliary escalator) (Boubel *et al*., 1994; Egenes, 1999; American Lung Association, 1978 cited in Boubel *et al*., 1994: 105). The smaller particulates are removed through Brownian motion, but the very small particulates (<0.07 μm) cannot be expelled from the lungs after being inhaled and are likely an important contributing factor to respiratory diseases (Burger & Scorgie, 2000a; Egenes, 1999; Schwartz *et al*., 1996 cited in Lee & Kang, 2001: 740; Pope *et al*., 1995a cited in Lee & Kang, 2001: 740; Reichardt, 1995 cited in Lee & Kang, 2001: 741; Boubel *et al*., 1994; Dockery and Pope, 1994 cited in Burger & Scorgie, 2000b: 21; Ross, 1972).

1.5.1.2 Immune system

Health effects of air pollution on immune system allergies manifest themselves in exacerbation of allergic asthma, allergic rhinoconjunctivits, extrinsic allergic alveolitis or hypersensitivity pneumonitis, and can produce permanent lung damage in sensitised individuals including pulmonary insufficiency (Schwela, 1998).

1.5.1.3 Skin

Health effects of air pollution on the skin and on mucusal tissues (eyes, nose, throat) are mostly irritating effects (Schwela, 1998). Primary sensory irritation includes dry, and/or sore throat, tingling sensation of nose, and watering and painful eyes (Schwela, 1998). Secondary irritation is characterized by edema and inflammation of the skin and mucous membranes up to irreversible changes in these organs (Schwela, 1998).

1.5.1.4 Central nervous system

Effects of air pollution on the central nervous system manifest themselves in damage of nerve cells, either toxic or hypoxia/anoxia (Schwela, 1998). Changes caused by lead (Pb) can result in developmental retardation and irreversible neurophysiological deficiencies in infants and young children (Schwela, 1998).

1.5.1.5 Cardiovascular systems

Effects of air pollution on the cardiovascular systems develop through reduced oxygenation and result in increased incidence and prevalence of cardiovascular diseases, myocardial infarction, and consequent increase in mortality (Schwela, 1998; Ayres, 1997; Stewart, 1979).

1.5.1.6 Carcinogenic effects

Carcinogenic effects of air pollution are associated with lung cancer, skin cancer, and leukaemia (Schwela, 1998; Stewart, 1979).

Atmospheric particulates have proven to have a major impact on human health (Table 1.4) (Houthuijs *et al*., 2001; Mitchell *et al.*, 2000; Dockery & Pope, 1996 cited in Querol *et al*., 2001: 845; Boubel *et al.*, 1994). Various epidemiological studies have been conducted showing the adverse effect of particulates on respiratory health in the short and long-term (*e.g.* Mintek in Mpumalanga; CSIR, Medical Research Council and the Department of Health in the Vaal Triangle; studies in Western Europe and the United States) (Egenes, 1999; Ostro *et al*., 1999 cited in Houthuijs *et al*., 2001: 2758; Abbey *et al*., 1998 cited in Houthuijs *et al*., 2001: 2758; Pope *et al*., 1995b cited in Houthuijs *et al*., 2001: 2758; Krige, 1994). The majority of international studies have been conducted in North America and Western Europe with less in Central and Eastern Europe due to limited resources and the absence of reliable air pollution data and health statistics (Houthuijs *et al*., 2001).

Table 1.4: Potential factors in particulates which influence human health (Rylander (1998) cited in Monn (2001); Peters *et al*. (1997) cited in Monn (2001); Pritchard *et al*. (1996) cited in Monn (2001))**.**

Physical properties	Size mode, number, volume	Hydrophobicity / philicity	Electrostatic forces
Chemical composition	Ionic compounds (Nitrates, sulphates, acids)	Transition metals (*e.g.* Fe, V, Cr)	Carbonaceous material (PAH; elemental carbon)
Biological species	Allergens (pollen, fungal spores, glucans)		Bacterial and bacterial structures

The Canadian Environmental Protection Agency (CEPA) has undertaken an extensive review of epidemiological studies conducted throughout the world with regard to the relationship between particulate concentrations and human health (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b). The conclusion reached was that daily or short-term variations in particulate matter, as PM_{10} or $PM_{2.5}$, were significantly associated with increases in all-cause mortality in 18 studies carried out in 20 cities across North and South America, England and Europe (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b). Results suggested that health effects are more strongly associated with exposure to airborne particulate matter less than 2.5 µm ($PM_{2.5}$) than with the coarse fraction of 10.0 µm (PM_{10}) (Wilson & Suh, 1997 cited in Houthuijs *et al*., 2001: 2758). The CEPA could find no evidence of a threshold in the relationship between particulate concentrations and adverse human health effects, with estimates of mortality and morbidity increasing with increasing concentrations (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b; Wark & Warner, 1981). The length of time of exposure is important (Wark & Warner, 1981).

1.5.2 Effects on vegetation and animals

In addition to the damage which air pollution causes in the human organism, it causes similar, and in some cases, more severe damage to animals and plant life (Table 1.5) (Ross, 1972). Small animals have a lower tolerance level for most of the deadly insecticides than humans, simply on the basis of total body weight and blood content (Ross, 1972). An indirect effect of air pollutants that has been observed for a considerable time is animals consuming air pollutants deposited on, or stored by plants usually near Smelters treating non-ferrous ores, and near factories (Strauss & Mainwaring, 1984; Wark & Warner, 1981). Cattle and sheep that have ingested vegetation on which arsenic-containing particulates have settled have been victims of arsenic poisoning (NAPCA, 1970 cited in Wark & Warner, 1981: 18).

Table 1.5: Factors influencing the sensitivity of plants and animals (Mellanby (1988); Strauss & Mainwaring (1984); Ross (1972)).

Type of pollutant	Season
Concentration	Number of pollutants
Meteorological factors	The length of time of exposure

Plant air pollutants can be categorised as primary pollutants (which are lethal to plants as they originate from the source), and secondary pollutants (which are formed through reaction of pollutants from the source) (Ross, 1972). Among the most frequently encountered gases toxic to vegetation are SO_2, ozone, PAN, hydrogen fluoride, ethylene, hydrogen chloride, chlorine, hydrogen sulphide, and ammonia (Wark & Warner, 1981). Each pollutant, or combination of pollutants, will produce a certain pattern of injury, which leaves graphic records of the level and type of pollutant (Ross, 1972). In some instances the destruction of vegetation has been followed by soil erosion, which has prevented recovery (Strauss & Mainwaring, 1984). Air pollution affects plants in two ways: incidence of high pollution causes visible damage, but also, chronic sub lethal levels of air pollutants contribute to the eventual destruction of the plants' physiological life process, affecting the growth, productivity, and quality of vegetation (Ross, 1972).

Particulates are less toxic to plants, as they are deposited on the hard, waxy upper surface of the leaves but may cause injury to vegetation both directly and indirectly (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b; Strauss & Mainwaring, 1984). Particulates can enter the food chain if animals consume the carriers (Strauss & Mainwaring, 1984). Plant responses, which have been observed, include: reduction in yield and growth without visible injury, increased disease incidence, injury to leaf cells and suppression of photosynthesis (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b). Particulates can also act as nuclei onto which ammonia, sulphuric acid and hydrogen fluoride may adhere, forming acidic dust, which can burn plant leaves (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b).

1.5.3 Effects on materials and structures

Depending upon their chemical composition and physical state, particulates cause wide damage to materials (Wark & Warner, 1981). Particulates will soil painted surfaces, clothing, and curtains merely by settling on them (Wark & Warner, 1981). More importantly, particulate matter can cause direct chemical damage either by intrinsic corrosiveness or by the action of corrosive chemicals absorbed or adsorbed, by inert particulates emitted into the atmosphere (Burger & Scorgie, 2000; Wark & Warner, 1981). Metals ordinarily can resist corrosion in dry air alone or even in clean moist air, but hydroscopic particulates commonly found in the atmosphere can corrode metal surfaces with no other pollutants present (Wark & Warner, 1981). Particulate matter may affect the appearance and durability of paint (Burger & Scorgie, 2000a; Harrison, 1990 cited in Burger & Scorgie, 2000b: 21). Effects on paints include soiling, discoloration, and loss of gloss due to the accumulation of particulates (Burger & Scorgie, 2000a; Harrison, 1990 cited in Burger & Scorgie, 2000b: 21). Particulates may also cause chemical deterioration of freshly applied paints that have not completely dried (Burger & Scorgie, 2000a; Harrison, 1990 cited in Burger & Scorgie, 2000b: 21). Ambient concentrations of particulates may impact negatively on sensitive industries, *e.g.* bakeries or textile industries (Harrison, 1990 cited in Burger & Scorgie, 2000a: 3-16).

1.5.4 Effects on the atmosphere

Air pollution has a definite effect on the atmosphere (Table 1.6).

Table 1.6: **Air pollution affecting atmospheric conditions** (Burger & Scorgie (2000a); Burger & Scorgie (2000b); Boubel *et al*. (1994); Bridgman (1990); Wark & Warner (1981); Ross (1972)).

Precipitation	Depending on its concentration, pollution can have opposite effects on the precipitation process. While pollution can and does cause more rainfall it can also have the opposite effect when clouds become so over seeded that no rain falls (pollution creates so many dust particulates that they cannot attract enough water vapour to grow to raindrop size).
Fog	The increased number of nuclei in polluted urban atmospheres can cause dense persistent fogs due to the many small droplets formed.
Violent Weather	Thunderstorms are found more frequently in heavily polluted areas than in non-polluted ones. Hailstorms are also directly associated with pollution.
Solar Radiation	Heavy smog has decreased ultraviolet radiation by as much as 90%. Pollution can reradiate heat back to metropolitan areas and causes cities and suburban areas to become warmer over the years. Pollution also shuts out sunlight form cities and suburban areas.
Ventilation	If air movement past a continuous pollutant source is slow, pollutant concentrations in the plume moving downwind will be much higher than they would be if the air were moving rapidly past the source. If polluted air continues to have pollution added to it, the concentration will increase. Generally, a source emits into different volumes of air over time. However, there can be a build-up of concentration over time even with significant air motion if there are many sources.
Visibility	A function of the number of aerosols, their chemical and physical characteristics, and humidity. Visibility is defined as a measure of the contrast of an object against its background. Aerosols act as interference to good visibility by scattering sunlight, creating diffusion that limits contrast. Reduction in visibility not only is unpleasing to an individual, but also may have strong psychological effects. In addition, certain hazards arise; in areas influenced by emissions sources, rapid changes in visibility can occur over short distances, associated with variations in aerosol characteristics. Costs are associated with the loss of visibility, including: the need for artificial illumination and heating; delays, disruption and accidents involving traffic; vegetation growth reduction associated with reduced photosynthesis; and commercial losses associated with aesthetics.

Chapter 2

The current international situation and management of airborne pollutants

As seen from Chapter 1, airborne pollutants and particularly those in the mining industry can contribute towards a decline in environmental and human health, while at the same time jeopardising the potential for sustainable development. The management of airborne pollutants (air quality management) requires further investigation to identify potential concerns and, therefore, improved procedures and strategies for alleviating problems regarding environmental and human health. In Chapter 2 the existing international situation is investigated with the latest legislation and management practices regarding air pollution for South Africa being discussed in Chapter 3.

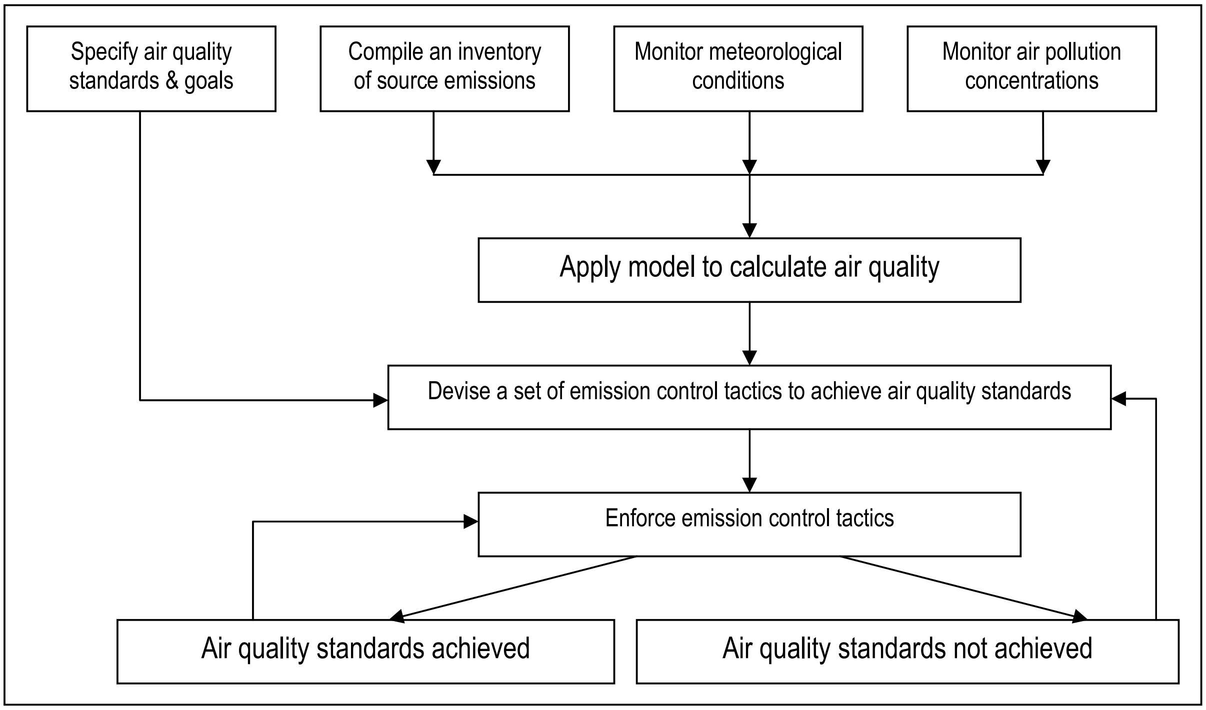
2.1. Defining air quality management

Although there is no universally agreed definition of air quality management (AQM), certain ideas have been proposed that adequately embody part of such a definition (Longhurst *et al.*, 1996). Laxen (1993, cited in Longhurst, 1996: 3980) considers air quality management to be "*the application of a systematic approach to the control of air quality issues*". A fuller definition would need to incorporate aspects of integration, cooperation and communication as a system "*on which all the factors determining air quality are considered in an integrated way*" (Williams, 1986 cited in Longhurst, 1996: 3980). Griffin (1994, cited in Longhurst, 1996: 3980) identifies a strong correlation between general management and the approaches taken in air quality management, which comprise five steps: definition, planning, control, implementation, and evaluation (Longhurst *et al.*, 1996).

The goal of air quality management is to maintain a quality of air that protects human health and welfare, animals, plants (crops, forests and natural vegetation), ecosystems, materials and aesthetics (WHO, 2000). The foundation for achieving this goal is the development of policies and strategies; without a suitable policy framework (which include policies in several areas) and adequate legislation it is difficult to maintain an active or successful air quality management programme (WHO, 2000). When goals and policies have been developed, the next stage is the development of a strategy or plan, where it is necessary to consider both the role and control ability of the various air quality managing agencies (WHO, 2000; Longhurst *et al.*, 1996).

There are numerous ways to envisage an Air Quality Management Plan (AQMP) (Longhurst *et al.*, 1996). Figure 2.1 represents the empirical component of an air quality planning system after which progression towards a fully functioning AQMP moves into the realms of the political process (Longhurst *et al.*, 1996). The operation of a successful AQMP requires a set of mutually agreed goals and a shared vision amongst the various agencies involved (Longhurst *et al.*, 1996).

Figure 2.1: Stages involved in the development of an air quality management strategy (WHO, 2000).



An AQMP provides opportunities for setting air quality standards or guidelines, new possibilities for public information and education and new mechanisms for the integration of a wide range of local authority and national policies (Longhurst *et al.*, 1996). The plan needs to be flexible to allow modifications for new knowledge about emissions or concentrations yet provide a suitable framework within which all groups can co-exist (Longhurst *et al.*, 1996). The involvement of agencies at a number of levels is important, ideally, an AQMP at the local scale would be a tier of a regional plan, which is in turn part of a national plan (Longhurst *et al.*, 1996).

2.2 Components of an Air Quality Management Plan

The following section consists of six examples of AQMP's (Fig. 2.2 – Fig. 2.7). The plans have been developed during the period 1993 to 2001 and vary in detail and length. One of the plans is very short and only outlines the basic principles with not much detail included (Fig. 2.7). Two of the plans are complicated and include a number of different role players (Fig. 2.4 and Fig. 2.5). Most of the plans are in a linear form (Fig. 2.2, Fig. 2.3, Fig. 2.6 and Fig. 2.7).

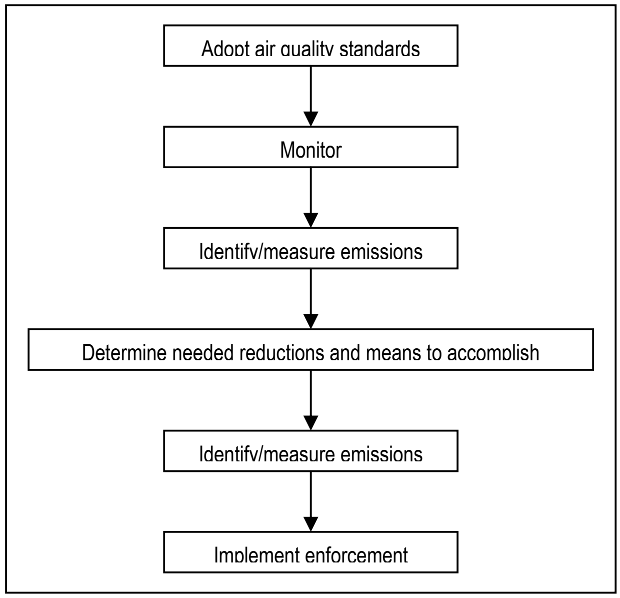


Figure 2.2: Air Quality Management Plan 1 (Guzmàn & Streit, 1993)**.**

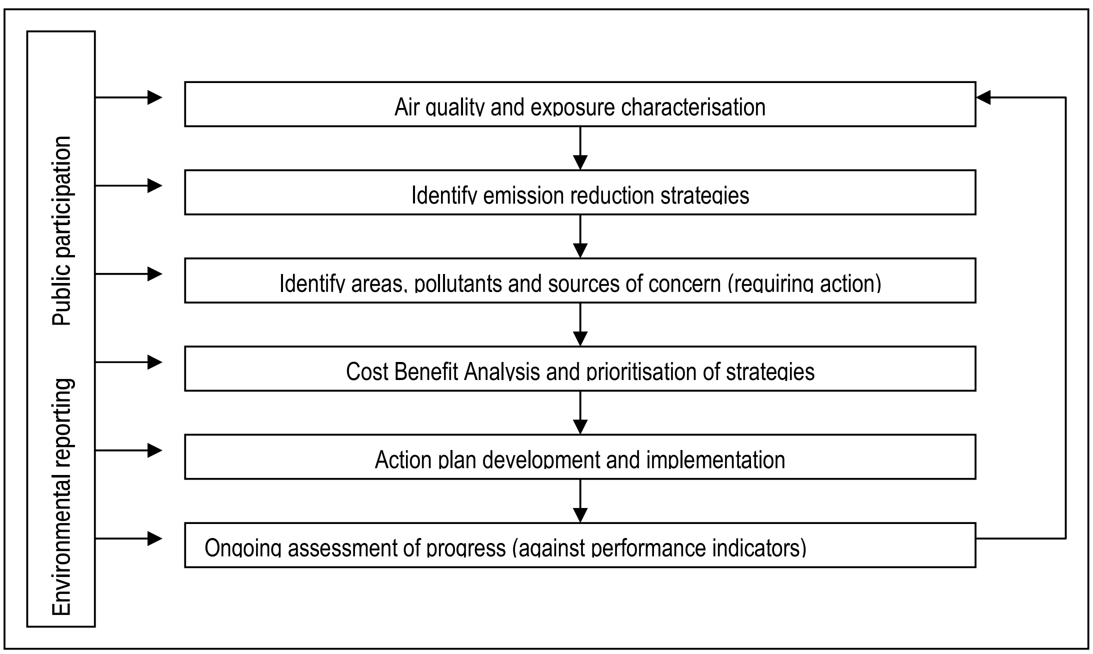
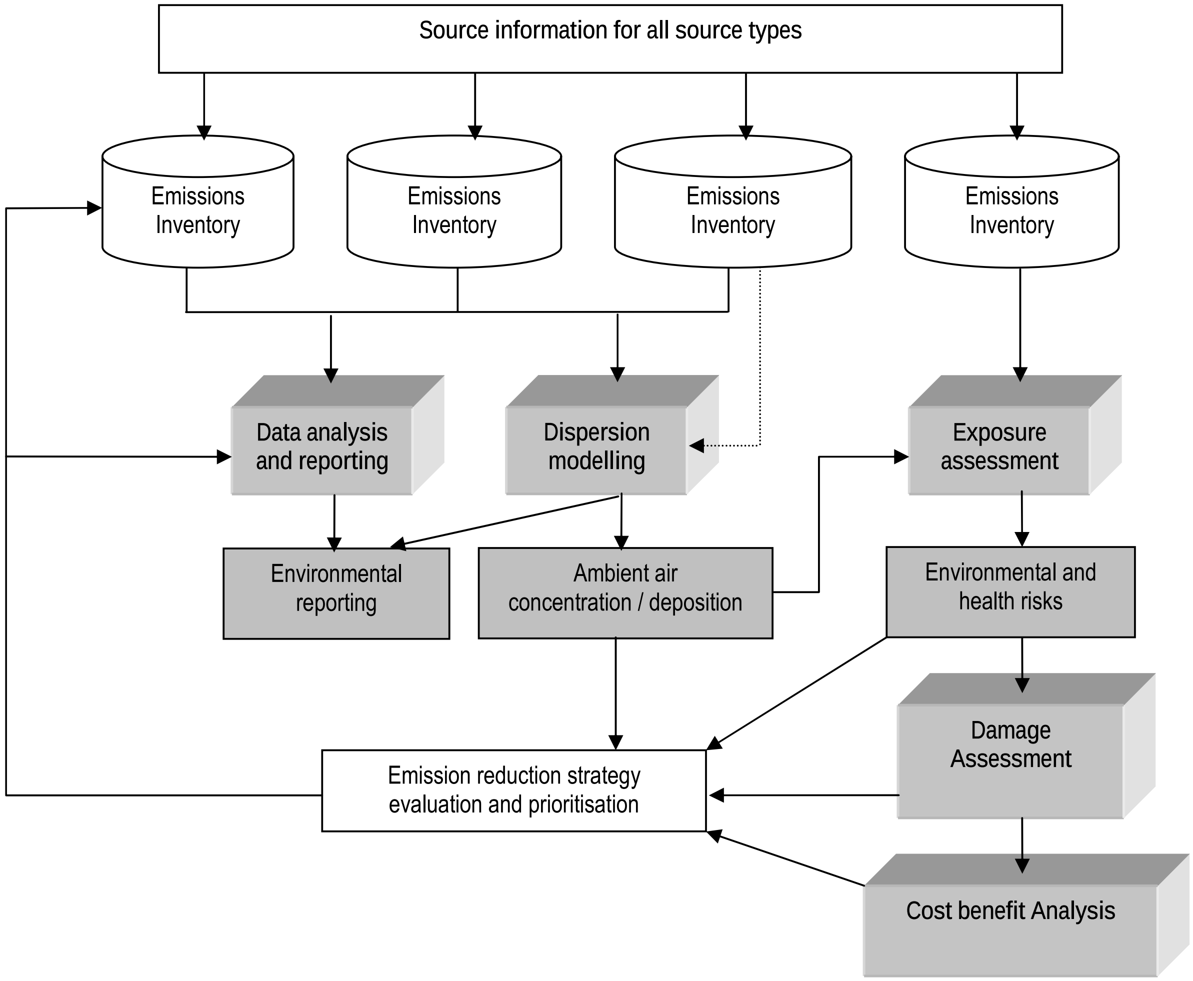


Figure 2.3: Air Quality Management Plan 2 (Scorgie, 2001a)**.**



	Data inputs
	Data bases
	Models and tools
	Enabling outputs
	Decision-making and review procedure

Figure 2.4: Air Quality Management Plan 3 (Scorgie, 2001a)**.**

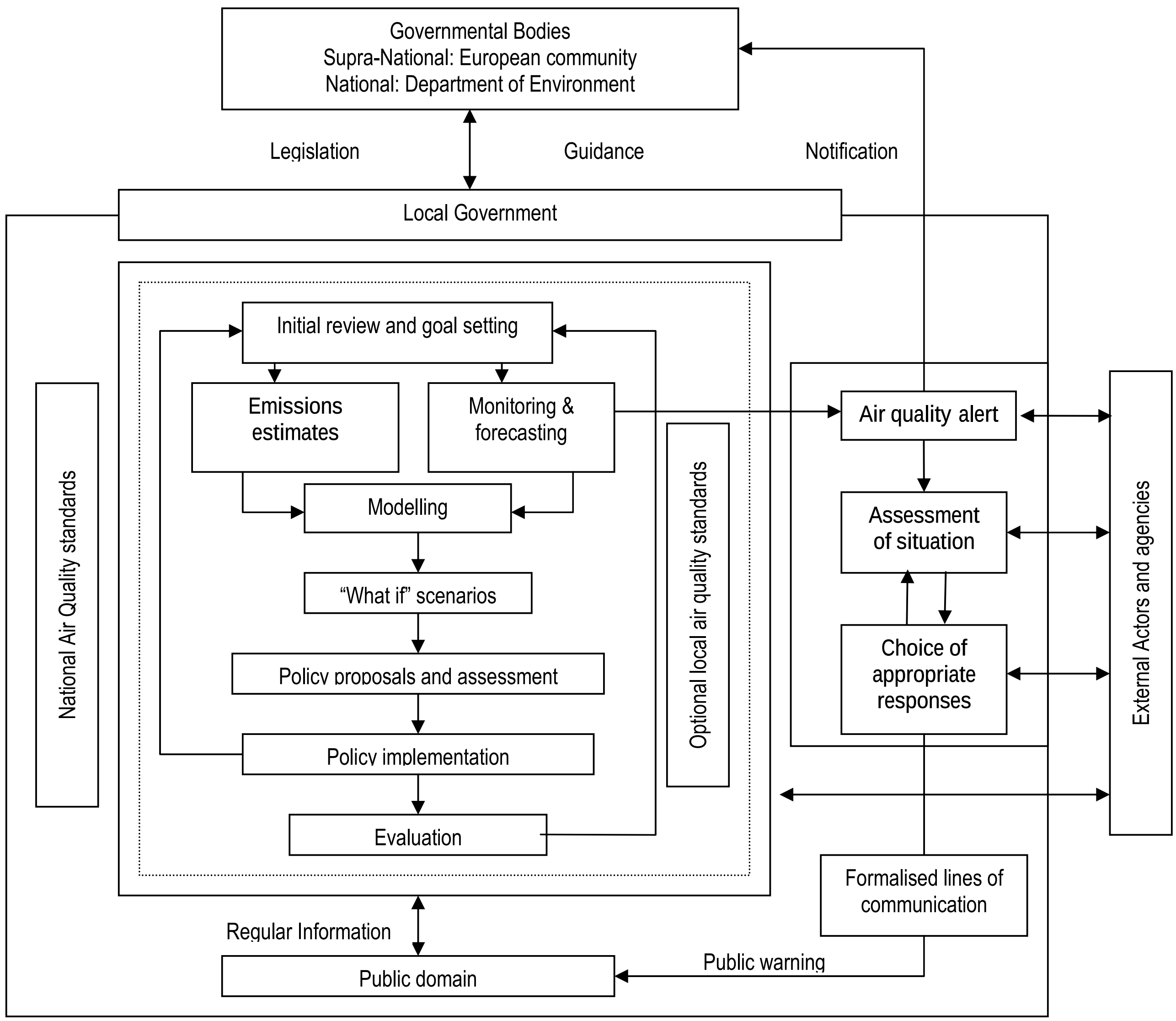


Figure 2.5: **Air Quality Management Plan 4** (Longhurst *et al.*, 1996)**.**

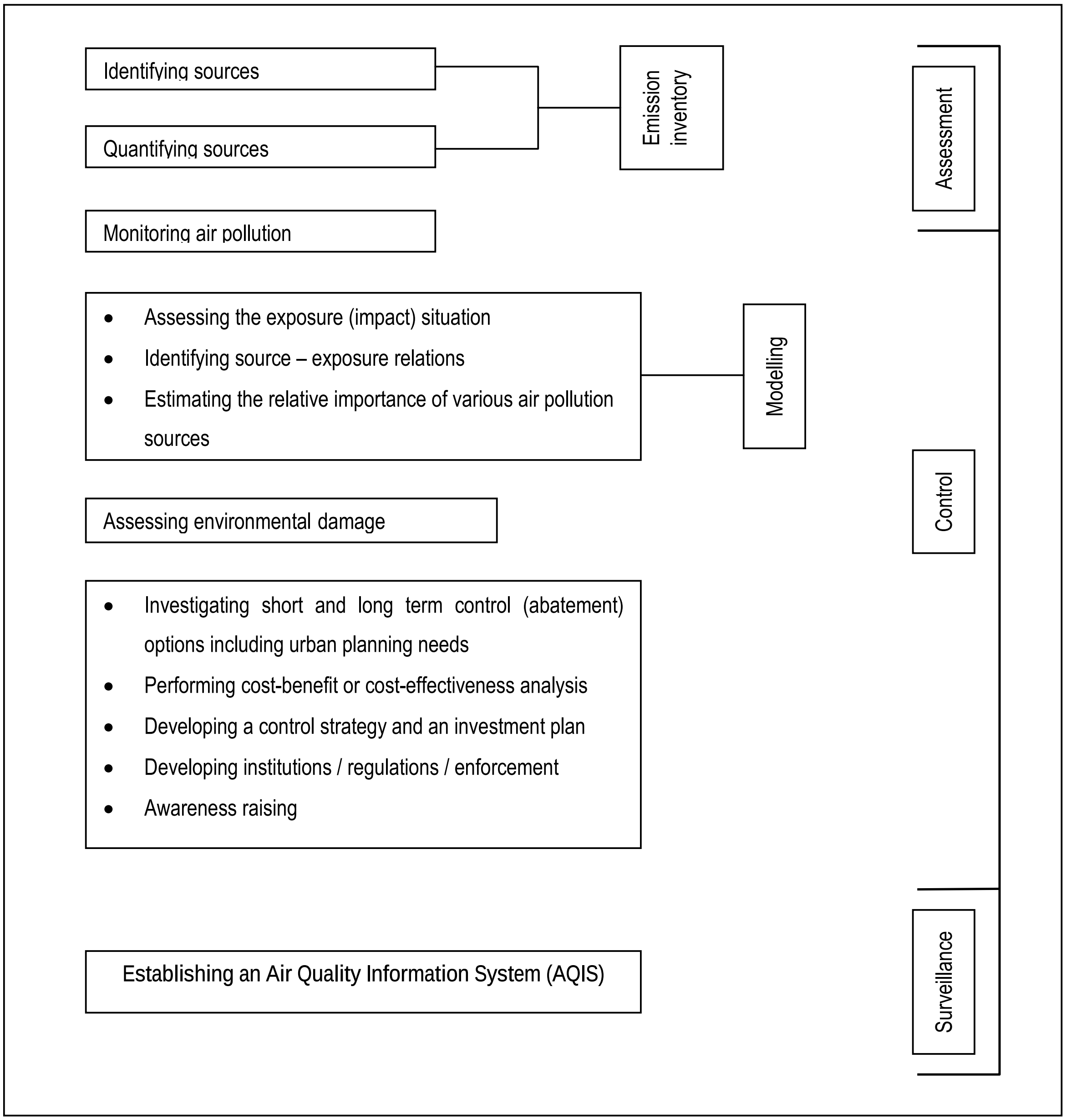


Figure 2.6: Air Quality Management Plan 5 (Scorgie, 2001a).

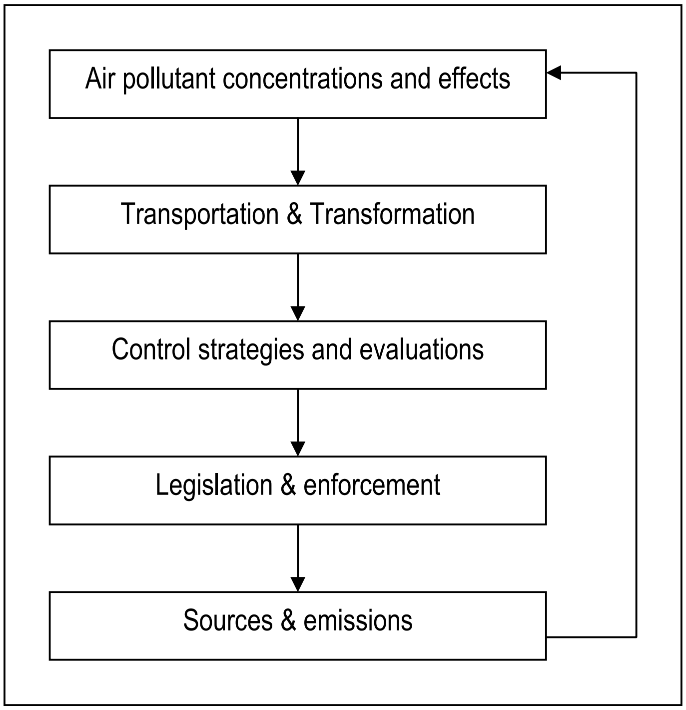


Figure 2.7: **Air Quality Management Plan 6** (Griffin, 1994 cited in Longhurst *et al.*, 1996: 3980).

2.2.1 Discussion

The AQMP's display a variety of different ideas and approaches. Some of the most important are:

a. Identification and quantification of pollution emissions (inventory),

b. Devising of control tactics and strategies (needed reductions and means to accomplish it),

c. Enforcement of the control tactics,

d. Evaluation and assessment of the tactics (are standards achieved or not?),

e. Public participation, and

f. Cost-benefit analyses.

Not all of the above aspects are included in all of the plans, which may lead to varying success in the implementation of the plans. The only aspect that is included in all of the plans is the evaluation and assessment of the process (*i.e.* were the standards achieved or not?).

Figure 2.4, Figure 2.5 and Figure 2.6 represent the AQMP's with the most detail included; these plans involve a number of different role players (*e.g.* national government, local government, public and industries). This will ensure that all the important aspects are covered but can give rise to expensive and complicated implementation of the plan. Two of these plans are non-linear which imply that different role players can have an influence on a specific section of the plan at the same time (Fig. 2.4 and Fig 2.5). Except for the management plans represented by Figure 2.2 and Figure 2.5, all of the plans are circular which ensures that problems can be solved and the process improved and refined over a period of time. The AQM plan represented by Figure 2.3 has two features (environmental reporting and public participation), which impacts on every step of the process and have to be taken into consideration constantly.

An important aspect that is included in three of the plans (Fig. 2.3, Fig. 2.4 and Fig. 2.6) is a Cost Benefit Analysis (CBA). Financial issues are very important and should always be included in a plan to ensure that all the steps of the plan can be implemented without having to change because of financial limitations. It further assures that sufficient money is spent on air quality management; an aspect often neglected. Another important aspect that is only included in three of the plans is public participation (Fig. 2.3, Fig. 2.5 and Fig. 2.6). The input of the public is crucial to the success of an AQMP since they will be greatly affected by the decisions made through the plan. Raising public awareness about air quality management can be combined with public participation as is done in the plan represented by Figure 2.6. Reporting (internally as well as externally) is not often addressed in AQMP's and is only a component of two of the above models (Fig. 2.3 and Fig. 2.4).

Measuring and monitoring of emissions, as well as the modelling of possible future scenarios are specifics that need to be included in every AQMP, although it is not always done (*e.g.* Fig. 2.2, Fig. 2.3 and Fig. 2.7). The above three aspects are crucial to determining the level of pollution in an area and testing possible methodologies that may be used to reduce emissions. It is important to model results of possible scenarios ("*what if*" – Fig. 2.5) particularly when developing contingency plans. An air quality alert (how to handle an emergency situation) only appears once (Fig. 2.6); this is one of the most important considerations in an AQMP, since there will always be situations where problems arise and a definitive plan is required to solve such a situation.

It is important that the steps included in an AQMP come to a logical conclusion. The order of actions in the AQMP's included differs significantly, which places doubt over the efficiency of the different plans. The setting of standards is the first step in some models (*e.g.*

Fig. 2.1 and Fig. 2.2) but only appears later in others (*e.g.* Fig. 2.5). In all the plans included, the development of an emission inventory is either the first or the second point of action.

2.3 International management of air quality

The specific air quality management of different countries will be discussed in the next section. There a however some trends in the international management of air quality that is applicable worldwide (Scorgie, 2001a):

a. Decentralization of air quality management (air quality management districts in the United States; non-attainment areas in Europe and local air quality management areas in the United Kingdom),
b. Development and implementation of plans for non-attainment areas,
c. Management of all pollution sources,
d. A shift from source-based to a receiving environment approach,
e. The existence of multiple levels of ambient air quality standards (limit values, target values, alert thresholds, prevention of significant decline, move towards "*banding*"),
f. Mandatory air quality monitoring in non-attainment areas,
g. Standardization of monitoring and modelling, and
h. Easy public access to information.

2.3.1 European community ambient air quality directive

In June 1995 the European Union Environmental Council published a Directive on Ambient Air Quality Assessment and Management (96/62/EC) (Annegarn & Scorgie, 1997), which is commonly known as the Ambient Air Quality Framework Directive (Beattie *et al*., 2001). The document consists of 10 articles that start with the objectives of the Directive and definitions of key words and further addresses ambient air quality assessment and management (Mitchell *et al.*, 2000; Annegarn & Scorgie, 1997). Twelve pollutants were identified for which target and limit values were set in subsequent daughter directives (Mitchell *et al.*, 2000; Annegarn & Scorgie, 1997); these directives set the framework in which the air quality management within member states must operate, but it is up to each country to decide how best to achieve the directive limit values (Mitchell *et al.*, 2000). The daughter directive on SO_2, NO_2, particulates and Pb, for example, sets legally binding limits that must be achieved by 1 January 2005 and 2010 (Mitchell *et al.*, 2000).

2.3.2 United Kingdom: The effects based approach

In the early 1990's episodes of poor air quality in the urban areas of the United Kingdom indicated that the existing framework for the control of air quality was inadequate (Longhurst *et al.*, 1996). The legislative framework, based largely on particular source emission controls and "*dilute and disperse*" approaches (Hughes, 1992 cited in Longhurst *et al.*, 1996: 3975), did not have the policy tools to provide an effective response (Vogel, 1986 cited in Longhurst *et al.*, 1996: 3975). Different emission sources tended to be controlled by separate government departments and their associated agencies, which resulted in a fragmented approach to air pollution control (Longhurst *et al.*, 1996). Along with more general air quality issues that were widely publicised in the media, the public concern and demands for more information about the potential risks rose (Longhurst *et al.*, 1996). To address these problems a discussion document "*Improving Air Quality*" (IM94) was published in which the following issues were discussed (Beattie *et al.*, 2001; Annegarn & Scorgie, 1997):

a. The reasons for a shift from a source based control policy to an effects based approach,
b. Air quality standards and their limitations,
c. Frameworks for standards and considerations in setting standards,
d. All the details and principles in the EU Directive,
e. Links between local air quality and land use planning,
f. Links between air quality and transportation planning,
g. The role of pollution monitoring and public information, and
h. Appropriate roles for local authorities in planning and implementing control measures within the defined air quality management areas.

The above document resulted in the AQM framework legislated through the Environmental Act 1995 and required the National Air Quality Strategy to be published (Fig. 2.8) (Beattie *et al.*, 2001).

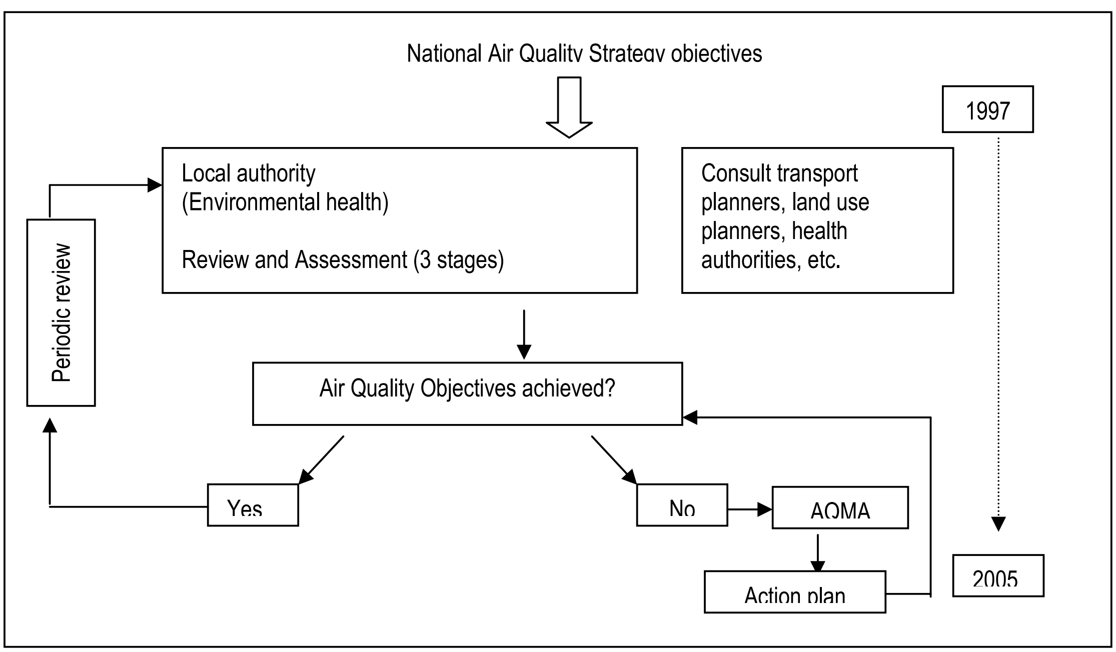


Figure 2.8: The NAQS as local authorities currently implement it (Beattie *et al.*, 2001)**.**

The NAQS required the implementation of Air Quality Regulations (1997), which meant that all unitary local authorities had to review and assess the air quality within their boundaries and implement sustainable pollution reduction strategies in areas where health-based national air quality targets and objectives are predicted not to be met by the year 2005 (Crabbe *et al.*, 1999; DoE, 1997 cited in Crabbe *et al.*, 1999). The NAQS was reviewed in 1999 to reflect developments in European legislation, technological and scientific advances, improved air pollution modelling techniques and an increasingly better understanding of the socio-economic issues involved (Beattie *et al*., 2001). Since the publication of the NAQS, AQM practice and capability within local authorities has flourished and monitoring and air dispersion modelling has increased (Beattie *et al*., 2001). The AQM process, as implemented by UK local authorities, provided an effective model for other European member states regarding the implementation of the Air Quality Framework Directive (Fig. 2.9) (Beattie *et al*., 2001).

2.3.3 United States: Environmental Protection Agency and State Implementation Plans

The United States, through the Environmental Protection Agency (EPA), has one of the most well developed procedures for air quality management (Fig. 2.10) (Annegarn & Scorgie, 1997; Longhurst *et al.*, 1996). In the late 1960's and 1970's the US environmental control system was forced to be overregulating, with disproportionate resources spent on legal disputes (Annegarn & Scorgie, 1997). By the late 1980's the EPA has moved towards a partnership approach with industry, providing technical advice and development, while nevertheless maintaining its role as the legal enforcement agency (Annegarn & Scorgie, 1997).

Urban metropolitan air quality planning is enforced at a state level (Annegarn & Scorgie, 1997). Areas not meeting National Ambient Air Quality Standards (NAAQS) for specified pollutants are designated as not in compliance (Annegarn & Scorgie, 1997). State governments are required to submit State Implementation Plans (SIP's), which can be described as ongoing documents that provide a regulatory framework for a state to demonstrate to the federal government the attaining and maintaining of national ambient air quality standards over a time span not to exceed 5 years (Annegarn & Scorgie, 1997; Griffin, 1994 cited in Longhurst, 1996: 3980). The EPA provides extensive guidance documents on the development of SIP's (Annegarn & Scorgie, 1997). Requirements for SIP's include most of the features already mentioned in the discussions on the European and British policies above, namely standards, modelling, monitoring, definition of air quality management areas and public participation (Annegarn & Scorgie, 1997).

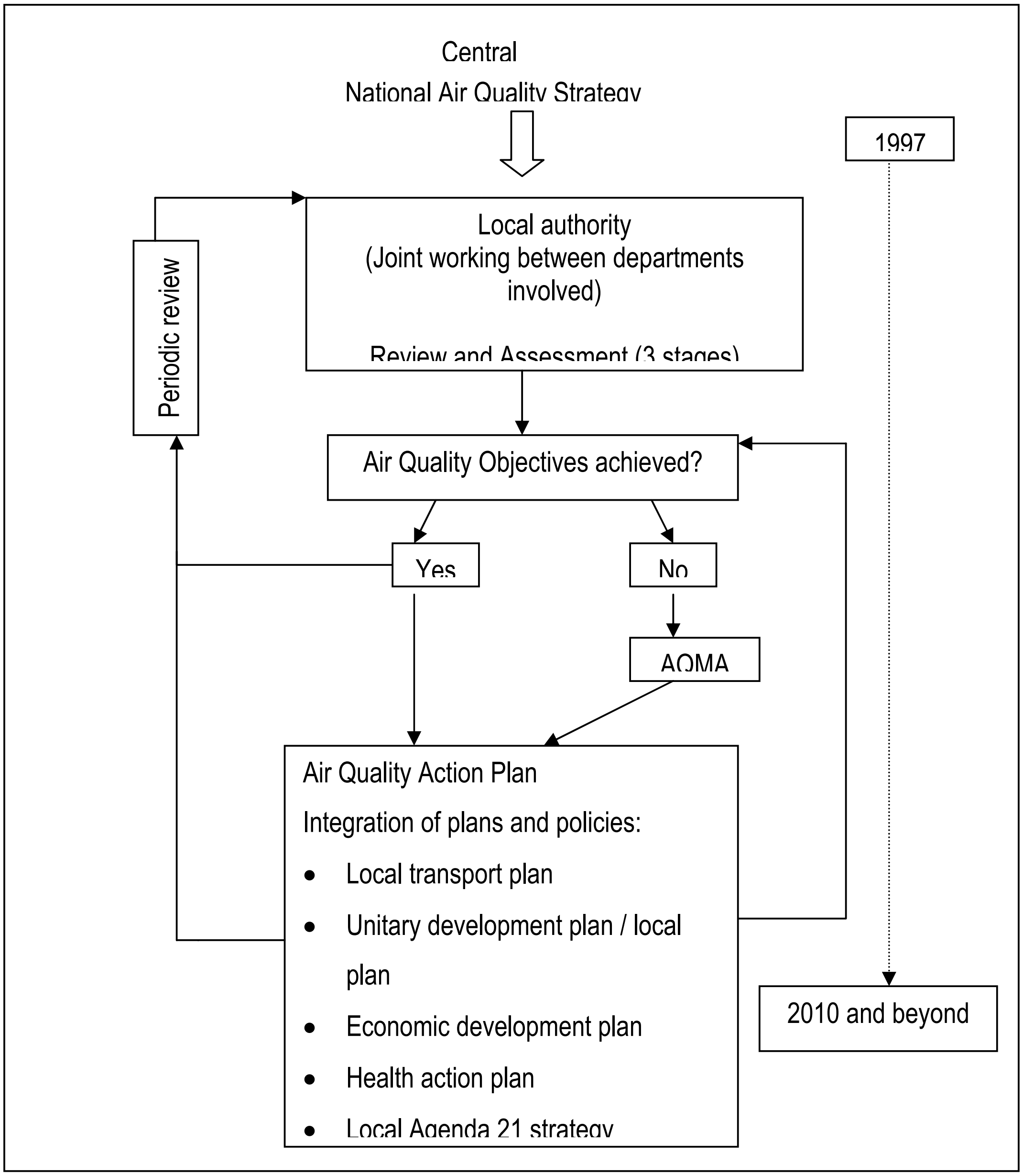


Figure 2.9: The ideal model for future AQM practice in local authorities and other agencies (Beattie *et al*., 2001)**.**

The United State's approach focuses strongly on quantitative emission inventories and modelling as a basis for all control strategies (Annegarn & Scorgie, 1997). Failure to submit a plan, or negligently failing to meet the goals may be punished by withdrawal of industrial development funding and mandatory freeze on new source permitting (if pollution is industrial sourced) (Annegarn & Scorgie, 1997). The punitive measures, while severe, are intended to encourage compliance by targeting appropriate sectors (Annegarn & Scorgie, 1997).

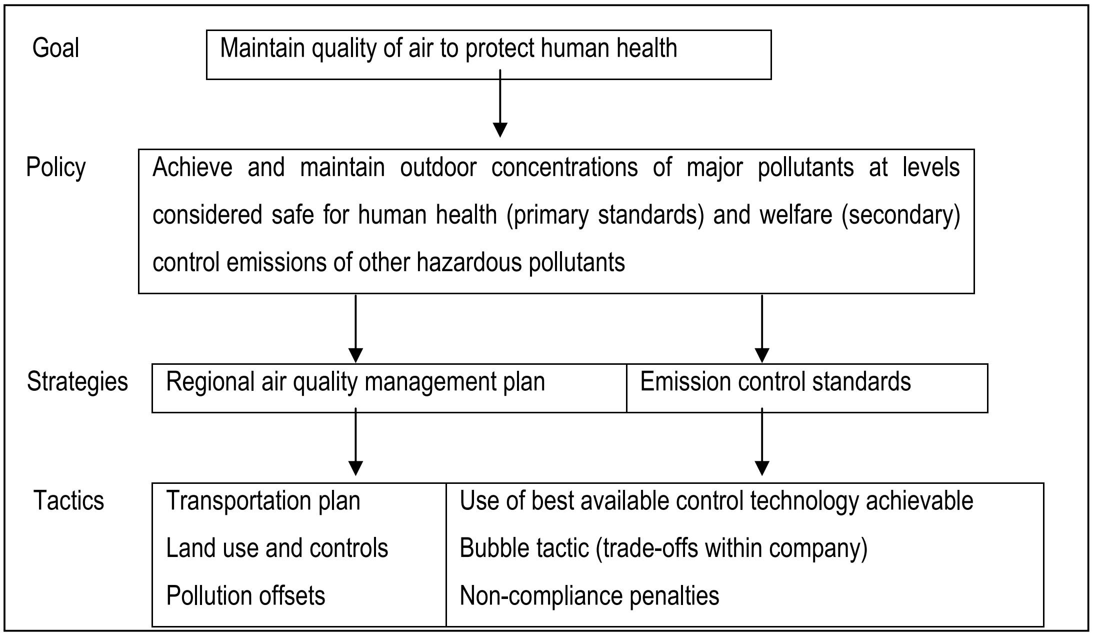


Figure 2.10: The structure of the U.S ambient air quality legislation as established by the Clean Air Act 1970, and amendments (WHO, 2000)**.**

2.4 New or alternative directions

The international management of air quality further includes a number of new or alternative directions that is not limited to a specific country.

2.4.1 Responsible care

Responsible Care is a framework that originated from the Canadian Chemical Producers Association (CCPA) in 1984 and has since been adopted formally in many other major industrialized countries (Gerrans, 1993). Although it was developed specifically for the chemical industry, the principles can be applied to other industries. The guiding principles of Responsible Care are (Gerrans, 1993):

a. To recognize and respond to community concerns about chemicals and operations;
b. To develop and produce chemicals that can be manufactured, transported, used and disposed of safely;
c. To make health, safety and environmental considerations a priority in planning for all existing and new products and processes;
d. To report promptly to officials, employees, customers and the public, information on chemical-related health or environmental hazards and to recommend protective measures;
e. To counsel customers on the safe use, transportation and disposal of chemical products;
f. To operate plants and facilities in a manner that protects the environment and the health and safety of employees and the public;
g. To extend knowledge by conducting or supporting research on the health, safety and environmental effects of products, processes and waste materials;
h. To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment;
i. To work with others to resolve problems created by past handling and disposal of hazardous substances; and
j. To promote the principles and practices of responsible care by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of chemicals.

2.4.2 Emission trading

The process of calculating tradable pollution credits is graphically depicted in Figure 2.11. The ecological target of environmental policy is the attainment of given standards (fixed by a political decision) of environmental quality (Zerlauth & Schubert, 1999). Given the standard, a compatible volume of predetermined total allowable emissions per year has to be computed which defines the maximum number of pollution credits that can be used in a given year ("*emission cap*") (Zerlauth & Schubert, 1999). The polluters are allocated a share of the credits for a year according to a predetermined key, which entitles them to emit residuals equal at most to the allocated volume of pollution rights (Zerlauth & Schubert, 1999). If the maximum number of emissions is not attained, the licensee is entitled to sell the surplus in a market for pollution rights (Zerlauth & Schubert, 1999). In the opposite case, additional credits must be purchased (Zerlauth & Schubert, 1999). Each polluter can thus choose the most cost-effective abatement strategy in a system that provides an incentive to lower emissions in order to be able to sell superfluous credits in the market (Zerlauth & Schubert, 1999).

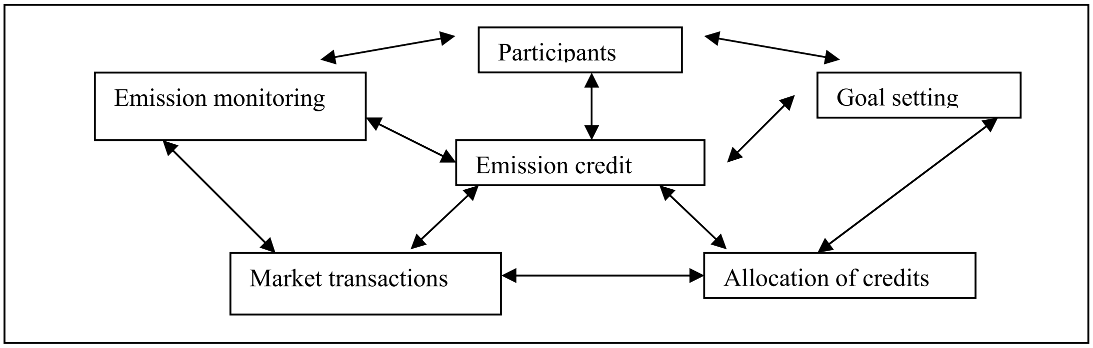


Figure 2.11: The basic elements of an emission-trading program (Zerlauth & Schubert, 1999)**.**

The system of emission trading combines elements of public decision-making (standards and institutional framework), and private decentralized decisions coordinated via a market of pollution rights (Zerlauth & Schubert, 1999). Use is made of the capability of markets to co-ordinate decisions, to achieve efficient solutions in the long run (cost effectiveness), and to set in motion innovation processes to lower costs of achieving better environmental quality (Zerlauth & Schubert, 1999). Compared to the classical "*Command-and-Control*" system prevalent in much of international environmental policy, there is little need for very detailed regulation and its concomitant problems of control: the pollution control authority only needs to set emission standards for the entire area in which the system is applied and monitor the emissions as compared to the credits (Zerlauth & Schubert, 1999). Monitoring is crucial in an emissions trading program and a completely new approach to track and enforce emissions and emission reductions is necessary (Zerlauth & Schubert, 1999). With South Africa's outdated approach to air pollution management, the proper introduction of emission trading would be limited.

2.4.3 Voluntary measures

The interest in so-called voluntary approaches to supplement or replace formal environmental or occupational health and safety regulations, has taken on new importance in both Europe and the United States (Ashford & Caldart, 2001; Cunningham, 2000). These approaches, which according to Cunningham (2000) are not working, can be divided into two groups (Ashford & Caldart, 2001):

a) Industry-initiated codes of good practice focusing on environmental management systems or performance goals, and
b) Negotiated agreements between government and individual firms or industry sector trade associations focusing on regulation or compliance.

2.4.4 Effects based approach

In recent years there has been a strong shift from air pollution control based exclusively on source-based methods (*e.g.* emission limits) to air quality management based on an effects-based approach (*e.g.* air quality objectives) because of shortcomings in the former (Burger & Scorgie, 2000a). Emission limits do not take the unique characteristics of the receiving environment (dispersion potential, existence of other sources, existing ambient pollutant concentrations and sensitivity of receiving environment) into account (Burger & Scorgie, 2000a). Therefore, no insurance is provided that ambient air quality objectives will be met and that there will be no adverse effects on human health and welfare (Burger & Scorgie, 2000a). Source-based controls cannot ensure acceptable levels of air quality, but they do represent an important means of achieving and attaining ambient standards and guidelines (Burger & Scorgie, 2000a).

The methodology of the effects-based approach is similar to food labelling (Seika & Metz, 1999). Food labelling enables each individual to combine the nutrition information of a product with unique circumstances such as age and life style (Seika & Metz, 1999). With air quality, the information would be an estimated personal intake, *e.g.* of benzene, for various locations or activities (Seika & Metz, 1999). Although air quality standards should not be exceeded, the driving force is the customer (citizen or consumer) of air and standards no longer hold the key position (Seika & Metz, 1999). By expressing a demand for information the customer receives individualised personal exposure data (indoor air quality, domestic activities or occupational exposure) (Seika & Metz, 1999).

Possible customers for the exposure-based AQM process are agencies, businesses, industry, individuals, interest groups, local political groups, research institutions and public service providers (Seika & Metz, 1999). In areas where the responsible agency cannot take any direct action themselves, adequate advice and information is given to the customer which include information on who can be made responsible for the particular exposure and what else can be done to lower the exposure level (Seika & Metz, 1999). Finally, it is the responsibility of the individual customer to decide whether or not personal exposure levels are acceptable, if more action is needed (political pressure, pressure on industries, property dealers, petrol stations, etc.) and in what area (Seika & Metz, 1999). The result could be a more targeted and effective AQM system (Seika & Metz, 1999).

Air quality management focusing on pollution control consists of a number of different aspects as has been discussed in section 2.2.1. There are however a few stages that is basic and crucial for the proper functioning of such a pollution control plan and include:

a. Ambient air quality guidelines and standards,
b. Measuring air pollution,
c. Monitoring of air pollutants,
d. Air pollution modelling and prediction, and
e. Air pollution control.

These five aspects will be discussed for pollution control (with specific reference to particulate pollution) in the remaining part of the Chapter.

2.5 Ambient air quality guidelines and standards

Legislation (air quality guidelines and standards) is the main driving force for effective air quality management, providing the link between the source of atmospheric emissions and the user (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b; Cunningham, 2000). However, the type of legislation and regulation is extremely important; air quality guidelines should be clearly distinguished from air quality standards (Cunningham, 2000; Schwela, 1998). Air quality standards are values limiting air pollutant concentration promulgated through legislation (take technological feasibility, costs of compliance, prevailing exposure levels, social, economic and cultural conditions into consideration) (Schwela, 1998). Air quality guidelines are derived from purely epidemiological and toxicological (or environment–related) data and have several objectives, including (Schwela, 1998):

a. Protection of public health from adverse effects of pollutants,
b. Elimination or reduction to a minimum of air contaminant concentrations,
c. Provision of background information for making risk management decisions,
d. Provision of guidance to governments in setting standards, and
e. Assistance in implementing local, regional, national action plans.

The most notable international trends in ambient air quality guidelines and standards identified are (Burger & Scorgie, 2000b; Chitwood *et al.*, 2000):

a. Guidelines and standards are becoming increasingly more stringent - initially allowing many exceedances but increasingly restrict the number of exceedances allowed (*e.g.* new EU standards and US-EPA standards);
b. Dose-response relationships are being introduced in place of threshold type limits - strongly supported by the WHO for particulates; and
c. Expansion of regulations from exclusive protection of human health to the protection of vegetation and ecosystems (*e.g.*UK objectives for SO_2 and NO_2, and the new EC standards).

Air quality guidelines and standards are normally given for specific averaging periods, which refer to the time-span over which the air concentration of the pollutant was monitored at a location (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b). Five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b).

2.5.1 Air quality guidelines and standards for particulates

Total Suspended Particulates (TSP) have previously been used as the measurement but since an important mass fraction of TSP is made of non-inhalable particulates with lower impact on respiratory and cardiovascular diseases, the relationship between health effects and TSP levels was found, on comparison, to be much lower than the levels of atmospheric particulates finer than PM_{10}, $PM_{2.5}$ and PM_1 (Querol *et al*., 2001). Currently, PM_{10} and $PM_{2.5}$ measurements are applied to the US ambient air quality standards and European Union (EU) countries (Table 2.1) (Querol *et al*., 2001; Boubel *et al*., 1994). Guidelines for particulates are normally given as a maximum daily or annual average (Burger & Scorgie, 2000a).

In determining "*acceptable*" airborne particulate concentrations a decision maker will be faced with the following controversial decisions (Burger & Scorgie, 2000a; Burger & Scorgie, 2000b; Junker & Schwela, 1998 cited in Burger & Scorgie, 2000a: 3-15):

a. Selection of the curve to be used for the derivation of an acceptable ambient particulate concentration (*i.e.* decide from which health effect the population is to be protected);

b. Determine the population or sensitive groups, which are to be protected from air pollution effects; and

c. Set a fixed value for the acceptable risk in a population so that a single value for a given exposure period may be defined.

Table 2.1: Air quality guidelines and standards for inhalable particulates (PM_{10}) (Scorgie (2001a); Burger & Scorgie (2000b); Chow & Watson (1998 cited in Burger & Scorgie, 2000a: 3-5); SRK (1997); Loveday (1995 cited in Burger & Scorgie, 2000a: 3-5); Cochran & Pielke (1992 cited in Burger & Scorgie, 2000a: 3-5)).

Country / Organisation	Inhalable particulates (PM_{10})		
	Maximum 1-hour Concentrations ($\mu g.m^{-3}$)	Maximum 24-hour concentrations ($\mu g.m^{-3}$)	Annual average concentrations ($\mu g.m^{-3}$)
South Africa		180 (1)	60 (4)
United States EPA (US – EPA)		150 (2) (3) 65 $\mu g.m^{-3}$ (PM2.5)	50 (4) 15 $\mu g.m^{-3}$ (PM2.5)
World Health Organisation (WHO)		150 – 230 (5)	60 – 90 (4) (5)
World Bank (WB)		260	75 (7)
Old European Union (EU) standards		130 (7) 250 (8)	80
New EU standards		50 (9)	30 (10) 20 (11)
UK National Air Quality Objectives		50	40
UK Department of Environment		< 50 $\mu g.m^{-3}$ = low 50 – 74 $\mu g.m^{-3}$ = moderate 75 – 99 $\mu g.m^{-3}$ = high 100 $\mu g.m^{-3}$ = very high	

Notes:
(1) Not to be exceeded more than three times per year.
(2) Requires that the three-year annual average concentration be less than this limit.
(3) Not to be exceeded more than once per year.
(4) Represents the arithmetic mean.
(5) Refers to pre-1998 guidelines. The WHO no longer publishes guidelines for particulates.
(6) Annual geometric mean.
(7) Median of daily means for the winter period (1 October to 31 March.)
(8) Calculated from 95th percentile of daily means for the year.
(9) Compliance by January 2005. Not to be exceeded more than 25 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.).
(10) Compliance by 1 January 2005.
(11) Compliance by 1 January 2010.

2.5.2 Dust deposition limits

Dust deposition is classified according to the criteria published by the South African Department of Environmental Affairs and Tourism (DEAT) (Table 2.2) (Burger & Scorgie, 2000a). The South African guidelines for dust deposition are similar to standards used in Germany (< 650 $mg.m^{-2}.day$ for residential areas and < 1300 $mg.m^{-2}.day$ for industrial areas) (Burger & Scorgie, 2000a). No criteria for the evaluation of dust deposition levels are available for the USA-EPA, EU, WHO, or the World Bank (Burger & Scorgie, 2000a).

Table 2.2: National guidelines for the categorisation of dust deposition (Burger & Scorgie (2000a, 2000b); SRK (1997)).

Dust deposition category	Dust deposition
Slight	<250 $mg.m^{-2}.day$
Moderate	250 to 500 $mg.m^{-2}.day$
Heavy	500 to 1 200 $mg.m^{-2}.day$
Very heavy	>1 200 $mg.m^{-2}.day$

Dust deposition monitoring can be conducted by means of (Scorgie, 2001a):

a. Single bucket dust fallout monitor, and
b. Twin bucket wind direction sampler

2.6 Measuring air pollution

2.6.1 Techniques used to measure air pollution

Measuring particulates involves a different set of parameters from those used for gases because particulates are inherently larger than the molecules of N_2 and O_2 and behave differently with increasing diameter (Boubel *et al*., 1994). Personal exposure measurements can be performed directly or indirectly (Ott, 1982 cited in Monn, 2001: 3). In the direct approach (Table 2.3 and Table 2.4) exposure levels are determined on an individual basis (by using a personal sampler or a biological marker); the indirect approach can include ambient measurements, the use of microenvironments (MEs), models and questionnaires (Monn, 2001; Ott, 1982 cited in Monn, 2001: 3). The credibility of air quality measurement is dependent on the following factors (Scorgie, 2001a):

a. Metrology (the science of measurement),
b. The accreditation of the laboratory,
c. Competence of persons undertaking the monitoring,
d. The traceability chain of the standard used, and
e. The quality system of the calibrating laboratory.

The evaluation of a method has to consider method-inherent criteria such as sensitivity, precision, accuracy, selectivity and detection limit (Monn, 2001). Besides these criteria, cost and applicability are important factors in the choice of a particular method (Monn, 2001).

Table 2.3: Techniques for measuring particulates (note: continuous refers to a response signal within a few seconds to minutes) (Wijnand (1996) cited in Monn (2001: 4)).

Pollutants	Measurement techniques	Time resolution
Particulates TSP PM_{10} $PM_{2.5}$	Gravimetry	One day, hours
	Beta meter	Integrated, day, hours
	Tapered element	Continuous, minutes
	Nephelometer	Continuous, minutes
	Photoelectric aerosol sensor (PAS)	Continuous, minutes
Particulates (personal)	Size fraction: impaction, cyclone gravimetry	Integrated: hours, 1 day
	Light scattering	Continuous, minutes
	Photo-emission sensor (PAS)	Continuous, minutes

Table 2.4: Comparing pollution measurement techniques (Scorgie (2001a); Dore & McGinlay (1997); Boubel *et al*. (1994)).

Passive samplers	Active samplers	Automatic real time point monitors	*Long path and spatially resolved monitoring*	Mobile monitoring
Advantages				
1. Give a good overall picture of average pollutant concentrations 2. No electricity or calibration required 3. Samplers are easy to prepare, assemble and analyse 4. Low operational cost 5. Low costs permits monitoring at a number of points ("hotspots", baseline surveys, area screening) 6. No field maintenance is required 7. Constant sampling rate	1. Relatively low capital cost 2. Reliable operation and performance	1. On-line, real-time results 2. Provide time-resolved data – short averaging periods (hourly or better)	1. Usually allow measurement of several different pollutants conveniently in one system 2. No direct contact with the sample gas 3. Useful in circumstances where large areas need to be scanned from a single point	1. The ability to obtain air quality information in the intermediate region between source monitors and stationary fixed monitors 2. Real-time measurement using small, light-weight instrument
Disadvantages				
	1. Provide daily averages 2. Require power supply 3. Labour intensive 4. Require laboratory analysis	1. Expensive 2. Require high standards of maintenance 3. Produce large quantities of data – necessitate effective data transfer and storage facilities	1. Expensive 2. Used for short-term monitoring campaigns due to expense 3. Measurement may be lost or degraded during low visibility weather conditions 4. Methods not currently appropriate for monitoring compliance with EC Directive limit values	1. Less sensitive than point monitors 2. Often subject to interference from other pollutant species, temperature and humidity 3. Stability of response may be a problem, frequent calibration required 4. Data recorded over limited period, not temporally representative of ambient conditions 5. Short-term studies cannot provide information on long-term trends

In selecting methods for measuring air quality or assessing air pollution effects the inherent averaging times must be borne in mind (Boubel *et al*., 1994). The three most important cycles are (Boubel *et al*., 1994):

a. Diurnal cycle,

b. Weekend-weekday, and

c. Seasonal cycle.

2.6.2 Steps in measuring for air pollution

2.6.2.1 Sampling site selection

The fundamental reason for controlling air pollution sources is to limit the build-up of contaminants in the atmosphere so that adverse effects are not observed (Boubel *et al*., 1994). Therefore, sampling sites should be selected to measure pollutant levels close to or representative of exposed populations of people, plants, trees, materials, structures, etc (Boubel *et al*., 1994). Generally, sites in air quality networks are near ground level, typically 3m above ground, and are located so as not to be unduly dominated by a nearby source such as a roadway (Boubel *et al*., 1994). Sampling sites require electrical power and adequate protection (which may be as simple as a fence or a shelter) (Boubel *et al*., 1994). Permanent sites require adequate heating and air conditioning to provide a stable operating environment for the sampling and monitoring equipment (Boubel *et al*., 1994). The tools available for site selection include climatological data, topography, population data, emission inventory data, diffusion modelling, maps and wind roses (Boubel *et al*., 1994). The overall approach for selection of sampling sites is to (Boubel *et al*., 1994; US EPA, 1977 cited in Boubel *et al*., 1994: 217):

a. Define the purpose of the collected data,
b. Assemble site selection aids,
c. Define the general areas for samplers based on chemical and meteorological constraints, and
d. Determine the final sites based on sampling requirements and surrounding objects.

2.6.2.2 Data logging and transfer

Although most analysers have internal data storage facilities, logging is usually carried out by means of a dedicated data logger (PC or specialized data logger) (Boubel *et al*., 1994). Data transfer may be undertaken in various ways (Boubel *et al*., 1994):

a. Downloaded intermittently from the instrument,
b. Real-time, continuous transfer via telemetry,
c. Near real-time, intermittent transfer via radio link, and
d. Continuous download via satellite.

2.6.2.3 Data analysis and display

Air quality information often consists of a large body of data collected at a variety of locations and over different seasons (Boubel *et al*., 1994). Raw data must be analysed and transformed into a format useful for specific purposes (*e.g.* summary tables, graphs, geographic distributions, pollutant concentration maps) (Boubel *et al*., 1994). In general, air quality data are classified as a function of time, location and magnitude (Boubel *et al*., 1994). Several statistical parameters may be used to characterize a group of air pollution concentrations, including the arithmetic mean, the median, and the geometric mean (Boubel *et al*., 1994). These parameters may be determined over averaging times of up to 1 year (Boubel *et al*., 1994). In addition to these three parameters, a measure of the variability of a data set, such as the standards deviation or the geometric standard deviation, indicates the range of data around the value selected to represent the data set (Boubel *et al*., 1994).

2.6.2.4 Quality assurance and quality control of ambient air quality measurements

Quality assurance (QA) and quality control (QC) are crucial components of air quality management, although it will only account for a small fraction of the total cost (Scorgie, 2001a; Sweeney *et al*., 1997). The principle objectives of QA/QC are to identify, quantify and reduce the potential for procedural and technical errors (Scorgie, 2001a).

a. Quality assurance

QA involves the management of the entire process (all the planned and systematic activities needed to assure and demonstrate the predefined quality of the data) (Scorgie, 2001a; Sweeney *et al*., 1997). QA requirements are related to precision and accuracy and include (Scorgie, 2001a; Boubel *et al*., 1994):

a. Monitoring objectives and data quality objectives,
b. Procedures for site selection and air quality monitoring network design,
c. Requirements for the laboratory responsible for implementation of the QA/QC plan, and
d. Selection of instrumentation based on justifiable criteria, including: measuring devices, calibration instrumentation, measurement data management and processing equipment, and infrastructure equipment such as sampling lines and station shelters.

QA programs are designed for the assessment of collected air quality data and the improvement of the data collection process (Boubel *et al*., 1994). These two functions form a loop - as air quality data are collected, procedures are implemented to determine whether the data are of acceptable precision and accuracy (Boubel *et al*., 1994). If they are not, increased quality control procedures are implemented to improve the data collection process (Boubel *et al*., 1994).

b. Quality control

Quality Control (QC) functions affect measurement-related activities such as site operation, calibration, data management, field audits and training and include (Scorgie, 2001a):

a. Site operation and equipment maintenance,
b. Calibration,
c. Data validation procedures, and
d. Data completeness.

In addition to fulfilling the in-house requirements for QC, air-monitoring networks are required to contain an external performance audit on an annual basis (Boubel *et al*., 1994). Under this programme, an independent organization supplies externally calibrated sources of air pollution gases to be measured by the instrumentation audited (Boubel *et al*., 1994). The performance of the instrument is summarized in a report after which further action must be taken to eliminate any major discrepancies between the internal and external calibration results (Boubel *et al*., 1994).

2.7 Monitoring of air pollutants

The identification and measurement of critical environmental variables is the backbone to defining and understanding the state of the environment and its changes with time (Demerjian, 2000). Monitoring objectives (Table 2.5) determine the quantity and quality of data required, the sampling frequency, the number of sampling locations and the permissible delay in obtaining results (Scorgie, 2001a).

Table 2.5: Purpose, relationship of the scale of representativeness and monitoring objectives (Scorgie, 2001a; Boubel et al., 1994)**.**

Purpose	*Objectives*
Compliance monitoring	*Source-specific investigations*
Temporal trend analysis	*Pollutant concentration trend analysis*
Spatial trend analysis	*Impact assessment*
Tracking of progress from pollution control measure implementation	*Information generation and compliance assessment*
Source contribution quantification	*Policy and planning*
Siting scales for monitoring objectives	
Highest concentration affecting people • Micro, middle, neighbourhood, (sometimes urban)	Source impact • Micro, middle, neighbourhood
High-density population exposure • Neighbourhood, urban	General/background concentration • Neighbourhood, region

2.7.1 Ambient monitoring network design

A monitoring system is selected to meet specific needs (e.g. measure the quality of air to which the general population is exposed) and is tailored to the unique properties of the emissions from a particular process (Table 2.5) (Boubel *et al*., 1994). It is necessary to take into account the specific process, the nature of the control devices, the peculiarities of the source, and the use of the data obtained (Code of Federal Regulations, 1992 cited in Boubel *et al*., 1994: 548). Environmental monitoring networks are designed either to determine the physical and chemical state of the environment (*e.g.* air quality, meteorological, water quality, etc.) or the ecological state of the environment (species diversity, soil erosion, biomass productivity, etc.) (Fig. 2.12) (Demerjian, 2000). A monitoring network should be established at least 12 months before construction to determine prior air quality (Boubel *et al*., 1994).

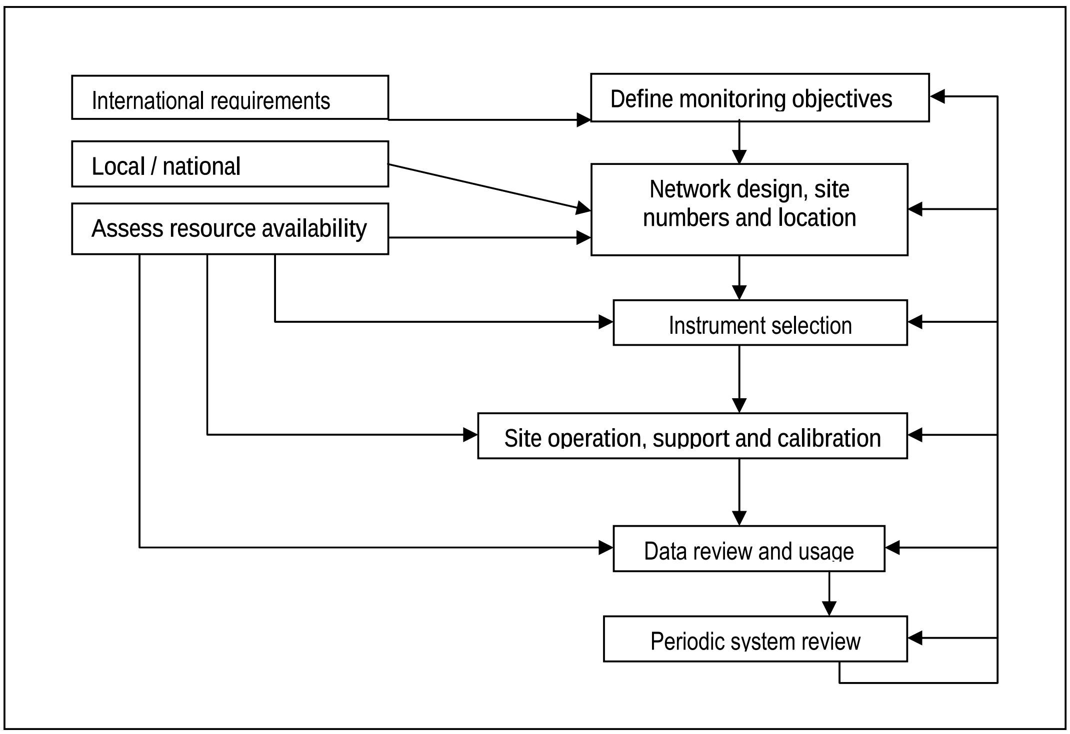


Figure 2.12: Systematic approach to ambient monitoring network establishment (WHO, 2000 cited in Scorgie, 2001a)**.**

2.7.2 Meteorological monitoring

Site-specific meteorological data from a well-maintained monitoring site represents one of the cornerstones of an effective air pollution management programme (Scorgie, 2001a). The meteorology of a site is important in (Scorgie, 2001a):

a. Determining the rate of emissions from fugitive sources (key parameters are wind speed, rainfall, evaporation), and

b. Governing the dispersion, transformation and eventual removal of pollutants from the atmosphere (key parameters include: wind speed, wind direction, atmospheric stability, temperature, relatively humidity, solar radiation, rainfall).

Hourly average meteorological data are typically required as input to atmospheric dispersion simulations, with wind speed, wind direction and ambient temperature representing the most important parameters for this purpose (Table 2.6) (Scorgie, 2001a). On-line, real-time meteorological data are useful for providing input to real-time emission calculation models and dispersion models (Scorgie, 2001a).

Table 2.6: Factors involved in meteorological stations *(Scorgie, 2001a)*.

Data used for	Factors to be taken into account in establishing a meteorological station	Meteorological parameters of interest	Meteorological data analysis
Emission estimation	Meteorological parameters to be recorded by the station	Wind speed, wind direction	Wind roses
Simulation of the atmospheric dispersion and removal of pollutants	Averaging period over which to record parameters	Ambient temperature, relative humidity	Rainfall roses
Interpretation of trends in ambient air concentration and deposition levels measured	Data transfer	Evaporation and precipitation	Atmospheric stability roses
Examining causes of peaks in pollution levels, and assisting in the investigation of complaints received	Correct siting of the meteorological station according to internationally accepted practices	Solar radiation and sigma-theta	The relationship between wind direction and atmospheric stability can similarly be illustrated graphically.
			Frequency of exceedance of wind speed thresholds

2.8 Air pollution modelling and prediction

Modelling is a powerful tool for the interpolation, prediction and optimisation of control strategies through computing temporal and spatial patterns of ambient pollutant concentrations and deposition levels occurring as a result of emissions from one or more sources (Scorgie, 2001a; WHO, 2000). Rather than construct and monitor to determine the impact, and whether it is necessary to retrofit additional controls, it is desirable to assess the air pollution impact of a facility prior to its construction (Boubel *et al.*, 1994). However, models need to be validated by monitoring data (WHO, 2000). Air quality simulation models allow the consequences of various options for improving air quality to be compared (Table 2.7) and are indispensable in at least three cases (WHO, 2000; Boubel *et al.*, 1994; Zannetti, 1993):

a. When measurements are not available or sufficient,
b. For assessing the degree of responsibility of different polluting sources, and
c. To make pollution forecasts and evaluate "*what if*" scenarios.

In its simplest form, a model requires two types of data inputs: information on the source or sources (including pollutant emission rate), and meteorological data (*e.g.* wind velocity and turbulence) (Boubel *et al.*, 1994). The model then mathematically simulates the pollutant's transport and dispersion, its chemical and physical transformations and removal processes (Boubel *et al.*, 1994). The model output is air pollutant concentration for a particular time period, usually at specific receptor locations (Boubel *et al.*, 1994). The accuracy of a model depends on many factors, including the accuracy of the source emissions data, the quality of knowledge of meteorological conditions in the area, and the assumptions about physical and chemical processes in the atmosphere involving the transport and transformation of pollutants (WHO, 2000).

Table 2.7: Model application and functions and the order of model application (Scorgie, 2001a)**.**

The main function of a model is the parameterisation of source-receptor relationship based on	Model applications	Order of model application
Source configurations	Determining compliance with regulations (proposed and existing sources)	Tier 1: screening models (*e.g.* SCREEN3) use worst-case meteorological conditions to estimate maximum downwind concentrations
Emission strengths (and temporal variations in such strengths)	Basis for quantitative health and environmental risk assessment	Secondary / Tier 2: screening models (*e.g.* ISCST) site specific meteorology and topography used as input but unable to account for spatial variations in airflow
Meteorological characteristics	Site selection for monitoring	Refined / Tier 3 models: characterises spatial variations in airflow due to complex terrain (*e.g.* CALPUFF, HAWK)
Terrain characteristics	Assessment of source contributions	
Receptor locations and heights	Buffer zone delineation	
	On-line applications	
	"What if" investigations: assessing mitigation measures, accident scenarios, etc.	
	Integral component of air quality management and planning	

2.8.1 Model types

A wide variety of models are available (Table 2.8) which are usually distinguished by type and source, pollutant, transformations and removal, distance of transport, and averaging time (Boubel *et al.*, 1994). Generally, models can be grouped into physical (deterministic) and statistical (or stochastic) models (Sexton & Ryan, 1988 cited in Monn, 2001: 6). Some models rely on both physical-chemical knowledge and incorporate statistical approaches (hybrid models) (Monn, 2001). Physical models are based on mathematical equations, describing known physical/chemical mechanisms in the atmosphere (Monn, 2001). Statistical models are based on measured data and explanatory variables (Monn, 2001). For outdoor pollutants, sophisticated dispersion models (*e.g.*

Gauss models), which incorporate meteorological variables and chemical processes, have been developed (Monn, 2001).

Mathematical models are the only practical tool that can answer "*what if*" questions - no strategy for emission reduction and control can be cost-effective without applying proper mathematical modelling techniques (Zannetti, 1993). Only a well-tested and well-calibrated simulation model could be a good representation of a three-dimensional real world, its dynamics, and its responses to possible future perturbations (Zannetti, 1993). Zannetti (1993) states that although mathematical modelling is an indispensable tool for air quality analyses, it cannot claim to be the "*solution*" to air pollution problems. Deterministic models are important for practical application by providing an unambiguous, objective, source-receptor relationship which is the goal of any study aiming either at improving ambient air quality or preserving the existing concentration levels from future urban and industrial development (Zannetti, 1993). Scorgie (2001a) describes the following types of models:

a. Source based models,
b. Receptor based models,
c. Gaussian plume (Eulerian) (*e.g.* Industrial Source Complex Model),
d. Lagrangian Puff models (*e.g.* CALPUFF, HAWK),
e. Lagrangian models,
f. Long-range transport (*e.g.* chemistry models),
g. Urban- (*e.g.* Urban Air shed Model) and street-scale modelling (*e.g.* STREET), and
h. Specialised dispersion models
    - Dense gas dispersion modelling (*e.g.* HAWK)
    - Modelling of visibility (*e.g.* PLUVUE)

Table 2.8: Different types of mathematical models (Zannetti, 1993).

	Mathematical models	Description		Mathematical models	Description
1	Meteorological models	Simulation of those meteorological parameters, such as wind, intensity of turbulence, etc., that affect the dispersion of pollutants in the atmosphere	9	Indoor air pollution models	Simulate the accumulation of pollutants inside buildings and poorly ventilated areas
2	Plume-rise models	Simulation of the initial dispersion phase of buoyant plumes, characterized by a rise of the plume above its emission level	10	Receptor models	Techniques that, solely through the chemical analysis of air pollution measurements, are able to apportion the contribution of each source (or each group of sources) to the measured concentrations without the need for reconstructing the dispersion pattern of pollutants
3	Gaussian models	Techniques in which atmospheric diffusion is approximated by assuming that the concentration field inside each plume maintains a Gaussian distribution horizontally and vertically	11	Stochastic models	Statistical or semiempirical techniques to understand trends, periodicities, and interrelationships of air quality measurements and to forecast the evolution of pollution episodes
4	Eulerian models	Numerical codes in which the computational domain is divided into cells and continuity equations are solved in each cell	12	Interpolation methods and graphical techniques	Such as Kriging, pattern recognition, cluster analysis, and fractals
5	Lagrangian models	Numerical techniques in which plumes are broken up into “elements” such as segments, puffs, or particulates	13	Optimisation methods	Identify the optimal allocation of monitoring networks or to minimize either the adverse effects of pollution or the cost of controlling it
6	Chemical models	Simulate the often non-linear chemical and photochemical transformations of atmospheric pollutants	14	Statistical techniques	Evaluate the performance of dispersion models when their simulations are compared with actual pollution measurements
7	Deposition models	Simulate the dry and wet deposition phenomena in which a fraction of atmospheric pollution is deposited on the surface	15	Modelling of adverse effects of pollution	Visibility impairment, climate changes, and stratospheric ozone depletion
8	Available computer packages				

2.8.2 Meteorological data required for air quality modelling

Knowledge of meteorological conditions in an area is necessary when applying models to calculate air quality. The following information is required (WHO, 2000):

a. Meteorological variables to parameterise atmospheric dispersion, transformation and removal: wind speed and wind direction, ambient temperature, relative humidity, evaporation and precipitation, solar radiation, sigma-theta, atmospheric stability and mixing depth;

b. Temporal resolution of meteorological data: hourly average meteorological data are typically required as input to atmospheric dispersion simulations. Such hourly average data may also be used in the estimation of hourly average emission rates for wind-dependent sources;

c. Spatial resolution: complex terrain or large landscape variations result in thermotopographical circulations and require meteorological data to parameterise horizontal deviations in airflow field, mixing depth, stability; vertical profiles of meteorological parameters required when considering elevated stacks;

d. Routinely measured meteorological variable: wind speed and direction, ambient temperature, relative humidity, rainfall;
e. Specific dispersion model requirements: Industrial Source Complex Model assumes a horizontally-uniform flow field; CALPUFF uses a 3D meteorological input regime; and
f. Meteorological modelling can:
    - Generate additional parameters which are not routinely measured,
    - Account for spatial variations in the airflow field, stability regime, *etc*.,
    - Provide vertical profiles of parameters, and
    - Provide single site-specific meteorological data where no observations exist.

2.9 Air pollution control

One of the major problems associated with controlling pollution arises from the complexity of natural systems and the changes brought about by human intervention (Table 2.9) (Gerrans, 1993). The rational control of air pollution rests on four basic assumptions (American Association for the Advancement of Science, 1965 cited in Wark & Warner, 1981: 4):

a. Air is in the public domain,
b. Air pollution is an inevitable concomitant of modern life,
c. Scientific knowledge can be applied to the shaping of public policy, and
d. Methods of reducing air pollution must not increase pollution in other sectors of the environment.

Table 2.9: Benefits of air pollution control (Ross, 1972).

	Public benefits		Private benefits
1	Improved health	1	Lower employee absenteeism
2	Reduced safety hazards	2	Reduced risk of civil damage suits
3	Reduced health risks to man and animal	3	Better employee relations
4	More comfortable enjoyment of life and property	4	Better public relations
5	Reduced property damage	5	Reduced maintenance costs
6	Increased property values	6	Increased property values
7	Less vegetation damage	7	Product recovery
		8	New markets for new products relating to air pollution control
		9	Reduced product contamination or damage

2.9.1 Types of control strategies

There are several different strategies for controlling air pollution (Boubel *et al*., 1994). The air quality management strategy of the United States primarily relies on the development and promulgation of ambient air quality standards (WHO, 2000; Boubel *et al*., 1994). Great Britain's strategy makes use of the emissions standard strategy where emission standards are developed and promulgated or an emission limit on sources are determined on a case-by-case basis, representing the best practicable means for controlling emissions from those sources (Boubel *et al*., 1994). A third strategy to control pollution is by adopting financial incentives (*e.g.* Hungary and Japan), which is usually but not necessarily in addition to the promulgation of air quality standards (WHO, 2000; Boubel *et al*., 1994). A fourth strategy seeks to maximize cost-effectiveness (cost benefit strategy) resulting in lower emissions from existing processes or promote process modifications (Boubel *et al*., 1994). A fifth strategy is pollution removal (the polluted carrier gas must pass through a control device or system, which collects or destroys the pollutant and releases the cleaned carrier gas to the atmosphere) (Boubel *et al*., 1994). The control device or system selected must be specific for the pollutant of concern (consider the pollutant itself, carrier gas, emitting process and the operational variables of the process) (Boubel *et al*., 1994). Once the control system is in place, its operation and maintenance becomes a major concern (Boubel *et al*., 1994). Source reduction is a sixth strategy, which can be either (WHO, 2000):

a. Management and operational changes (management audits of emissions, sources and source strength; subsequent operational changes to reduce emissions in a cost-effective way). The implementation of good practices in housekeeping and maintenance is required to ensure systems are in place to ensure equipment is maintained and staff are trained and properly supervised. The aim is to minimize fugitive emissions, by changing the composition of material used, while maintaining product quality; or
b. Process optimisation: Emission reductions are achieved by altering the production process (*e.g.* temperature, ventilation or line speed) without loss of product quality or production volume.

Other strategies suggested by the WHO (2000) are:

a. Co-regulation involving the formulation and adoption of rules, regulations and guidelines in consultation with stakeholders, negotiated within prescribed boundaries;
b. Self-regulation: self-imposition of regulations and guidelines and environmental audits by industry groups; voluntary adoption of environmental management measures; and
c. Risk assessment requires an evaluation of health risks for the general or sensitive population, and establishes acceptable levels of health risk for these populations.

2.9.2 Control methods for particulates

Generally, important factors that need to be taken into account whenever a control method is selected (Table 2.10) (Boubel *et al*., 1994):

a. Specificity: does the method measure only the gas of interest, or does it have a response to other gases;
b. Sensitivity: will the method measure the highest and lowest concentrations expected;

c. Reliability: is the instrument to be used continuously or intermittently? If continuously, will it be visited daily, weekly or less frequently? Will it be acceptable for the analyser to be out of action for maintenance periods;
d. Stability: are the instruments calibrated;
e. Cost: range considerably from cheaper pre-concentration methods to continuous analysers; and
f. Precision and accuracy: precision – there may be variations between co-located samplers but similar sampling devises will produce equivalent results. Accuracy – measured concentration closely comparable to actual concentration.

Table 2.10: Characteristics of particulate pollutants that can have an influence on the effectiveness of control devices (Boubel *et al.*, 1994).

Size range and distribution	Hygroscopic tendencies
Particle shape	Stickiness
Agglomeration tendencies	Inflammability
Corrosiveness	Toxicity
Abrasiveness	Electrical resistivity
	Reactivity

When dealing with particulate pollution in a mining environment different sections can have different control measures (Table 2.11). Some of the measures will be very effective controlling particulate pollution on paved roads, while other control measures will be more effective on unpaved roads.

Table 2.11: Dust suppression for different sections of a mine (Scorgie, 2001a).

Materials handling Dust control options	Wind entrainment controls	Dust control for paved roads	Dust control for unpaved roads
Wet suppression: liquid and foam spray systems	Wet suppression and chemical stabilization of stockpiles	Reducing vehicle traffic on roadway	Paving, traffic reduction and speed reduction
Wind sheltering through the installation of transfer chutes	Dust spillage avoidance and removal	Reducing road surface loading	Wet suppression systems
Air atomising spray systems	Wind sheltering		Chemical stabilization of unpaved roads

When dealing with particulate pollution specifically in the Smelter, there are different control measures (particulate collection system) that can be used with different success rates (Table 2.12).

Table 2.12: Techniques commonly used to control particulate emissions in a Smelter (Scorgie (2001a); WHO (2000); Johnson (1998)).

Particulate collection system	Action	Removal mechanism	Particle size removed	Control efficiency	Uses	Relative cost
Gravity settlers	The waste gas swirls in a vessel and particulates are removed by inertial impaction on the walls of a cylindrical vessel	Gravitational settling	>50 – 100 μm	Low CE > PM40	Precleaner prior to more efficient devices	Low cost, cheap to maintain
Cyclone collectors	The waste gas swirls in a vessel and particulates are removed by inertial impaction on the walls of a cylindrical vessel	Inertial impaction	>5 - 10μm	68 – 90% (depending on type)	Precleaner prior to more efficient devices	Low cost, cheap to maintain
Filters	The waste gas is forced through a fabric bag or filter beds on which particulates are physically collected	Impaction Interception Diffusion	>0.1 μm; 99% of 0.5 μm removed; even PM of 0.01 μm	99.5%+	Final control	
Electrostatic precipitation	A negative charge is imparted to particulates in the waste gas, which are attracted to positively charged collection plates	Electrical forces (adhesion, cohesion)	>0.3 μm	70 – 99.5%+ (99.5% for PM10)	Remove respirable fraction	Expensive
Wet scrubbers	Liquids are brought into contact with particulates to form agglomerates, which are removed from the waste stream by impaction on plates or on the walls of vessels	Impaction Interception Diffusion	2.5 μm (>0.3 μm for Venturi)	90% (spray tower) 99.5% (Venturi)	Final control	Range from relatively cheap (spray tower) to high cost (Venturi)

2.9.3 Evaluation of control strategies

To determine air pollution control requirements one of two different approaches can be used (WHO, 2000):

a. Effect-oriented: an assessment of the effects of the pollutants on health and the environment. Increased emissions may be permitted when there will be no health or environmental impacts, or ambient air quality standards will not be exceeded. Action may be taken to reduce ambient concentrations where impacts or exceedances are shown to occur; or

b. Source-oriented: air quality management policies are based on the requirement for best available technology (BAT), or best available techniques not entailing excessive cost (BATNEEC).

2.10 Closing

In countries at the first stage of industrialization, emission controls usually do not keep pace with economic development, energy consumption, urban population growth or waste generation (Hien *et al*., 2001). As a consequence, air pollution may tend to rise until comprehensive emission controls become practicable (Hien *et al*., 2001). Although a developing country, South Africa has one of the largest industrialized economies in the Southern Hemisphere (Turner *et al*., 1995). A large proportion of the industrial infrastructure, much of which is coal based, is concentrated in Gauteng and on the extensive coalfields in Mpumalanga (Turner *et al*., 1995). The co-existence of heavy industry, alongside underdeveloped communities creates a very real potential for serious air quality degradation to take place (Turner *et al*., 1995). By 1995, there were approximately 5 million licensed vehicles in South Africa, many of which were used for relatively short urban driving cycles (Turner *et al*., 1995). In addition, a large proportion of the fuel for these vehicles is manufactured from coal, adding to the pollution burden from the road transport sector (Turner & Snyman, 1994 cited in Turner *et al*., 1995: 9). Studies have been carried out with respect to pollution dispersion, climatology and air quality impacts such as health issues among residents of low income, high-density residential areas in South Africa (*e.g.* Terblanche *et al*., 1992; Tosen & Turner, 1990 cited in Turner *et al*., 1995: 9; Tosen and Jury, 1987a cited in Turner *et al*., 1995: 9; Tosen and Jury, 1987b; Tosen & Pearce, 1986 cited in Turner *et al*., 1995: 9). Although there is an extensive knowledge of air quality degradation, its impacts and the scientific understanding of pollution transport and dispersion mechanisms in South Africa has been scientifically established (Turner *et al*., 1995), there are still huge problems regarding air pollution control in South Africa. These problems will be discussed in the following Chapter (Chapter 3).

Chapter 3

Airborne pollutants in South Africa: Current legislation and management

3.1 Atmospheric Pollution Prevention Act, 1965 (Act. 45 of 1965)

South African air pollution control is modelled on a British approach and is primarily administered nationally under the Atmospheric Pollution Prevention Act, 1965 (Act. 45 of 1965) (APPA), as amended (the Act), by the Department of Environmental Affairs and Tourism (DEAT) and specifically the office of Chief Air Pollution Control Officer (CAPCO) (Table 3.1) (Burger & Scorgie, 2000a; Annegarn & Scorgie, 1997). In addition, several other components of legislation also impact on atmospheric pollution in South Africa (Table 3.1) (Scorgie, 2001a). Prior to April 1995, the Department of National Health and Population Development (now the Department of Health), was responsible for air pollution control (Annegarn & Scorgie, 1997).

Table 3.1: Legislation and regulatory requirements pertaining to air quality (Scorgie, 2001a).

National Environmental Management Act, Act 107 of 1998
White Paper on Integration Pollution and Waste Management
Atmospheric Pollution and Prevention Act, Act 45 of 1965
Ambient air quality guidelines
Emission limits (guidelines for scheduled processes)
EIA regulations (no. R 1182 and 1183 of September 1997)
Aide Memoire Environmental Management Programme Report (EMPR) requirements (DME)
Major hazard installation regulations (1998)
Proposed national policy on airports and airspace management

3.1.1 Chief Air Pollution Control Officer (CAPCO)

The amended Atmospheric Pollution Prevention Act has established the office of Chief Air Pollution Control Officer (CAPCO), which is responsible for administering compliance with legislation and the issuing of permits for Scheduled Processes (as defined by the Act) that may impact on air quality (Scorgie, 2001a; Burger & Scorgie, 2000a; Annegarn & Scorgie, 1997; Turner *et al*., 1995; Glazewski, 1989). CAPCO publishes emission limits and ambient concentration guidelines for Sulphur dioxide (SO_2), Nitrogen oxides (NO_x), Lead (Pb), particulates (TSP, PM_{10}), Carbon monoxide (CO) and ozone (O_3) with no provision being made for ambient air quality standards or emission standards (Scorgie, 2001a; Annegarn & Scorgie, 1997; Turner *et al*., 1995). Although these guidelines are aimed at protecting human health and welfare, they can be used as standards or compliance values by which ambient air quality is assessed (Scorgie, 2001a; IUAPPA, 1991 cited in Turner *et al*., 1995: 9).

One of the principles of environmental policy, both locally and internationally, is to adopt an emission strategy that is used to ultimately establish limits on emissions for specific groups of sources (Burger & Scorgie, 2000a). CAPCO makes use of the Best Practicable Means (BPM) (achievable measures) concept, which is distinguishable from the Best Available Control Technology (BACT) approach, where the emphasis is on reducing emissions based on state-of-the-art technology without a major consideration of capital and operating costs (Burger & Scorgie, 2000a). Under the Atmospheric Pollution Prevention Act, provincial tiers of government are not involved in air pollution control (Annegarn & Scorgie, 1997). However, there has been a move toward devolving authority from a national level; by 2001 air pollution management control was transferred to provincial level in the North West Province and for the Durban-Pietermaritzburg area[5*]. The Air Pollution Control Officer (APCO) for North West province was appointed by the Minister of Environmental Affairs and Tourism in the province's Department of Agriculture, Conservation and Environment (DACE)[8]. APCO's duties for the North West province are the same as the national Chief Air Pollution Control Officer[8].

3.1.2 Air pollution permit requirements

Any operator of a Scheduled Process is required to hold a permit or be liable to criminal prosecution (Glazewski, 1989). Platinum mining has several Scheduled Processes that require a permit[2]:

a. Roasting Process (No. 27 of the Second Schedule),
b. Vanadium Process (No. 60 of the Second Schedule),
c. Sulphuric Acid Process (No. 1 of the Second Schedule), and
d. Waste Incineration Process (No. 39 of the Second Schedule).

CAPCO issues an operating permit for an individual case after discussions with the industry and affected local authority (Burger & Scorgie, 2000a). A permit is issued on the assumption that emissions of atmospheric pollution are below prescribed levels (Burger & Scorgie, 2000a; Annegarn & Scorgie, 1997; SRK, 1997; Turner *et al*., 1995; Glazewski, 1989). When determining permitted pollution levels, CAPCO has discretion under the Atmospheric Pollution Prevention Act to take into account available technology, costs of abatement, age of a plant, the available control options and local and special circumstances (Burger & Scorgie, 2000a; Annegarn & Scorgie, 1997; Glazewski, 1989). The effective

*Notes explained at end of references

operation of the Act is largely dependent on the opinion of CAPCO, rather than the imposition of statutorily laid-down standards (Scorgie, 2001a; Glazewski, 1989). While the current approach allows for flexibility and cooperation between government and industry, there are doubts as to whether the approach is effective (Glazewski, 1989).

3.1.3 Problems with air pollution control structures and legislation in South Africa

Administration of air pollution control in South Africa has become highly fragmented (Scorgie, 2001a; Annegarn & Scorgie, 1997). At a national level, the Department of Environmental Affairs and Tourism, the Department of Health, the Department of Water Affairs and Forestry and the Department of Minerals and Energy are responsible for implementing various sections of the Atmospheric Pollution Prevention Act (Annegarn & Scorgie, 1997). Comprehensive control of air pollution at a local level is hindered due to the division of responsibilities for implementing regulations between national and local authorities (Annegarn & Scorgie, 1997). The fragmented organisational structure of air pollution legislation and control has several adverse consequences (Scorgie, 2001a; Annegarn & Scorgie, 1997):

1. Discrepancies, anomalies and ineffectiveness exist in South African air pollution control. Not all pollution sources are covered in legislation; various sources of fugitive particulate emissions such as roads, open pit mining, construction and demolition and agriculture are omitted. Emissions from biomass burning, aviation, and toxic substance transport and spills are also overlooked. Furthermore, little emphasis is placed on fugitive emissions and no standards exist for non-criteria pollutants (*e.g.* carcinogens, odourants);
2. Air pollution control is based entirely on source-based controls rather than on the achievement and maintenance of ambient air quality standards;
3. Not enough attention has been paid to exposure levels (*e.g.* human exposure to domestic coal burning emissions in townships);
4. Regulations are applied inconsistently, and there is no regular review of the threshold levels (particulate control is only applicable to declared dust control areas; the Government mining engineers are responsible to control mine dumps, while vehicle emissions control is clumsy and time-consuming);
5. Air pollution considerations are afforded a low priority in planning;
6. Answers required for air pollution management decisions can not be obtained quickly;
7. Air pollution control personnel do not form a coherent and recognisable body and consequently lack both status and authority and have few prospects for promotion. Furthermore, inadequate staffing at national level has severely limited the effective enforcement of the legislation; and
8. The national authority is not bound in all respects by its own legislation, which provides the potential for inconsistencies and subjectivity in the decision making process.

3.2 New legislation

As a result of the problems mentioned in section 3.1.2 the Integrated Pollution Control (IPC) Project of DEAT was initiated in 1993 to facilitate a review of governmental functions and structures concerned with pollution control, and to initiate a process of restructuring the regulatory system to produce a more effective pollution control system (IN95b) (Annegarn & Scorgie, 1997). The IPC Air Work Team was responsible for drafting a new approach to air pollution control amenable to Integrated Pollution Control (Annegarn & Scorgie, 1997). The White Paper on Integrated Pollution and Waste Management was published in March 2000 and indicated a shift from a source-based to a receiving-environment approach (Table 3.1) (Scorgie, 2001a). Four tiers of authority were suggested for the control of air pollution, namely (Annegarn & Scorgie, 1997):

1. A single national agency that has the mandate for the coordination of air quality management. Functions of the national agency would include legislation, transboundary pollution management, international agreements, dispute resolution and the demarcation of local air quality management areas;
2. Provincial authorities, who are charged with executive powers for the implementation of control, which may be delegated to lower tiers where the capacity exists;
3. Metropolitan authorities identified by the national agency, who are responsible for local air quality management areas; and
4. Local authorities outside metropolitan areas that derive certain powers from provincial authorities that are proportionate to their abilities.

A process to set national air quality standards was initiated, but suspended by the SABS (South African Bureau of Standards) pending further guidance by the DEAT (Scorgie, 2001a).

3.2.1 The National Environmental Management: Air Quality Bill

a. After renewed efforts, the National Environmental Management: Air Quality Bill (which will repeal the Atmospheric Pollution Prevention Act, 1965) was published for comment and inputs from interested parties and the general public in April 2003 (DEAT, 2003). The main object of the new Act is to protect, restore and enhance the air quality in South Africa, having regard to the need to ensure sustainable development, by providing (DEAT, 2003):
b. The framework for governance of air quality management through the establishment of national norms and standards;
c. A regulatory framework for an air quality management planning and reporting regime;
d. Numerous regulatory instruments for the control of air pollution; and
e. A comprehensive approach to compliance and enforcement.

The new Air Quality Bill differs on a number of points from the Air Pollution Prevention Act. The main differences are discussed below.

3.2.1.1 National, provincial and local framework

The Minister must establish a national framework setting national norms and standards for achieving the objectives of the Act, which may include norms and standards (not only guidelines) for (DEAT, 2003):

a. Ambient air quality,
b. Emissions from point or non-point sources,
c. Air quality monitoring,
d. Air quality management planning, and
e. Air quality information management.

National norms and standards set must be aimed at (DEAT, 2003):

a. Providing opportunities for public participation in the protection, restoration and enhancement of air quality,
b. Ensuring public access to air quality information systems,
c. Preventing air pollution and the degradation of air quality,
d. Reducing to harmless levels discharges likely to impair air quality (including the reduction of air pollution at sources),
e. Promoting efficient air quality management,
f. Effective air quality monitoring,
g. Regular reporting on air quality, and
h. Complying with the Republic's obligations in terms of international agreements.

On a provincial level the MEC (Member of the Executive Council), and on a local level, a municipality in terms of a by-law responsible for air quality may (DEAT, 2003):

a. Identify substances or mixtures of substances in ambient air (through ambient concentrations, bioaccumulation, deposition or in any other way) that present or is likely to present a threat to health or the environment; and
b. In respect of each of those substances or mixtures of substances, establish standards for
    1. Ambient air quality, including the permissible amount or concentration of each such substance or mixture of substances in ambient air; or
    2. Emissions from point or non-point sources in the province or in any geographical area within the province or municipality.

If national (or provincial) standards have been established for a particular substance or mixture of substances, it may not be altered on a provincial (or local level) except when stricter standards for the province or for any geographical area within the province are established (DEAT, 2003). The Minister, or any MEC responsible for air quality may further identify and proclaim an area as a priority area if ambient air quality standards are being, or are likely to be exceeded; and such exceedances are causing, or may cause, a significant negative impact (DEAT, 2003). Pending the setting of such standards, the ambient air quality guidelines contained in the Atmospheric Pollution Prevention Act continue to apply (DEAT, 2003).

A national Air Quality Advisory Committee with an officer in the DEAT designated as the National Air Quality Officer must be established to advise the Minister on the implementation of the Act, and be responsible for co-ordinating matters pertaining to air quality management in the national government (DEAT, 2003). In the same manner MECs on a provincial level and municipalities on a local level must designate an air quality officer responsible for co-ordinating matters pertaining to air quality management (DEAT, 2003). Air Quality Management Plans (AQMP's) must be included on a national and provincial level in Environmental Implementation Plans (EIPs) or Environmental Management Plans (EMPs) and on a local level in Integrated Development Plans (IDPs) (DEAT, 2003).

3.2.1.2 Atmospheric emission licences

Metropolitan and district municipalities are charged with implementing the atmospheric emission licensing system and must perform the functions of licensing authority (DEAT, 2003). The licensing authority will require the applicant, at the applicant's expense, to obtain and provide the licensee by a given date with, (DEAT, 2003):

a. An assessment in terms of the National Environmental Management Act of the likely effect of the proposed license on air quality,
b. An independent review of such assessment, by a person acceptable to the licensing authority, and
c. Any other relevant information, in addition to the information contained in or submitted in connection with the application.

The authority may conduct its own investigation on the likely effect of the proposed license on air quality and invite written comments from any other state departments and further afford the applicant an opportunity to make representations on any adverse statements or objections to the application (DEAT, 2003). The responsibility is placed on the applicant to ensure that all relevant state departments, interested persons and the general public (*e.g.* publication of a notice in newspapers circulating in the area) are aware of the application (DEAT, 2003).

When considering an application for an atmospheric emission license, the licensing authority must take into account all relevant matters, including (DEAT, 2003):

a. The pollution being or likely to be caused by the carrying out of the listed activity applied for and the effect or likely effect of that pollution on the environment, including health, social conditions, economic conditions and the cultural heritage;
b. Any practical measures that could be taken:
    1) To prevent, control, abate or mitigate that pollution, and
    2) To protect the environment from harm as a result of that pollution;
c. Any relevant tradable emission scheme;
d. Whether the applicant is a fit and proper person;
e. The applicant's submissions;
f. Any submissions from organs of state, interested persons and the public; and
g. Any guidelines issued by the Minister or the MEC responsible for air quality in the relevant province relating to the performance by licensing authorities of their functions.

If an application for an atmospheric emission license has been granted the licensing authority must first issue a provisional atmospheric emission license to enable the installation and commissioning of the listed activity (DEAT, 2003). The holder of a provisional atmospheric emission license is entitled to an atmospheric emission license when the commissioned facility is in full compliance with the conditions and requirements of the provisional atmospheric emission license (DEAT, 2003). An atmospheric emission license must specify the (DEAT, 2003):

a. Activity in respect of which it is issued;
b. Property in respect of which it is issued;
c. Person to whom it is issued;
d. Duration of the license;
e. Periods at which the license may be reviewed;
f. Maximum allowed concentration of pollutants that may be discharged in the atmosphere:
    1. Under normal working conditions, and
    2. Under normal start-up, maintenance and shut-down conditions;
g. Any other operating requirements relating to atmospheric discharges, including non-point source or fugitive emissions;
h. Point source emission measurement and reporting requirements;
i. On site ambient air quality measurement and reporting requirements;
j. Penalties for non-compliance;
k. Greenhouse gas emission measurement and reporting requirements; and
l. Any other conditions which are necessary to protect air quality.

3.3 Existing local air quality management structures

In South Africa, several local air quality management structures (as is envisioned by the new Air Quality Bill) exist and are already functioning, including (Scorgie, 2001a):

a. Air pollution liaison committee (APLCOM),
b. Durban SO_2 Management System Steering Committee (Durban Steering Committee),
c. Richards Bay Clean Air Association (RBCAA),
d. Rustenburg Air Quality Forum (RAQF),
e. Coega Implementing Authority / Coega Development Corporation (Pty) Ltd (CDC), and
f. Cape Metropolitan Council (CMC).

While the development of the above air quality management structures has tended to be random and disjointed, there are notable similarities in the composition, objectives and functions of the different committees, associations, forums and councils (Table 3.2) (Scorgie, 2001a). The Rustenburg Air Quality Forum operates in the region where, in particular, the Platinum Smelters form the main focus.

Table 3.2: Defining local Air Quality Management structures (Scorgie, 2001a).

Composition	Objectives	Functions
Multi-stakeholder bodies (representatives from industry, local and provincial government, communities, etc.)	Quantify ambient pollutant levels	Emissions inventory establishment
Government only	Determine source contributions	Air quality and meteorological monitoring and modelling (on-line dispersion modelling, source-receptor modelling)
Weaknesses	Dissemination of information (public, CAPCO)	Develop local (more stringent) air quality guidelines
Multi-stakeholder structures do not move beyond baseline air quality characterization and dissemination of information, no "plan of action" for emission reduction	Additional structure-specific objectives	Dealing with public complaints and concerns
Government structures: uncertainty as to how and when stakeholders are to be consulted with during air quality management planning	Assess efficiency of pollution abatement equipment	Air pollution status reporting (web, presentations, briefs to DEAT, etc.)
Financing	Emission quota stipulation	Identifying emission reduction options
Multi-stakeholder air quality management structures - activities funded through membership fees	Development of air quality management plans / emission reduction strategies	Implementation of strategies set out in air quality management plan
Fee allocation (extent and type of emissions, uncertainties related to cost allocation procedure)		
Government funds		

3.4 Closing

As described in this Chapter, South African legislation regarding air quality management has been lacking and has lost track with international legislation and standards (Chapter 2). The Atmospheric Pollution Prevention Act was published in 1965 and only revised in 2003; not much emphasis has been placed on air quality management and the health and environmental effects that air pollution can have. South African companies that wanted to adhere to good environmental practice and air quality standards had to apply international standards voluntarily and not because they complied with South African legislation. The situation created lead to government departments becoming toothless and too much power given to industries.

The new proposed National Environmental Management: Air Quality Bill will go a long way to improve the situation. Much more detail is included in the legislation and international trends are taken into account. Air quality management will be taken right to ground level and local problems will be handled by the local authorities. A problem might be that suddenly too much responsibility is placed on the provincial and local level of government where experience to handle difficult situations might be lacking. A case in point is the situation as found in the Rustenburg region and described in Chapter 4 (pollution quantification in the Rustenburg area). This region is significant for the large Platinum mining industry found there and has very specific characteristics that contributes to the pollution problems experienced which will need special attention and expert knowledge to solve. One of the first tests to examine the efficiency of the new legislation will therefore be to see how problems in this region are handled.

Chapter 4
Pollution quantification in the Rustenburg area

4.1 Introduction

Platinum is a precious metal that occurs in ore bodies as one of a group of six closely related greyish to silver-white metals known as the Platinum Group Metals (PGMs) (Aquarius Platinum, 1998 cited in Steyn, 2000: 49). Associated with the PGMs are gold and the base metals Nickel, Copper and Cobalt (Aquarius Platinum, 1998 cited in Steyn, 2000: 49). The most important use of Platinum is in the automotive industry where autocatalysts reduce vehicle exhaust emissions (Aquarius Platinum, 1998 cited in Steyn, 2000: 49). Other uses of PGMs include jewellery and decoration for coins, medallions and bars for investment (Aquarius Platinum, 1998 cited in Steyn, 2000: 49). The electrical, chemical, petroleum refining, medical and dental industries as well as glass and fibre manufacturing further make use of PGMs (Aquarius Platinum, 1998 cited in Steyn, 2000: 49).

South Africa predominates in global Platinum production; supplying 74% of the world's mined production in 1997 (Aquarius Platinum, 1998 cited in Steyn, 2000: 49). In South Africa, Platinum is mined almost exclusively from the Bushveld Igneous Complex (Appendix B: Fig. 4.1) (Steyn, 2000; Hochreiter, 1985, cited in Steyn, 1996: 23). The area surrounding Rustenburg forms part of the western lobe of the Bushveld Igneous Complex and has especially rich reserves (Aquarius Platinum, 1998 cited in Steyn, 2000: 49).

The research problem for the study is discussed in this Chapter (section 4.4). In order to fully understand the problem stated, it is important to firstly examine the regional setting of Rustenburg (section 4.2), which is the focus area of the study, as well as the pollution emission inventory (pollution quantification) (section 4.3) for the area.

4.2 Regional setting

Rustenburg is situated in the North West Province of South Africa (Pulles *et al.*, 2001). While Rustenburg is the only large urban area in the region, there are a number of smaller towns and residential areas in its vicinity (*e.g.* Thlabane, Waterval, Mooinooi, Phokeng, Kana, Mafika, Luka and Mogono) (Appendix B: Fig. 4.2 and Fig.4.3) (Pulles *et al.*, 2000).

4.2.1 Surface infrastructure

While not originally being a primary destination, the Rustenburg area is relatively well serviced in terms of its infrastructure with two main roads that link to the major urban areas of

Pretoria and Johannesburg of the Gauteng province (Appendix B: Fig. 4.2 and Fig. 4.3). The N4 Platinum Highway (national Toll road) is the main east-west tending route that links Pretoria with the study area (Appendix B: Fig. 4.2 and Fig. 4.3); this road is part of the Trans-Kalahari route that links Maputo in the east with Walvis Bay in the West. The Johannesburg-Magaliesburg-Rustenburg-Sun City road is the Rustenburg area's primary link to Johannesburg in the south-east.

4.2.2 Land use

Agriculture originally dominated landuse in the Rustenburg area, but this has changed with mining now dominating development and the financial component of the region (NW DACE, 2002). Other dominant landuses that have been identified in the study area are (Burger *et. al.*, 2002; Pulles *et al.*, 2000) (Table 4.1; Appendix B: Fig. 4.4):

a) Urban development and informal settlements, and

b) Mining-related industry.

Table 4.1: Land cover classification for the Rustenburg study area (Pulles *et al*., 2001).

Land use	Area (km^2)	Proportion (%)
Cultivated land	399.110	33.740
Cultivated: permanent – commercial irrigated	0.520	0.040
Cultivated: temporary – commercial dry land	154.000	13.000
Cultivated: temporary – commercial irrigated	221.000	18.700
Cultivated: temporary – semi-commercial/subsistence dry land	23.400	1.980
Forest plantations	0.190	0.020
Veld	674.600	56.970
Degraded: Thicket and Bushland	6.700	0.570
Forest and Woodland	0.410	0.030
Thicket and bushland (etc)	637.000	53.800
Unimproved grassland	26.200	2.210
Water bodies	4.210	0.350
Wetlands	0.080	0.010
Industry and Residential	110.530	9.340
Mines and Quarries	41.000	3.500
Urban / built-up land: commercial	1.780	0.140
Urban / built – up land: industrial / transport	1.630	0.130
Urban / built – up land: residential	64.000	5.360
Urban / built - up land: residential (small holdings: bushland)	2.120	0.170

4.2.3 Hydrology

The Rustenburg area is located in the Crocodile River catchment of the Limpopo River basin (Appendix B: Fig. 4.2) (Pulles *et al.*, 2000). Rivers in the area drain into the Elands River, which flows northward into the Vaalkop Dam, and ultimately into the Limpopo River (Pulles *et al.*, 2000). The Vaalkop dam is one of the major water sources for industries in the area and is particularly important, considering the seasonal and long-term variability of the region's rainfall (Pulles *et al.*, 2000).

4.2.4 Geology

The underlying geology of the Rustenburg area comprises the Pyramid Gabbro-Norite Formation of the Main Zone of the Bushveld Igneous Complex and the Mathlagame Norite-Anorthosite formation of the Critical Zone of the Bushveld Igneous Complex (Pulles *et al.*, 2000).

4.2.5 Climate

Rustenburg and its surrounding areas fall within the South African Highveld Climatic Zone where temperatures are generally mild, with a mean annual maximum temperature of 26.4 °C, and a mean monthly maximum of more than 30°C in summer (Pulles *et al.*, 2000). Mean annual minimum temperatures are 10.9 °C, while radiation loss under clear winter night skies results in mean monthly minima as low as 2.8 °C (Pulles *et al.*, 2000). The mean annual precipitation is 685 mm/annum, 85% of which falls during summer thunderstorms between November and March (Pulles *et al.*, 2000). During winter the winds are generally light, southwesterly and northwesterly during summer (Pulles *et al.*, 2000).

4.2.6 Topography

The region around Rustenburg is bordered by the Magaliesberg Mountain Range to the south and west with a relatively flat area to the north and east (Appendix B: Fig. 4.5 and Fig. 4.6) (Burger *et. al.*, 2002). Gently undulating plains at an altitude of 1 130m, close to the northern section of the Magaliesberg Mountain Range with peaks in this section rising to altitudes of between 1 400m and 1 500m (Pulles *et al.*, 2000).

The natural environment as described above has a definite influence on the atmospheric pollution dispersion in the Rustenburg area. The Magaliesberg Mountain Range's close proximity, the relatively calm (in terms of wind) conditions that are prevalent in the area and the presence of three or four inversion layers in winter means that pollution is staying much longer at ground level than under normal circumstances (Moneyweb, 2003b; Rapport, 2003). Mixing only starts from about 10h00 in the morning which means that emission plumes stay at the respective levels at which they were emitted until then (Moneyweb, 2003b; Rapport, 2003). Because of these circumstances, it is important to examine the different sources and their relative contributions to the amount of atmospheric pollution in the Rustenburg area.

4.3 Regional emission inventory in the Rustenburg area

A study conducted in 2001 (Pulles *et al*., 2001) on behalf of the Rustenburg Air Quality Forum (RAQF) attempted to quantify emissions from all sources in the region (Table 4.2). Although emission levels from each of the sources were obtained directly from the persons responsible for the sources, the data are incomplete and do not include all pollution sources (Pulles *et al.*, 2001).

Table 4.2: Estimated emission source contributions in the Rustenburg area (Pulles *et al*., 2001)

Sulphur dioxide	Oxides of nitrogen	Suspended Particulates	
Large industrial (99.25%)	Domestic (65.83%)	Unpaved roads (62.14%)	Domestic (1.54%)
Domestic (0.41%)	Large industrial (25.98%)	Large industrial (28.55%)	Veld fires (1.27%)
Small boilers (0.31%)	Exhaust (6.46%)	Paved roads (3.47%)	Tailings dams (0.45%)
Exhaust (0.03%)	Small boilers (0.99%)	Small boilers (2.26%)	Urban paved roads (0.20%)
	Veld Fires (0.75%)		Exhaust (0.13%)

From this study, the following main contributors to the atmospheric pollution in the Rustenburg area have been identified and are discussed in the section below.

4.3.1 Pollution from scheduled processes in the Rustenburg area

Large industry has been identified as one of the main contributors to air pollution (and specifically SO_2 and particulate pollution) in the Rustenburg area due to the nature and processing of the Platinum Group Metal (PGM) bearing ore (Pulles *et al*., 2001; Burger & Scorgie, 2000a). Platinum mining activities comprise several different components, namely: extraction, concentrating, smelting (and converting) and refining (of Base Metals and Precious Metals); all of these activities are conducted in the Rustenburg area (Pulles *et al*., 2000). Three Platinum mines (*i.e.* Lonmin Platinum, Impala Platinum and Anglo Platinum) are responsible for 96.2% of total emissions (Table 4.3; Table 4.4 and Appendix B: Fig. 4.7) (Pulles *et al*., 2001; Burger & Scorgie, 2000a).

Table 4.3: Pollutant allocation for large industrial sources (Pulles *et al.*, 2001).

	Sulphur Dioxide	Nitrogen Oxides	Particulate emissions (no tailings dams)
Anglo Platinum	51.77%	57.77%	86.35%
Impala Platinum	27.84%	18.10%	4.03%
Lonmin Platinum	17.60%	6.03%	5.15%
Xstrata	2.79	18.10%	4.48%

The Chrome industry is smaller than the Platinum industry in the Rustenburg area and is dominated by Xstrata (formerly called Chromecorp) and Samancor (relatively small operations in the Kroondal area) (Pulles *et al*., 2001). Emissions from industries other than mining comprise only 3.4% of the total (Table 4.4) (Burger & Scorgie, 2000a).

Table 4.4: Scheduled processes identified by Chief Air Pollution Control Officer (CAPCO) in the Rustenburg area (Pulles *et al*., 2001).

Source Name	Nature of source	Source Name	Nature of source
Anglo Platinum	Smelter – Acid plant	Lonmin Platinum	Smelter– Roasting process
Anglo Platinum	Smelter – Roasting process	Lonmin Platinum	Base Metals Refinery – Boiler
Anglo Platinum	Base Metals Refinery Boiler	Xstrata Wonderkop	Smelter – Furnace operations
Anglo Platinum	Precious Metals Refinery Incinerator	Xstrata Rustenburg	Smelter – Furnace operations
Impala Platinum	Smelter – Acid plant	Rainbow Chickens	4 Boilers
Impala Platinum	Smelter– Roasting process	Rustenburg Abattoir	Boiler
Impala Platinum	Smelter– Incinerator	Trek Engineering	Induction Furnaces
		Ferncrest Hospital	Medical Incinerator

Burger *et al.* (2002) conducted a follow-up study in which the emissions from large industries were further quantified and classified into point, area and volume sources (described below).

4.3.1.1. Point Sources

Point sources of atmospheric pollution are defined as that emitted from a small area (*e.g.* a stack) and contribute significantly to pollution approximately 2 to 10 km downwind but not at the source (Burger *et al.*, 2002). The stack height assists in the dispersion of the pollution while pollutant exit temperatures and exit velocities contribute to an "effective" stack height so that when the pollution reaches ground level it has undergone significant dilution (Table 4.5) (Burger *et al.*, 2002). Due to the small area of the stack it is possible to measure pollutant parameters accurately (Appendix B: Fig. 4.8) (Burger *et al.*, 2002).

Table 4.5: Point sources of atmospheric pollution in the Rustenburg area (Burger *et al.*, 2002).

Site	Source Name	Stack height (m)	Stack diameter (m)	Exit gas temperature (K)	Exit gas velocity (m/s)
Anglo Platinum	Acid Plant	66.7	1.6	350	11.2
Anglo Platinum	Flash Drier 1	50	0.98	333	30
Anglo Platinum	Flash Drier 2	50	0.98	333	30
Anglo Platinum	Flash Drier 3	50	0.98	333	30
Anglo Platinum	Flash Drier 4	50	0.98	333	30
Anglo Platinum	Main Stack	183	4.62	438	3.72
Base Metals Refinery	Boiler	28	1.5	493.15	12.5
Impala Platinum	Acid Plant	60	1	353.15	10
Impala Platinum	Dryer 1	40	2.5	606.15	30
Impala Platinum	Dryer 4	34	3.25	606.15	30
Impala Platinum	Dryer 5	40	2.5	606.15	30
Impala Platinum	Incinerator	40	2.5	606	30
Impala Platinum	Main Stack	91.4	1.82	473.15	10
Lonmin Platinum	Coal Boiler Stack	27.1	1.4	446	10.9
Lonmin Platinum	Dryer Baghouse Stack	53	1.34	413	15.13
Lonmin Platinum	Main Stack	127.8	3.4	442	20.5

In the Rustenburg area, point sources of atmospheric pollution are reasonably well documented including those from small sources; not all sources have fully quantified all the pollutants from the stacks (Burger *et al.*, 2002). It is believed that the Department of Environmental Affairs and Tourism is planning to implement monitoring of the chemical composition of stack emissions, which will assist in quantifying pollution and evaluating its impact (Burger *et al.*, 2002).

4.3.1.2. Area Sources

Area sources of atmospheric pollution are places where pollutants are released from a wide area such as tailings dams (Appendix B: Fig. 4.9) (Burger *et al.*, 2002). Emissions from area sources are related to the wind speed, particle sizes and moisture content of the dumps (Table 4.6) (Burger *et al.*, 2002).

Mine tailings dams from the three Platinum mines represent a significant source of particulate emissions, particularly during windy periods (Pulles *et al.*, 2001). Compounding the issue, it is believed that several tailings facilities may exist that have not yet been identified (Pulles *et al.*, 2001). The locations and sizes of most tailings dams in the study area were available for the estimation of quantities of wind-generated dust, but little information was available regarding dump geometries, particle size distributions and moisture content (Burger *et al.*, 2002; Pulles *et al.*, 2001). Much more work is required to quantify area sources and to be able to evaluate the impact of such pollution (Burger *et al.*, 2002). Conservative estimates were made (mean particle size of 30 µm; moisture content ~2%) that have resulted in inaccuracies in calculations of emission rates (Pulles *et al*., 2001). Particulate emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed is exceeded (Burger *et al.*, 2002; EPA, 1992 cited in Pulles *et al.*, 2001: 7-18). Significant amounts of particulates (directly proportional to the wind speed) will be eroded from the dry sections of tailings dams and dumps under wind speeds of greater than 5.4 m/s (Burger *et al.*, 2002; Pulles *et al.*, 2001).

Table 4.6: Area sources of atmospheric pollution in the Rustenburg area (Burger *et al.*; 2002).

Site	Source Name	Length (m)	Width (m)	Angle (°)	Area (m^2)
Anglo Platinum	Tailings Klipfontein	1612	1612	0	2600000
Anglo Platinum	Tailings Phases1-3	2040	2040	0	4160000
Anglo Platinum	Tailings Waterval East	735	735	0	540000
Anglo Platinum	Tailings Waterval West	1285	1285	0	1650000
Impala Platinum	Tailings Dam 1&2	2000	975	34	8800000
Impala Platinum	Tailings Dam 3&4	2300	860	34	13000000
Lonmin Platinum	Tailings Eastern Platinum	860	860	0	740000
Lonmin Platinum	Tailings Karee Mine	980	980	0	960000
Lonmin Platinum	Tailings Western Platinum (East)	656	656	0	430000
Lonmin Platinum	Tailings Western Platinum (North)	1131	1131	0	1280000
Lonmin Platinum	Tailings Western Platinum (South)	600	600	0	360000
Lonmin Platinum	Tailings Western Platinum (West)	616	616	0	380000

4.3.1.3 Volume Sources

Volume sources of atmospheric pollution are normally classified as ill-defined uncontrolled emissions (*e.g.* ore processing) that are by their nature transient and unpredictable (Table 4.7) (Burger *et al.*, 2002). Volume sources are difficult to measure and control and are normally estimated according to fixed percentages passing through the process (Burger *et al.*, 2002). Typically a fraction (5 to 20%) of the gas from industrial processes is assumed to escape as fugitives (Burger *et al.*, 2002). Volume sources need to be better quantified before more attention can be given to fugitive emissions (Burger *et al.*, 2002).

Table 4.7: Volume sources of atmospheric pollution in the Rustenburg area (Burger *et al.*, 2002).

Site	Source Name	Release Height (m)	Initial Lateral Length (m)	Initial Vertical length (m)	Orientation wrt North
Anglo Platinum	Converter fugitives	36.683	32.56	9.3	0
Anglo Platinum	Furnace fugitives	30	7	12	0
Impala Platinum	Fugitives	10	30	10	0
Lonmin Platinum	Converter fugitives	12	23.3	11.9	0
Lonmin Platinum	Infurnco fugitives	12	23.3	11.9	0
Lonmin Platinum	Pyromet fugitives	12	23.3	11.9	0

4.3.2 Domestic fuel combustion

The spatial extent of the use of coal in the domestic sector is not known; therefore, previous estimates for domestic coal burning emissions were based on the total sales for the Rustenburg region (Burger *et al.*, 2002; Pulles *et al.*, 2001; Burger & Scorgie, 2000a). The respective populations in the traditionally coal burning residential areas in the Rustenburg area were used to apportion the use of coal with the emission rate estimates taken from the Department of Environmental Affairs and Tourism's National Emission Database (Table 4.8) (Burger *et al.*, 2002; Pulles *et al.*, 2001). Since only coal was included as an energy carrier (*i.e.* not wood and other sources of fire), it is believed that the emissions could be under-estimated (Table 4.2) (Pulles *et al.*, 2001).

Table 4.8: Pollution emission factors for domestic coal usage (Burger *et al.,* 2002; Pulles *et al.*, 2001)

Pollutant	Emission factor (g of pollutant per kg of coal used)
Sulphur dioxide (SO_2)	4.167
Oxides of nitrogen	50.000
Particulates	2.976
Carbon monoxide (CO)	595.238
Volatile organic compounds	79.762

4.3.3 Vehicle emissions

A total of 1 450 kilometres of road are located within the study area of which approximately 800km are unpaved (Appendix B: Fig. 4.10) (Pulles *et al*., 2001). An evaluation of the traffic flow pattern was based on a road count conducted in 1998, and information provided by the local town council (Burger *et al.*, 2002; Pulles *et al.*, 2001). The study indicated the following traffic levels (Pulles *et al.*, 2001):

a. Nelson Mandela Drive (one way South to North): 15 720 vehicles per 12 hours,
b. Oliver Tambo Drive (one way North to South): 14 381 vehicles per 12 hours, and
c. Eastern bypass: 8 517 vehicles per 12 hours

Traffic flow patterns on the outskirts of Rustenburg where a gradual decrease in traffic were estimated from the flow along the national road, average volumes, in vehicles per 12 hours were 14 730 at Kroondal, 12 585 at Buffelspoort, and 11 469 at Mooinooi (Appendix B: Fig. 4.2) (Burger *et al.*, 2002; Pulles *et al.*, 2001). The traffic situation has changed noticeably since 1998 because of all the new developments (described in section 4.4); therefore it can be assumed that the traffic count is under-estimated.

Vehicle emissions include both tailpipe gases, particulates as well as entrained particulates from road surfaces (one of the largest sources of fugitive particulate emissions at industrial sites) (Burger *et al.*, 2002; Pulles *et al.*, 2001). The essential parameters necessary to estimate these emissions include (Table 4.2; Table 4.9) (Burger *et al.*, 2002; Pulles *et al.*, 2001):

a. The type of vehicle:
   1. Petrol engines: small (< 1 500cc); medium (1 500 cc to 2 000 cc); large (> 2 000cc), and
   2. Diesel engines: light (< 3.5 tons); medium (3.5 tons to 16 tons); heavy (>16 tons).
b. The road surface:
   1. Paved: open roads; urban roads; industrial, and
   2. Unpaved.
c. The number and type of vehicles on each of the road types listed.

Table 4.9: South Africa pollution emission factors for various vehicle types (Pulles *et al.*; 2001).

	Hydrocarbons	CO	Nitrogen Oxides	SO_2	Particulates
Petrol	1.76	15.20	2.1	0.055	0.00
Diesel Light duty vehicles	0.14	0.11	1.73	0.54	1.02
Diesel Medium duty vehicles	1.27	9.86	5.22	0.58	0.70
Diesel Heavy duty vehicles	1.27	9.86	17.24	1.77	1.64

The contribution of unpaved roads to the total pollution budget is a function of their extent in the study area, the utilisation of these roads, and the class of vehicles using these roads (Table 4.9) (Pulles *et al.*, 2001). In addition to traffic volumes, emissions also depend on a number of parameters, such as average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (Table 4.10) (Burger *et al.*, 2002; Pulles *et al.*, 2001; EPA, 1996 cited in Pulles *et al.*, 2001: 7-16). A constant silt content of 10% was assumed for the 800km of unpaved roads in the study area (Burger *et al.*, 2002; Pulles *et al.*, 2001).

Table 4.10: Factors taken into account when estimating particulate pollution from roads (Pulles *et al.* 2001)

Estimated mean number of wheels	Estimated mean vehicle mass
Petrol vehicles – 4 Diesel vehicles Light duty tracks – 4 Medium duty trucks – 6 Heavy duty trucks – 10	Petrol vehicles – 1.5 ton Diesel vehicles Light duty trucks – 1.5 ton Medium duty trucks – 5 ton Heavy duty trucks – 20 ton

4.3.4 Veld fire emissions

Veld fires are random processes that can occur almost anywhere and in Rustenburg area they significantly contribute to particulate pollution (Table 4.2) (Burger *et al.*, 2002). An inventory of veld fires attended by the Rustenburg Fire Department was furnished; however, the value of these data are limited since the area burned was not consistently recorded, and because controlled veld burning, which is a fairly extensive practice in the area, is not always attended to or logged by the Fire Department (Table 4.11) (Pulles *et al.*, 2001). Further, although the burning of tyres at dumping sites and in bulk refuse containers, particularly on winter nights, is erratic in location and frequency and cannot be quantified, it should not be neglected as a source of pollution (Appendix B: Fig. 4.11 and Fig. 4.12) (Pulles *et al.*, 2001).

Table 4.11: Pollution emission factors for veld fires (Pulles *et al.*, 2001)

Pollutant	Emission factor (Kg of pollutant per hectare)
Oxides of nitrogen oxide	40
Particulate matter	172
Carbon monoxide	1410
Volatile organic compounds	242

4.3.5 Other emission sources

The emission sources described thus far are more prevalent in the Rustenburg area, but are by no means the only sources of pollution. Other smaller sources also occur and exacerbate the amount of pollution in the region.

4.3.5.1 Light industry

Light industry in the Rustenburg area is almost entirely comprised of boilers and incinerators that use coal as a heat source and their individual contribution to the atmospheric pollution was estimated by Pulles *et al.* (2001) (Table 4.12 and Fig. 4.7.). However, their contribution to the overall pollution budget is small (Table 4.2).

Table 4.12: Atmospheric pollution from light industry in the Rustenburg area (Pulles *et al*. 2001)

Site	Stack Height (m)	Exit gas Temperature (K)	Exit gas Velocity (m/s)	Stack Diameter (m)	SO_2 (g/s)	NOx (g/s)	CO (g/s)	TSP (g/s)	PM10 (g/s)
Rainbow Chickens Steam Boilers	23	563	8	0.7	2.87	1.10	1.27	25.15	10.40
Rustenburg Abattoir Overfeed stoker	15	648	8	0.45	0.15	0.02	0.02	0.62	0.23
Joerg Foundry (Trek Engineering) Induction Furnaces	5	648	8	0.28	0.00	0.00	0.00	0.00	0.00
Ferncrest Hospital Medical incinerator	16	1473	8	0.38	8.24	1.98	0.72	138.35	27.67
Western Chrome Mines Fluidised bed dryer	5	648	8	0.2	0.11	0.01	0.04	0.57	0.44
Pro-Kleen dry cleaners Overfeed stoker	15	648	8	0.5	0.05	0.01	0.31	0.25	0.10
MKTV Tobacco Limited Boiler	9	648	8	0.7	0.82	0.11	0.09	3.36	1.26
Mageu Number one Boiler	9	648	8	0.5	0.27	0.04	0.03	0.62	0.34
British American Tobacco Products Spreader stoker	11.5	648	8	0.65	0.46	0.11	0.04	7.73	1.55
Rustenburg provincial hospital Overfeed stokers	20	648	8	0.7	0.65	0.09	0.07	2.65	0.99

4.3.5.2 Fugitive dust: Small mines

Several small mines exist in the area around Rustenburg; although, no comprehensive inventory of the locations has been set up by the Department of Minerals and Energy (DME) (Pulles *et al*., 2001). An inventory of all mines in the North West Province was formulated by the Department of Agriculture, Conservation and Environment (DACE) for the North West province (Pulles *et al*., 2001), but is not yet available for public scrutiny.

4.3.5.3 Fugitive dust: Agriculture

Wind-blown dust and dust generated through ploughing of cultivated land is the primary source of particulate pollution from agriculture in the Rustenburg area (Pulles *et al*., 2001). To quantify the impact of agriculture on particulate pollution, data relating to the specific crops grown and the distribution thereof are required (Pulles *et al*., 2001). Roughly one third of the study area is cultivated land, including semi-commercial and subsistence farming (Table 4.1) (Appendix B: Fig. 4.4) (Pulles *et al*., 2001). In the Rustenburg area, the crops selected for planting are chosen on an annual basis (based on strategic considerations) and local farmers are, in general, not willing to disclose the crop types or the areas used to cultivate each crop (Pulles *et al*., 2001). However, the following crops are known to be cultivated in the area (Pulles *et al*., 2001):

a) Wheat, which is harvested in November,
b) Chillies, sunflowers and tobacco planted in October / November, and
c) Citrus is planted closer to the mountains, predominantly in the Olifantshoek area.

4.4 The research problem

The North West province experienced a decline in economic growth of 0.6 % between 1991 and 1996, primarily due to a decline in the mining sector, apart from the Platinum industry (NW DACE, 2002), which has experienced considerable growth during the 1990's and 2000's (rapidly increasing Platinum price reaching levels of ± $600/oz combined with a favourable exchange rate). The above growth has lead to all three Platinum mines expanding their activities and increasing their production. As a result, the Rustenburg region experienced remarkable growth; by 2003 Rustenburg was the third fastest growing city in Africa and the sixth fastest growing in the world (African EPA, 2003).

Large industry is responsible for 99.25% of SO_2 emissions and 28.55% of particulate emissions (Table 4.2 and Table 4.3) with the largest single source of emissions being the three Platinum Smelters that are situated within 60km from each other (Appendix B: Fig. 4.13 and Fig. 4.14). Because of the increase in production, the amount of ore delivered to the Smelters of all three Platinum mines increased, but little attention was given to improvement (upgrading) of the air pollution control technology used in the Smelters to combat the amount of pollution emitted (Table 4.2; Fig. 4.15 and Fig.4.16). The situation was worsened by the specific atmospheric conditions present in the Rustenburg area (described in 4.2.6). Air quality management plans (especially regarding particulate emissions) were incomplete and did not support the preventative measures that were in place (Fig.4.17).

External pressure (from the public) as well as internal pressure (money squandered because particulate emissions contains Platinum) has lead to a new approach and resulted in new plans being made by all three of the mines to measure, monitor and control (reduce) particulate emissions[1]. It further became evident that because of the mining developments in the region, as well as all the expansions, a regional plan for the management of particulate emissions is required to co-ordinate efforts and manage the emissions more effectively. The existing regional plans (Appendix C) were too general and insufficient to fulfill the requirements for the Rustenburg area.

The primary aims of this study are to establish the level of particulate pollution originating from the Platinum industry (specifically the Smelters), examine current and future management plans and procedures regarding pollution prevention and the development of a regional and site-specific Air Quality Management Plan (AQMP) for particulate emissions of the three Platinum Smelters (Anglo Platinum, Impala Platinum and Lonmin Platinum). Essential components of the study, require a review of international and national issues as well as specific considerations for the Rustenburg area, namely:

a. International trends in air quality management (including guidelines and standards).
b. The impacts of air pollution on society and the natural environment.
c. The essential components of an air quality management plan.
d. Measuring, monitoring, modelling and control of particulates.
e. Management and legislation regarding air pollution management in South Africa.
f. Regional setting and pollution quantification in the Rustenburg region.
g. The situation in the Rustenburg Platinum industry prior to expansion (until the end of 2001):
    1. Smelter processes description,
    2. Permit requirements,
    3. Air quality monitoring inside Smelters and ambient monitoring,
    4. Pollution management structures, and
    5. Management plans (overall air quality management, particulates).
h. The situation in the Rustenburg Platinum industry during expansion (from 2002):
    1. Smelter processes description,
    2. Permit requirements,
    3. Air quality monitoring inside Smelters and in the ambient monitoring,
    4. Pollution management structures, and
    5. Management plans (overall air quality management, particulates).
i. Comparison and discussion of results (data, management plans, procedures and structures).
j. The role of civil society in air pollution management.
k. The development of a new regional air quality management plan.

A component of the study is an evaluation of the levels of atmospheric particulate pollution; to this end data are being collected and provided by the Platinum industry that measure emissions from Smelters. The study is limited to measuring particulates less than 10µm in diameter, as this is the component that is inhalable and, therefore, considered to be dangerous (Burger & Scorgie, 2000). The above data are the first regarding particulates in the study area and are being utilised to test compliance with national legislation and international norms. One of the critical issues in the Rustenburg region is the involvement of all role players, namely:

a. Mining industry,
    1. Anglo Platinum: Waterval Smelter
    2. Impala Platinum Smelter
    3. Lonmin Platinum Smelter
b. Government departments,
    1. Department of Environmental Affairs and Tourism
    2. Department of Agriculture, Conservation and Environment: North West
    3. Department of Minerals and Energy

c. Rustenburg Air Quality Forum, and
d. North West Ecoforum (acting on behalf of the public).

Information was collected through discussions, interviews, meetings and written correspondence and was analysed to determine the best possible strategies for managing pollution in the study area.

Chapter 5

Airborne Pollutants in the Rustenburg area: Contributors and Management Until the end of 2001

As discussed in Chapter 4 the mining sector is the lead contributor to the North West province's economy, both financially and by its labour absorption capacity (35,5% contribution to the domestic economy in 1996) (NW DACE, 2002). Formal employment opportunities provided by the mining sector in the Province absorb approximately 118 000 employees (22%) (NW DACE, 2002). The average annual remuneration for this sector in the Province is R41 967 (Urban-Econ, 2002). In the Rustenburg area the mining sector is also the main contributor towards the GGP of the local economy with the remaining sectors' contributions relatively small if compared to the mining sector (Urban-Econ, 2002). The community services and trade sectors are the second and third most important sectors and are followed by the finance and manufacturing sector in fourth and fifth places respectively (Urban-Econ, 2002).

In Chapter 5 the contributions of the Platinum mining industry (which is relevant for this study) to particulate pollution are described as well as the management plans in place (up to the end of 2001) to control the particulate emissions. Background information is provided about the Smelter process and the regions from where the particulate emissions originate. The permit conditions as issued by the Air Pollution Officer (APCO) (described in Chapter 3) are given. Air quality monitoring inside the Smelters is described in detail (different sections contributions to particulate emissions) as well as outside the Smelter (ambient monitoring of fugitive emissions). Results from gravimetric (personal) sampling are included to indicate the effect of the emissions on the Smelter employees. In the last section the overall environmental management plans for the Smelters are described as well as the specific plans in place to minimise particulate emissions. This information (where available) is supplied for all three of the Smelters.

From 2002 onwards, major changes were implemented by all three Smelters to minimise the particulate pollution in the region (described in Chapter 6). In Chapter 7 a review and synthesis is given of the particulate pollution management as described in Chapter 5 and Chapter 6.

5.1 Anglo Platinum: Waterval Smelter

Anglo American Corporation is the largest primary Platinum producer in the world (~38% of the worlds production) and is the majority shareowner (owns 67%) of Anglo Platinum since 1999 (Hamann, 2003). The registered office of Anglo Platinum is in Johannesburg where the primary listing is, with secondary listing in London (Hamann, 2003). In 2003 production was 2.25 million oz of Platinum with an expansion goal of 3.5 million oz in 2006 (Hamann, 2003). The total number of employees were approximately 45 000, of which nearly 21 000 were contracting staff (up from ~10 000 in 2001) (Hamann, 2003). The total operating profit was ~R9 500 million (Hamann, 2003). In the Rustenburg area, the company has five mining sections, one Smelter and two refineries (Hamann, 2003). There are two main operations in the study area which contributed ~R3 200 million in operating profit (almost 1/3 of total operating profit for the Group) (Hamann, 2003):

1. RPM Rustenburg section mine: ~1 million oz, 15 000 employees; and
2. Bafokeng Rasimone mine: ~260 000 oz, ~3 300 employees.

5.1.1 Site description

Waterval Smelter is located approximately 8km to the east of Rustenburg (Anglo Platinum, 2001a; Burger & Scorgie, 2000a). The Waterval Concentrator is located along it's western boundary, a large laboratory and administration complex belonging to Rustenburg Platinum Mine (RPM) to the east, the Waterval East Tailings dam complex to the north, and the Process Division's Security and Waterval Sewage complexes and the Rustenburg Base Metals Refiners (RBMR) to the south and south east (Appendix B: Fig. 5.1) (Anglo Platinum, 2001a).

The Waterval Smelter is surrounded by other mining activities (*e.g.* Anglo Platinum: Rustenburg Section, Kroondal Chromium Mine, Bleskop Mine, and Rustenburg Chromium Mine), several formal settlements (*e.g.* Thlabane, Waterval village, Boepa and Phokeng), farmsteads, and informal settlements (Burger & Scorgie, 2000a). There are various potentially sensitive receptors located within 5km of the Waterval Smelter (Entabeni Hostel, C-Hostel, a hospital and the residential areas of Waterval, and Arnoldistad) (Appendix B: Fig. 5.1) (Burger & Scorgie, 2000a).

5.1.2 Process description

Operations at Waterval Smelter commenced in 1969 and in 2002 almost 800 people were employed (Anglo Platinum, 2001a)[5]. The main function of the Waterval Smelter is to extract a concentrate that is rich in Platinum Group Metals (PGM's) (Anglo Platinum, 2001a; Pulles *et al.*, 2001). The process employed consists of different sections, namely (Pulles *et al.*, 2001):

a. Concentrate receiving,
b. Concentrate drying,
c. Furnaces,
d. Converters,
e. Slow cooling,
f. Slag milling, and
g. Acid plant.

A schematic illustration of the Anglo Platinum Smelter operations is found in Appendix B (Fig.5.2) with a detailed description of the process in Appendix D.

5.1.3 Permit requirements for Waterval Smelter

The Department of Environmental Affairs and Tourism (DEAT), through the Chief Air Pollution Control Officer (CAPCO), is responsible to issue a registration certificate under which the Smelter is to operate. This certificate must include stipulations regarding air quality management. A provisional registration certificate for the Waterval Smelter was issued on 16 February 1999, and included the following stipulations (Burger & Scorgie, 2000a):

a. The total particulates concentration of the final emission from the Flash driers will be less than 50 $mg.m^{-3}$, measured at $0^{\circ}C$ and 101.3 kPa;
b. Gasses released from the submerged arc furnaces will pass through two banks of candle filters, each with a filtration area of 1146 m^2. The final particulates concentration from these filters will be less than 50 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa;
c. All emissions from the furnaces and converters will either be vented to atmosphere by means of a 182 m high stack or passed through an off-gas Sulphuric Acid plant where the SO_2 to SO_3 conversion efficiency will be a minimum of 96%;
d. All air pollution abatement equipment will be operational for 96% of the time, each month at the prescribed efficiency; and
e. A final certificate will only be issued once emissions from Waterval Smelter plant comply with a total SO_2 emission quantity of less than 20 $t.day^{-1}$.

5.1.4 Air quality monitoring inside the Smelter

Waterval Smelter emits particulates from the Main and Flash drier stacks (Appendix B: Fig. 4.15), the furnace and converter building (Appendix B: Fig. 4.17) as well as general plant fugitive emissions (*e.g.* stockpiling, reclamation and vehicle-entrained particulates from the paved road network) (Anglo Platinum, 2001a). Monitoring of these emissions started in 1998 and has been updated over the years until a total of 20 indicators were monitored in 2001 (Table 5.1) (Anglo Platinum, 2002a).

Table 5.1: Parameters (indicators) monitored at Anglo Platinum between 1998 and 2001 (Anglo Platinum, 2002a[5]).

1998	1999	2000	2001
1. Furnace off-gas particulates to main stack	Ongoing monitoring of parameters (1 – 9)	Ongoing monitoring of these parameters (1 – 11)	20. PM10 monitoring
2. Converter off-gas particulates to main stack	10. Water use and balance	12. SO_2 plume prediction and modelling	
3. Overall main stack emissions	11. Ambient SO_2 concentrations	13. Electricity used	
4. Acid plant stack		14. Fossil fuel burned	
5. Fugitive emissions		15. Light fuel oil used	
6. Flash drier emissions		16. Diesel used	
7. Sulphur balance		17. Liquid fossil fuel gases used	
8. Surface water		18. Total land altered by operations	
9. Ground water		19. Land rehabilitated	

In the following section the different areas inside the Smelter from where particulates are emitted are listed and data regarding the emissions are supplied and discussed.

5.1.4.1 Flash drier emissions

There are four Flash driers that emit particulates in use (Anglo Platinum, 2002a). The alternative to Flash driers is Spray driers; however, there is no real difference between the two methods in terms of particulate emission control[7]. Particulate emissions are controlled through baghouses (Flash Driers 2, 3 and 4) and a wet scrubber (Flash drier 1) (Anglo Platinum, 2002a)[7]. Flash Driers 2 and 3 have 1440 bags while Flash drier 4 has 3200 bags (Anglo Platinum, 2002a). The fourth Flash drier was commissioned in August 2000 while Flash drier 1 was phased out and is only used for stand by (Anglo Platinum, 2002a).

Particulate emissions from the four Flash driers were routinely measured (isokinetically) for the period December 1999 to December 2002 (Fig. 5.4). The emissions are reported on a monthly basis to the APCO (limit of 50 $mg.N^{-1}.m^{-3}$) (Anglo Platinum, 2002a; Anglo Platinum, 2001b)[7]. From Figure.5.4 it is clear that monthly measurements were not conducted at all four Flash driers which means that it is impossible to test conformance with the requirements stipulated on the provisional permit.

The values for Flash drier 1 vary between 7.4 $t.month^{-1}$ and 10.8 $t.month^{-1}$ with outliers of 349 t for November 2000 and December 2000; it is suggested that the reason for the anomalies is that the baghouses were replaced during this period[5]. Measurements were discontinued from February 2002 onwards. Flash drier 2 has values ranging between 0.14 $t.month^{-1}$ and 5.71 $t.month^{-1}$ with outliers for November and December 2000 of 6.1 $t.month^{-1}$. From June 2001 to October 2002 no measurements were taken and the value stayed exactly the same at 0.62 t.month^{-1}. Emissions from Flash drier 3 have been relatively consistent varying between 0.64 and 0.8 t.month^{-1}. The highest values were recorded in March and May 2000. From April 2001 no measuring were conducted and therefore the values is each time the same as the previous months. Measurements were conducted for Flash drier 4 from January 2001 onwards. The values range between 0.2 and 0.74 t.month^{-1}. The emissions started at 0.2 t.month^{-1} and increased to 0.6 t.month^{-1} from July 2001 to November 2002. The first value change was in December 2002 to 0.74 t. Despite the use of additional bags and a wet scrubber, there was still a steady increase in particulate emissions.

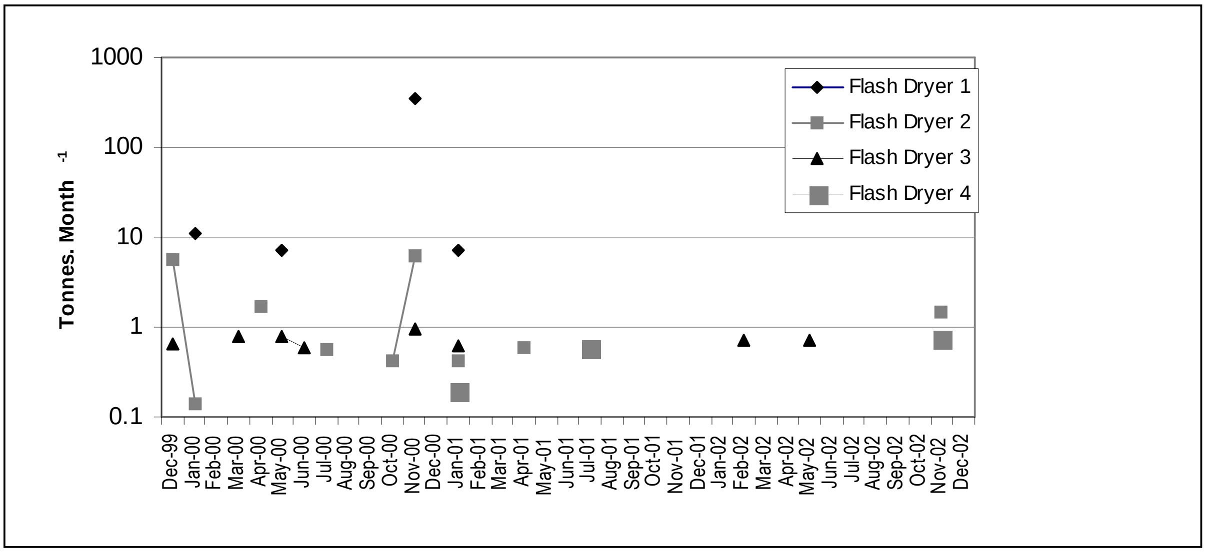


Figure 5.4: Flash drier emissions from the Anglo Platinum Smelter in the Rustenburg area (Anglo Platinum, 2002b)

5.1.4.2 Furnace off-gas particulates to Main stack

The Furnace area is the biggest source of particulate emissions inside the Smelter and respirators are worn in parts of this section (Appendix B: Fig.5.3)[7]. The main reason for the amount of emissions is that after the drying process the concentrate is in the form of a dry, very fine powder that is very difficult to control effectively and leads to a very dusty environment[5]. Blowbacks occur irregularly (because of temperature and pressure control) but still contribute along with tapping to the amount of particulate emissions[5]. All the off-gases pass through six ceramic element modules where most of the particulates are captured (theoretical efficiency: 98.5%) and routed back into the process (Anglo Platinum, 2002a)[7]. After cleaning, the air is vented to the atmosphere through the Main stack (Anglo Platinum, 2002a)[7]. To minimise the volume of particulates lying on the surface area, the furnace surface area has been cemented and a vacuum cleaning system is used on a daily basis[7]. Occasionally an independent company is contracted to clean the entire Smelter[7].

The particulate emissions are measured by a SICK monitor situated after the ceramic filters (before the Main stack) (Anglo Platinum, 2002a)[7]. The monitor uses an infrared beam, which counts the number of particulates passing through that specific point[7]. Measurements (in $t.day^{-1}$) are taken on a continuous basis and sent to the HAWK system where it can be converted to $\mu g.m^{-3}$.[7] Information regarding the conversion calculations is found in Appendix E. It is extremely difficult to monitor the actual particulate concentrations, due to the high particulate loading and the sensitivity of the monitoring equipment (Anglo Platinum, 2002a). An OPSIS monitor that makes use of a laserbeam measures SO_2 emissions separately[7].

Furnace off-gas emissions were measured over a three-year period from December 1999 to December 2002 (Fig. 5.5). No data were recorded for the period September 2000 to December 2001. The reason for this is the breakdown of the ceramic candles. During 1996 and 1997 ceramic candles were installed to capture and recycle particulate emissions emanating from the off-gas stream of the electric furnaces more effectively at a cost of R60 million (Anglo Platinum, 2002a; Anglo Platinum, 2001b)[5]. The installation of ceramic candles at the Smelter was the largest operation of its kind in the world (Anglo Platinum, 2001b). After commissioning in 1998 the ceramic candle system performed well and resulted in a significant reduction in particulate emissions from the Smelter (Anglo Platinum, 2002a). However, the effectiveness of the ceramic elements started deteriorating after the first year of operation and dropped to about 75% (September 2000), and was then constant at this level for the rest of the year (Fig. 5.5) (Anglo Platinum, 2002a). The reduction in effectiveness of the ceramic candles was apparently due to increased breakages and a reduction in the availability of the elements (Anglo Platinum, 2002a). The problem with ceramic elements and non-compliance of the Smelter to prescribed limits was reported to CAPCO; detailed process investigations followed to determine the cause and to present solutions (Anglo Platinum, 2002a).

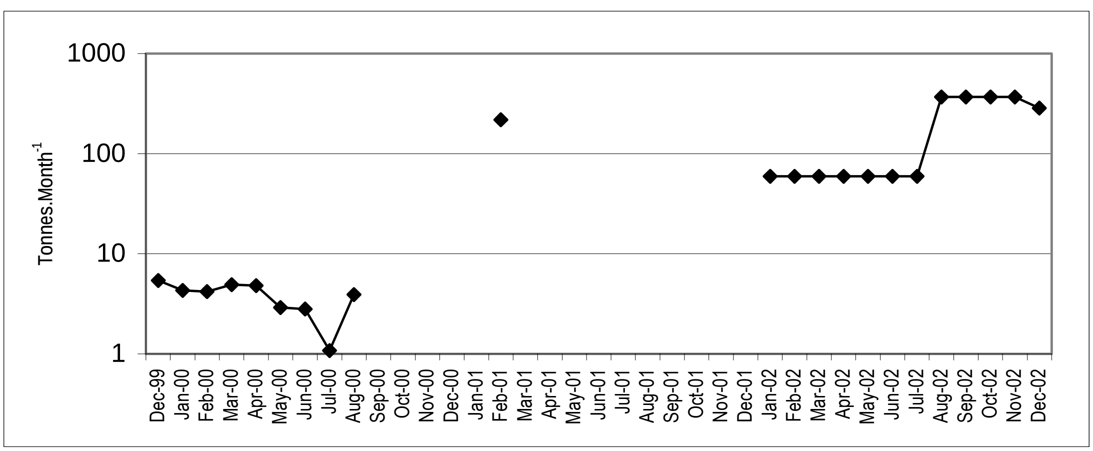


Figure 5.5: Furnace off-gas emissions at the Anglo Platinum Smelter in the Rustenburg area from December 1999 to December 2002 (Anglo Platinum, 2002b).

A solution to the problem required redesign of the Venturi scrubbers and modification of the operating conditions (Anglo Platinum, 2002a). The test period of the new design started in the middle of November 2000 and at the end of that year no element failures had been reported for the specific module (Anglo Platinum, 2002a). The test period ended in January 2001 and all the modules were equipped with the new design by April 2001 (efficiency back to 98,5%) (Anglo Platinum, 2002a)[5]. Regular measurements were only conducted again from January 2002. Although the filtering of particulate emissions was said to have been corrected, they were significantly higher (59.47 $t.month^{-1}$) than before the breakages occurred. From August 2002 measurements increased even further to 370 $t.month^{-1}$.

5.1.4.3 Converter off-gas particulates to main stack

Particulate emissions (off-gases) from the converter pass through the Acid plant after which the "clean air" is routed to the Main stack[7]. The emissions are measured on a continuous basis by a monitor situated after the Acid plant and before the Main stack and are then sent to the HAWK system[7]. No Isokinetic sampling is conducted for the Converter area (Anglo Platinum, 2001b). Measurements were conducted between December 1999 and December 2002 for the converter off-gas (Fig. 5.6). The off-gas emissions measured in the Main stack stayed relatively consistent (59 $t.month^{-1}$ to 62 $t.month^{-1}$) although a very high value was recorded for January 2001 (452 $t.month^{-1}$) because of the annual shutdown that continued for 24 days[5]. No further measurements were available after January 2001. Emissions measured for gasses routed to the Acid plant continued and varied between 46 tonnes and 81 tonnes per month until July 2001. There was a sharp decrease in emissions monitored (August 2001). No further testing was conducted until December 2002 when emissions increased to level higher than ever before (158 t).

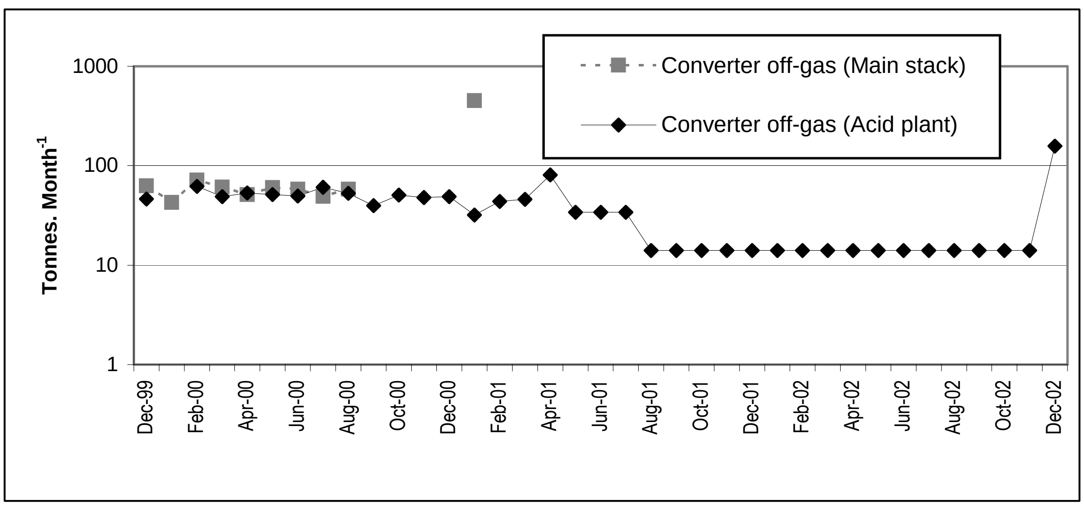


Figure 5.6: Converter off-gas emissions to the main stack and Acid plant (Anglo Platinum, 2002b).

5.1.4.4 Overall main stack emissions

The particulates emitted from the Main stack are measured (isokinetically) according to a schedule and not on a monthly basis (Anglo Platinum, 2002a; Anglo Platinum, 2001b).

Figure 5.7 depicts particulate emissions measured for the period December 1999 to December 2002. In 1998, monthly particulate emissions varied between 200 – 500 tonnes but the installation of the ceramic filters saw a steep improvement to just over 100 tonnes in November 1998 (Anglo Platinum, 2002a). Emissions were measured continuously until August 2000 and ranged between 58 tonnes and 68 tonnes per month. A sudden rise in emissions (September 2000 – April 2001) was due to the failure of the ceramic filters. Numerous problems were experienced during 2001 with the monitoring equipment, as it was damaged following the failure of the ceramic filters (Anglo Platinum, 2002a). A steadily decline in particulate emissions occurred during 2001, but did rise again in November 2001. For 2002 similar values for consecutive months were recorded, because measurements were not conducted on a monthly basis.

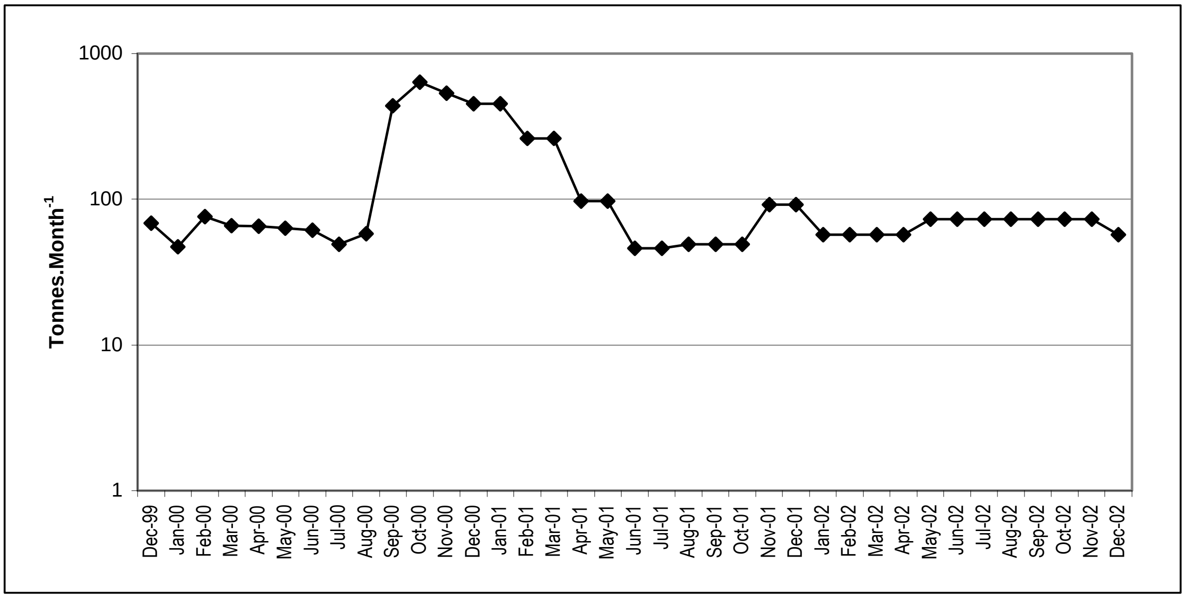


Figure 5.7: Overall emissions recorded for the Main stack of Waterval Smelter (Anglo Platinum, 2002b).

5.1.4.5 Visual monitoring

Visual monitoring is conducted by means of cameras focused on the Main stack; the images are relayed to a television monitor in the environmental department of the Smelter[7]. No formal procedure or specific plans exist for processing the information gathered[6,7].

5.1.5 Air quality monitoring outside the Smelter (ambient monitoring)

It is important to measure the particulate emissions inside the Smelter, but also those emissions that are vented through the stacks (Main and Flash drier) to the atmosphere to determine the amount of particulates found in the environment that affects human health. These emissions are measured by means of an ambient monitoring station. A typical ambient monitoring station comprises an enclosed shelter that houses the monitoring equipment in a controlled environment (Anglo Platinum, 2002a). A 10-metre weather mast is mounted next to the station to collect weather data such as temperature, wind speed and direction (Anglo Platinum, 2002a). The monitoring is carried out on-line on a real-time basis and it is, thus, possible to measure the ambient concentrations at any given time at any one of these stations (Anglo Platinum, 2002a). Data are transferred via radio telemetry to the HAWKView Software System (Anglo Platinum, 2002a)[5]. Although SO_2 emissions are not the focus of this study, ambient monitoring of these emissions are described along with the monitoring of particulate emissions since the same monitoring stations are used to measure both.

5.1.5.1 Ambient SO_2 monitoring

Ambient SO_2 monitoring has been conducted since July 1995 with four stations being moved to different sites to assess various scenarios and environmental impacts (Table 5.2; Appendix B: Fig.5.1) (Anglo Platinum, 2002a; Burger & Scorgie, 2000a). Bergsig station (R4) is situated in Rustenburg mid-town and monitors the background SO_2 concentrations in the residential areas (Anglo Platinum, 2001a). Waterval station (R6) is downwind of the Smelter operations to the southeast of the plant and is used to determine maximum ground level concentrations and worst-case emissions (Anglo Platinum, 2001a). Hexriver station (R8) is used for validation as it is in line with the Bergsig station (Anglo Platinum, 2001a). Previous modelling indicated that the monitoring station at Frank Shaft should be relocated for a better prediction of plume movement and concentrations (Anglo Platinum, 2001a). During July 2000 this station was moved to Paardekraal Shaft (R9), which covers the other dominant wind direction (northwest) (Table 5.2) (Anglo Platinum, 2001a).

5.1.5.2 Ambient particulate monitoring

Particulate emissions were measured at two sites (Pathology Lab and Hoërskool Bergsig sites) from August 1995 to February 1996 (Table 5.2) (Burger & Scorgie, 2000a). Based on the fact that the measured concentrations comprised between 20% and 53% of the DEAT guideline value, a decision was made to terminate the monitoring of particulates (Burger & Scorgie, 2000a). The reconsideration of the data revealed that the measured concentrations did exceed the later, more stringent European Union Environmental Council (EC) standard (24-hour average of 50 $\mu g.m^{-3}$) (Burger & Scorgie, 2000a). The monitoring of fine particulates (PM_{10}) recommenced during 2001 with monitors placed at the Bergsig and Waterval village stations (Fig. 5.8) (Anglo Platinum, 2002a).

Table 5.2: Anglo Platinum monitoring sites (Anglo Platinum (2002a); Pulles *et al*. (2001); Burger & Scorgie, 2000)).

Station	Position, Relative to Smelter	Operating Date	Minimum Temperature	Maximum Temperature	Wind Speed	Wind Direction	Particulates
Pathology Lab	In a built up area, 8.25km West	01/08/1995 - 31/10/1995	Y	Y	Y	Y	
Rex Farm	On a farm, 10.5km NNE, near Rex Village	01/08/1995 - 30/09/1996	Y	Y	Y	Y	
Brakspruit Shaft	9.25km ESE	01/08/1995 - 30/09/1996	Y	Y	Y	Y	
Hoërskool Bergsig	10km WSW	01/10/1995 - Ongoing	Y	Y	Y	Y	Y
Townlands Shaft	Sited 8.25km NW	01/12/1995 - 30/09/1996	Y	Y	Y	Y	
Waterval Village	2.2km South	01/09/1996 - Ongoing	Y	Y	Y	Y	Y
Frank Shaft	1.75km NNE	01/09/1996 - 2000	Y	Y	Y	Y	
Hex Complex	4.9km NW	01/09/1996 - Ongoing	Y	Y	Y	Y	
Paardekraal	NW	2000 - Ongoing					
Kroondal	R10	Ongoing					

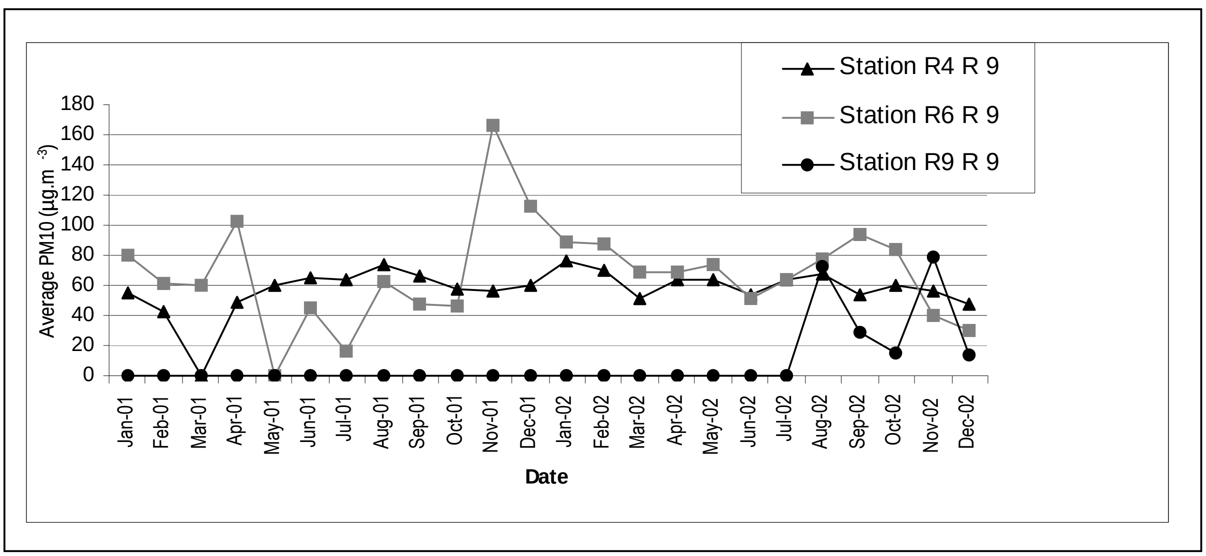


Figure 5.8 Ambient particulate monitoring at three monitoring stations (Anglo Platinum, 2002b).

Values were recorded at Bergsig (R4) and Hexriver (R8) stations since January 2001, with values recoded at Paardekraal station (R9) since January 2002. The highest values were recorded at Hexriver station (166.16 $\mu g.m^{-3}$) and differed considerably from month to month, while the values recorded at Bergsig station stayed more consistent. The values recorded for Paardekraal station (R9) also varies between 78.78 $\mu g.m^{-3}$ and 14.75 $\mu g.m^{-3}$.

5.1.6 Gravimetric (personal) sampling

The Divisional Occupational Hygienist (responsible for the Smelter, Base Metal Refinery and Precious Metal Refinery) is responsible for taking samples from workers from various locations inside the Smelter on a regular basis to (Anglo Platinum, 2001b):

a. Obtain a measure of the pollution of the air breathed by workers,
b. Detect areas and operations with unsatisfactory particulates and fume concentrations,
c. Determine the cause of such conditions,
d. Determine the effectiveness of control efforts, and
e. Provide records of dust conditions.

Information about the basic sampling techniques used as well as the sampling method and reporting procedure is included in Appendix F.

5.1.6.1 Analyses of samples

The Divisional Occupational Hygienist responsible for Waterval Smelter conducted an important Fingerprint study in which every activity area of the Smelter was sampled (17 samples) for 32 different elements (Fig. 5.9)[7].

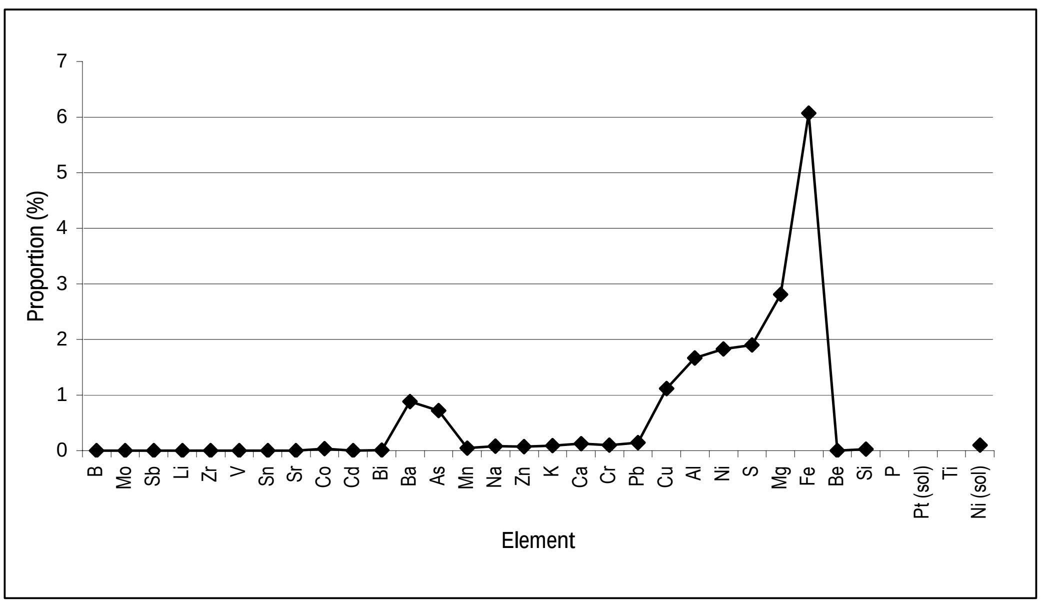


Figure 5.9: Elements identified at Waterval Smelter during the Fingerprint Survey (Anglo Platinum, 2001b).

Results indicated that quantities were relatively low for most of the elements with the exception of Cu, Al, Ni, S and Mg. The most common element identified was Iron (Fe - 6%). Only four of the elements identified in the Fingerprint study are monitored on a regular basis (Fig. 5.10). The available data are not sufficient to draw definite conclusions. Further, monitoring was stopped during 2002 and only commenced at the end of that year again with new guidelines of DME in place[5]. The representative values recorded for specific elements (Fig 5.10) are discussed below:

1. Copper: Values are relatively low (< 3.5%). The values for 2002 were all lower than those recorded for 2001. Measurements were undertaken in the furnace and converter area, Flash driers and flux reverts sections, as well as in the engineering sections. The highest values were recorded in the flux reverts section.
2. Nickel: Values for 2001 were higher than those of 2002. An outlier was recorded in 2001 (22.44%). The second highest value was recorded in the flux reverts section.
3. Lead: Few data are available; the highest levels of Lead were found on the crane drivers in the furnace and converter areas.
4. Iron: The values for 2001 were slightly higher than those of 2002. The highest levels of Iron were recorded in the furnace area and in the fitter and boilermaker workshops.

The next two sections focus on the management structures and plans in place at Waterval Smelter to deal with particulate emissions.

5.1.7 Environmental departmental structure

The Environmental department of the Smelter has a staff complement of two, namely a Chief Environmental Officer and Assistant Environmental Officer (who reports to the Smelter Business Manager) (Anglo Platinum, 2002a)[7]. The department cooperates with the Occupational Hygiene department on an informal basis (all emissions inside the Smelter below 2m are managed by the Occupational Hygienist; all fugitive emissions, above 2m, are managed by the Environmental department)[7]. Occupational Hygienists of the Smelter, Base Metal Refinery (BMR) and Precious Metal Refinery (PMR) all report to the Divisional Manager (Occupational Hygiene)[7]. The structure of the Environmental department changed a great deal in 2002 and is described in Chapter 6.

5.1.8 Environmental management plan

In order to develop a regional and site-specific air quality management plan for particulate emissions (Chapter 8), it is necessary to examine the environmental management plans (overall and specifically for air quality) as it was until the end of 2001 (historically) and how it developed since then to incorporate the changing situation (Chapter 6) in the Rustenburg area for each of the three Smelters.

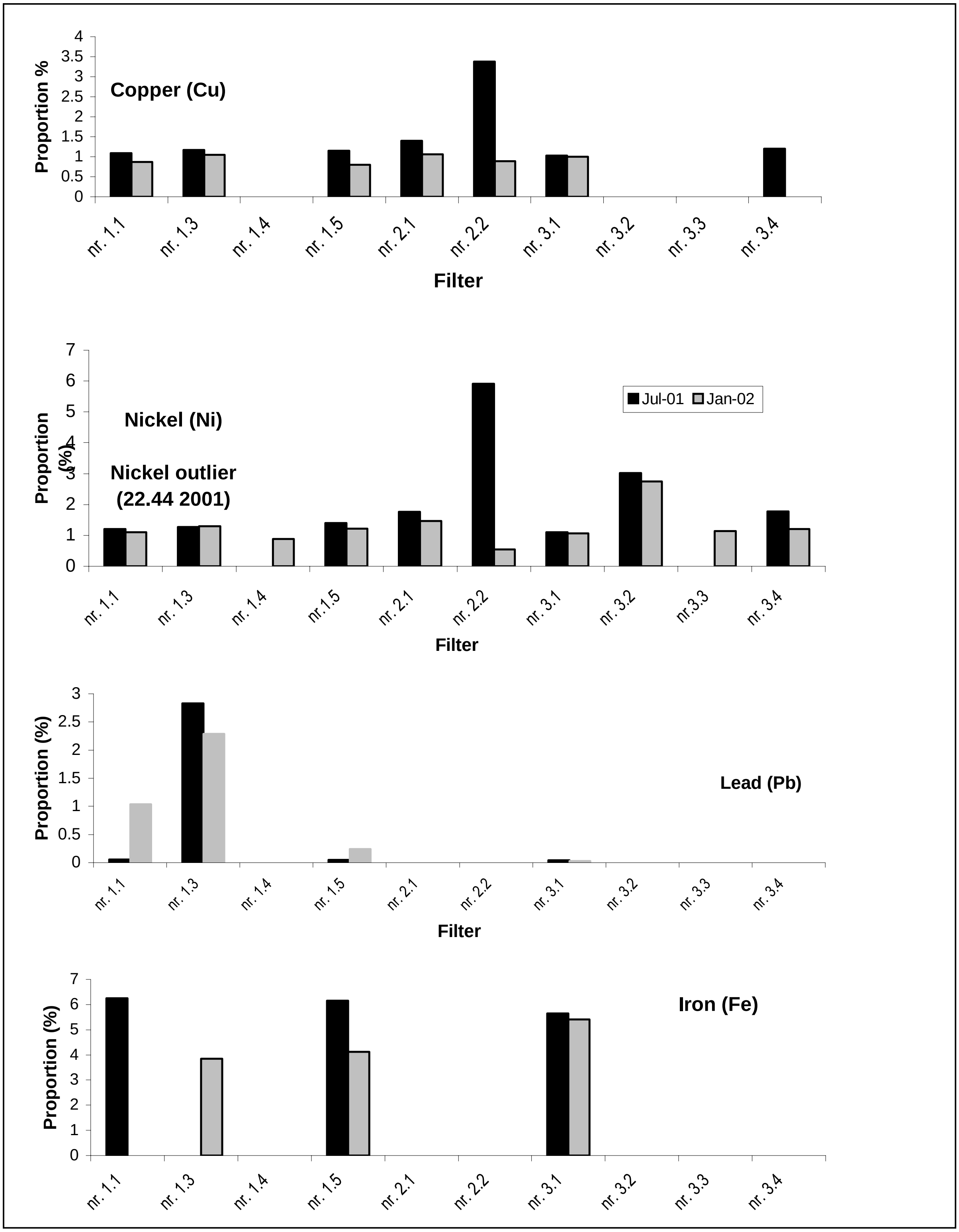


Figure 5.10: Analysis of samples taken in Waterval Smelter (2001 – 2002) (Anglo Platinum, 2002b).

5.1.8.1 Overall environmental goals

Waterval Smelter is an important part of the Anglo Platinum operations in the Rustenburg region and therefore the overall environmental goals of Anglo Platinum as well as the company's vision for Waterval Smelter are examined firstly to understand the specific management plans that the Smelter has in place to reduce particulate pollution. The Anglo Platinum: Safety, Health and Environmental Policy can be found in Appendix G. The following management plans are in place to increase production, reduce costs and actively reduce the impact on the environment (Anglo Platinum, 2001a):

a. Create a suitable environmental management system in line with the Environmental Management Programme Report (EMPR) commitments; and
b. Implement and integrate an environmental management system at the Smelter and the ACP site through:
   1. The monitoring of gaseous and particulate emissions, surface and ground water monitoring, local weather conditions and ambient levels of SO_2 in the vicinity of Waterval Smelter,
   2. The upgrading and maintenance of pollution abatement equipment,
   3. The adoption of alternative, economically feasible practices and technologies for production and pollution control,
   4. Consultation with local communities and other interested and affected parties, and
   5. The development of an Environmental Management Programme, adherence to the Group Environmental Policy, as well as the Anglo Platinum vision and values.

5.1.8.2 Air quality management (particulate management)

Waterval Smelter has initiated a number of specific procedures in order to maintain and improve air quality, comply with permit conditions and reduce the impacts of fugitive particulate emissions (Anglo Platinum, 2001a; Anglo Platinum, 2001b):

a. Keep furnaces effectively sealed,
b. Optimise furnace off-gas systems to keep volumes to a minimum,
c. Ensure maximum containment of gases within the capabilities of existing equipment,
d. Maintain the existing Acid Plant in operable condition,
e. Minimize Acid Plant downtimes,
f. Monitor stack emissions as well as:
   1. Ground concentrations of particulates at appropriate locations along the perimeter of the site (real-time fence-line monitoring system),
   2. Ground level concentrations of particulates inside the plant, and
   3. PM_{10} concentrations at existing off-site regional monitoring stations (real time) to identify any deterioration in conditions.
g. Routinely inspect and maintain the real-time monitoring system and monitoring equipment,
h. Shutdown relevant sections of the Smelter if there is a risk of exceeding the permit requirements (*e.g.* shut-down furnaces if availability of ceramic candles is not 100%),
i. Undertake regular audits to assess that the predicted emission reductions are realised in practise,

j. Continually review opportunities for emission reductions,
k. Register non-complaint incidents and make records available to authorities,
l. Create annual monitoring reports and submit to authorities, and
m. Develop a maintenance programme (*e.g.* identify problems and repair immediately).

To ensure that the above-mentioned targets are met, procedures for a number of important areas are described in detail, updated and audited on a yearly basis[5]:

a. Ceramic candle maintenance,
b. Stack monitoring,
c. Ambient monitoring,
d. Monitoring site management,
e. Handling environmental incidents,
f. Operating procedures, and
g. Normal conditions.

The next section deals with Impala Platinum and provides the same information (operations and management plans) as that supplied for Anglo Platinum in order to compare the different operations with one another (Chapter 7).

5.2 Impala Platinum

Impala Platinum is the second largest producer of PGMs in the world (Hamann, 2003). Gencor's 46% stake in the company was unbundled in May 2003 with 80% of shares held by trust funds and investment companies (Hamann, 2003). Impala Platinum has a close association with the Royal Bafokeng Nation (owners of the mineral rights over the lease area) but there are negotiations in progress regarding the conversion of Impala's royalty agreement with the Royal Bafokeng Nation into a shareholding stake (Hamann, 2003; Impala Platinum, 2001a). The registered office is in Johannesburg, with a listing on the Johannesburg Securities Index (Hamann, 2003). The total operating profit is approximately R 6 000 million with a total of 28 600 employees and nearly 6 350 contractors (Hamann, 2003).

The largest contributor to the group is the Impala business segment in the vicinity of Rustenburg (13 shafts plus refining and smelting plants) where nearly 1.9 million oz of PGMs and more than 1 million oz of Platinum are produced per year (Hamann, 2003).

5.2.1 Site description

Impala Platinum is situated approximately 16 km northwest of Rustenburg and Thlabane (Appendix B: Fig. 5.11) (Impala Platinum, 2001a; Burger & Scorgie, 2000b; Pulles *et al.*, 2000). Portions of land not owned by the Royal Bafokeng Nation, are owned by private individuals or are state land (Pulles *et al.*, 2000). Minerals are exploited from two reefs, namely the Merensky and UG2 Chromitite Reefs and are estimated to be sufficient to sustain continued operation for thirty to thirty-five years (Pulles *et al.*, 2000). Various smaller formal villages are located close to the Smelter (Phokeng, Kana, Mafika, Luka and Mogono) as well as an informal settlement (Freedom Park) (Appendix B: Fig. 5.11) (Burger & Scorgie, 2000b; Pulles *et al.*, 2000). Land in the immediate vicinity of the Smelter is used primarily for mining activities and subsistence livestock farming (Pulles *et al.*, 2000). Drainage from the Smelter is predominantly into the Leragane Stream, which flows into the Elands River and ultimately flows into the Vaalkop Dam (Appendix B: Fig. 5.11) (Pulles *et al.*, 2000).

5.2.2 Process description

Operations at Impala Platinum Smelter commenced in 1969 (Pulles *et al.*, 2000). The main function of the Smelter is to extract a concentrate that is rich in Platinum Group Metals (PGM's) (Pulles *et al.*, 2001). The process employed consists of different sections, namely (Pulles *et al.*, 2001):

a. Concentrate receiving,
b. Concentrate drying,
c. Furnaces,
d. Converters, and
e. Acid plant.

A schematic illustration of the Impala Platinum Smelter operations is found in Appendix B (Fig.5.12) with a detailed description of the process in Appendix D.

5.2.3 Permit requirements

In accordance with the Atmospheric Pollution Prevention Act (1965), the Department of Environmental Affairs and Tourism, through the Chief Air Pollution Control Officer (CAPCO), issued a provisional registration certificate for Impala Platinum Smelter (Impala Platinum, 2001b). Stipulations set out in the certificate include (Impala Platinum, 2001c):

a. Off-gases from the arc furnace pass through three 2-field electrostatic precipitators;

b. Off-gases from the converters pass through one of two 2-field electrostatic precipitators at any point in time;
c. Off-gases from the electrostatic precipitators contain less than 120 $mg.m^{-3}$ as measured at 0^oC and 101,3 kPa;
d. All other off-gases from the furnaces and converters are vented to atmosphere by means of a stack height of 91 m above ground level;
e. The particulates concentration of the final emissions of the spray driers does not exceed 120 $mg.m^{-3}$ as measured at 0^oC and 101,3 kPa;
f. In the event of a major breakdown or when the plant is off-line all converter and furnace flue gases are vented to atmosphere by means of a 91 m stack;
g. All emissions abatement equipment has an availability of 96% of the time per month at the prescribed efficiency. The Acid Plant is available for 90% of the operational time per month; and
h. The availability of all abatement equipment is included in a monthly report that states the reasons for non-compliance where applicable as well as the necessary steps taken to prevent the reoccurrence of any cases where permit stipulations are exceeded.

5.2.4 Air quality monitoring in the Smelter

Impala Platinum Smelter emits particulates from the Main and Spray drier stacks, the furnace and converter building as well as general plant fugitive emissions (Pulles *et al.*, 2000). The Drier stack, Main stack and Acid Plant stack at Impala Platinum measures SO_2 and particulate emissions on a continuous basis after which the results are recorded in the plant control room (manned 24-hours-per day) and included in an automatically created daily report (Table 5.3) (Pulles *et al.*, 2000)[2]. The report is sent to the environmental department as well as operations managers (Pulles *et al.*, 2000)[2]. Impala Platinum had problems with faulty instrumentation since inception; since May 2002 correct measurements have been recorded[2]. Although Impala Platinum made a commitment at the beginning of this study to make measurements available; no data were provided as it was regarded as not representative[2]. The different sections in the Smelter are described but no data are included as in the case of Anglo Platinum and Lonmin Platinum.

Table 5.3: Information included in the daily report *(Pulles et al., 2000).*

Acid plant	Furnaces	Converters	Driers	Weather station
Gas in from scrubber	Gas to main stack: Flow (m^3/sec)[1] Particulates load (mg/Nm3) Particulates loss (kg/hr) Total kg particulates	Converters 1 & 2 SO_2 sensors	Flow (Nm^3/sec) Particulates load (mg/Nm3) Particulates loss (kg/hr) Total kg particulates	UG2 (mobile unit)
Gas outlet to stack	Furnace 3 SO_2 sensors	Converters 3 & 4 SO_2 sensors	Drier 1 gas outlet	Luka
	Furnace 4 SO_2 sensors	Converters 5 & 6 SO_2 sensors	Drier 4 gas outlet	Boshoek
	Furnace 5 SO_2 sensors		Drier 5 gas outlet	Minpro high level water tower

1. The flow rate is calculated for every measurement and is then averaged out over a 15-minute period and used to calculate an average flow rate for every 24-hour period[2]. Measurements (mg.Nm^{-3}) are converted to tonnes per month particulates emitted[2].

5.2.4.1 Spray drier emissions

There are three Spray driers in the Smelter, each with an electrostatic precipitator prior to movement through the Spray drier stack where an Opacity monitor continuously measures particulate emissions[2]. Prior to 2001, Impala was not requested by CAPCO to measure or report these emissions[2]. Because of faulty monitors, particulates were mainly controlled through visual inspection[2].

5.2.4.2 Furnace off-gas particulates to main stack

Since 2000, off-gases from the furnace section of the Impala Platinum Smelter have been monitored, in mg.Nm^{-3} (together with pressure and temperature) just before the emissions enter the Main stack[2]. A restriction of 120 mg.Nm^{-3} is set by CAPCO, but Impala Platinum have made their own commitment not to exceed 80 mg.Nm^{-3}; mainly achieved through upgrading the electrostatic precipitators in 2001 to incorporate the newest available precipitator technology[2]. Impala Platinum does not perceive particulate emissions to be a significant problem in the furnace area; no worker is required to wear a respirator and workers work their full shift (8 hours)[2]. An example of a furnace can be seen in Appendix B: Figure 5.13.

5.2.4.3 Converter off-gas to main stack

Converter off-gas is directed through a wet scrubber before moving through the Acid Plant where particulates have been monitored since 2000[2]. Converter off-gas is redirected through and measured in the Main Stack when the Acid Plant is off-line (Pulles *et al.*, 2000)[2]. An example of a converter can be seen in Appendix B: Figure 5.14.

5.2.4.4 Overall main stack emissions

Emissions from the Main stack are treated to remove particulate content by three electrostatic precipitators in parallel (theoretical collection efficiency of 99.97%) (Scorgie, 2001a; Pulles *et al.*, 2000)[2]. If one of the precipitators is off-line for maintenance, the particulates still move through the other two precipitators[2]. Particulate emissions are continuously monitored using on-line instrumentation, and failure or inefficiency of the electrostatic precipitators is immediately detected in the control room and remedial action is taken (depending on the problem) (Pulles *et al.*, 2000)[2]. Isokinetic sampling is conducted once a year by independent consultants[2]. Static monitors that measure SO_2 are installed at various points in the Smelter, but no particulate emissions are measured by these monitors[2].

5.2.4.5 Visual monitoring

Visual monitoring of the Main stack is conducted (for internal use only) to determine if and when problems arise[2]. The visuals cannot be viewed by the general public[2].

5.2.5 Fugitive emissions

As is the case with Anglo Platinum, ambient monitoring stations are in place for monitoring SO_2 as well as particulate emissions; the same stations is used to measure both of these emissions. Particulate emissions have been measured since 2002, but like the air quality monitoring inside the Smelter no data have been made available for the purpose of this study.

5.2.5.1 Ambient SO_2 monitoring

Three air quality monitoring stations have been installed in the vicinity of the Impala Platinum Smelter and have collected SO_2, wind direction, wind speed, and temperature data since December 1999 (Appendix B: Fig.5.11) (Burger & Scorgie, 2000b; Pulles *et al.*, 2000)[2]:

1. Luka Station located within the demarcated residential area of Luka (±2.2 km to NNE),
2. Phokeng Station is approximately 5.5 km to the south of the Smelter, and
3. UG2 Station located approximately 3.5 km to the southeast of the Smelter.

Stations are relocated periodically if required, but remain in a location until at least one year's data have been accumulated and sufficient information is available in terms of the air quality in the area (Pulles *et al.*, 2000)[2]. During 2001 the following changes were made[2]:

1. Phokeng to Boshoek (the area, which lies in the direction in which impacts are expected to be highest), and

2. UG2 to central offices.

5.2.5.2 Ambient particulate monitoring

Fugitive emissions include (Pulles *et al.*, 2000):

1. Emissions that have escaped gas capture and treatment processes (gas produced in the converters not captured by the extractor hoods), and
2. Emissions from material handling and transfer, and from the mobilisation of spilled materials through activities on the plant.

Spilled materials on site are recovered on a regular basis using a mechanical sweeper vehicle that collects particulates and, thereby, effectively reduces the amount of particulates that may become airborne through traffic or other on-site activities (Pulles *et al.*, 2000)[2]. All roads leading to the Smelter are tarred and the entire area inside the Smelter is concreted and hosed down on a regular basis (Pulles *et al.*, 2000)[2].

5.2.6 Gravimetric sampling

As required by the Department of Minerals and Energy (DME) personal sampling needs to be conducted in order to ensure the safety of all workers in the Smelter[11]. The personal (gravimetric) sampling is handled by the Occupational Hygienist, which forms part of the ventilation department[2]. Although the monitoring is done in conjunction with the Environmental Department, the Occupational Hygienist operates alone under a Ventilation Manager (Fig. 5.15)[11].

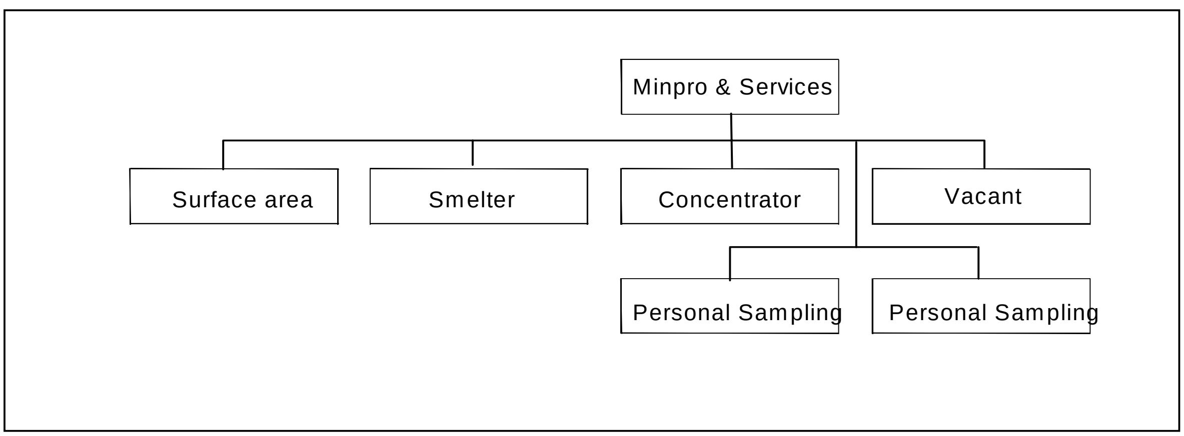


Figure 5.15: Structure in place for gravimetric sampling at Impala Platinum Smelter[11].

Information about the basic sampling techniques used as well as the sampling method and reporting procedure is included in Appendix F.

5.2.6.1 Analyses of samples

Data relating to personal sampling were made available by the Occupational Hygienist and is depicted in Figure 5.16 (1998 – 2000) and Figure 5.17 (2000 – 2002). The data made available for this study are not sufficient to make any significant deductions. The data for the period 1998 to 2000 were calculated by Burger & Scorgie (2000b) and students employed by Impala Platinum collated the data for the period 2000 – 2002[11]. The values for ambient particulate concentrations between 1998 and 2000 appear to be higher than those from 2000 onwards. Unfortunately, there is no clarity on the accuracy and reliability of the data as well as the calculation methods used. The Occupational Hygienist at the time of this study could not provide any information about the collection and calculation methods used or the accuracy of the data, except to say that there are too many question marks over the data and it is not possible to determine the real state of affairs[11]. For this reason, Impala Platinum implemented a new system for compiling and calculating the data recorded from December 2002[11].

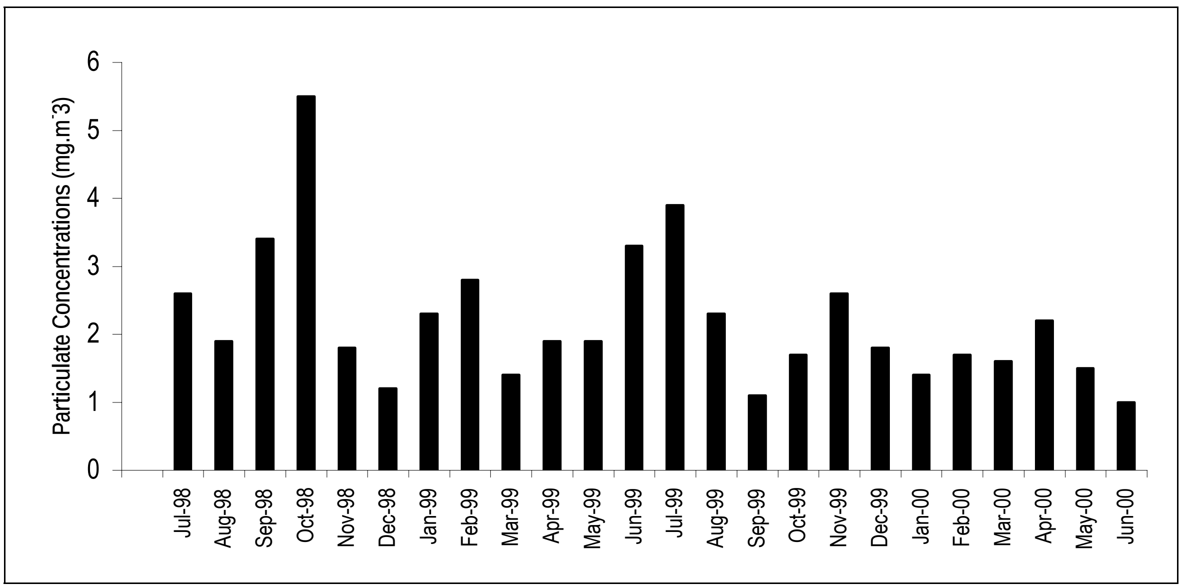


Figure 5.16: Averaged exposure to particulate concentrations by personnel working within the Impala Platinum Smelter – 1998 to 2000 (Total Particulates: TLV of 5.5 mg/m^3; Respirable Particulates: TLV of 3.0 mg/m^3) (Burger & Scorgie, 2000b).

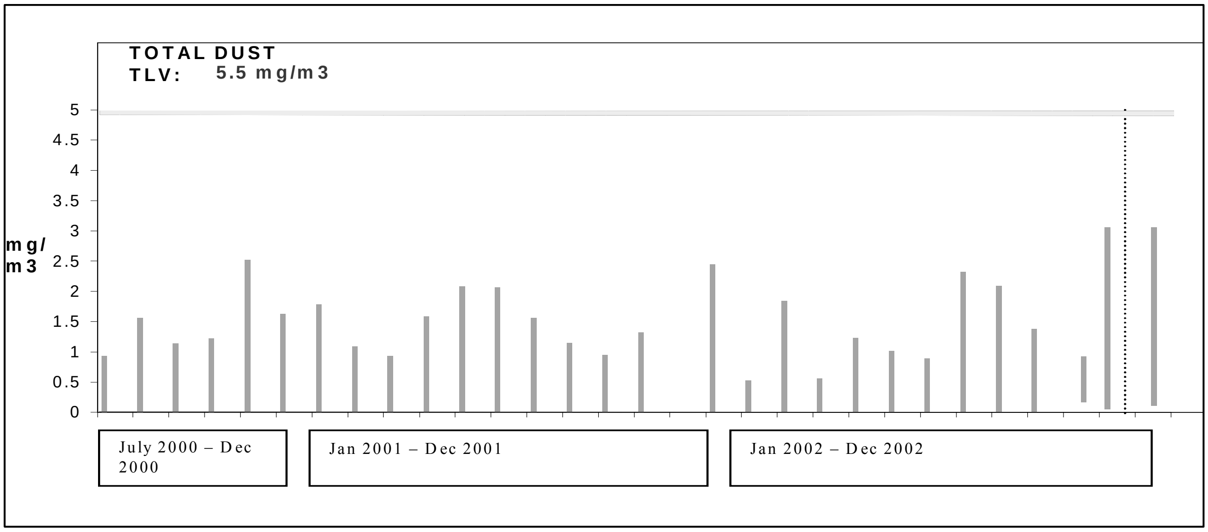


Figure 5.17: Average total particulates exposure at the Impala Platinum Smelter (2000 – 2002)[11].

The next two sections focus on the management structures and plans in place at Impala Platinum Smelter to deal with particulate emissions.

5.2.7 Environmental departmental structure

The environmental manager is responsible for the air quality management of the Smelter and is supported by an air quality management committee that convenes once a month and consists of members of the Smelter as well as the Environmental Department (Fig. 5.18)[2].

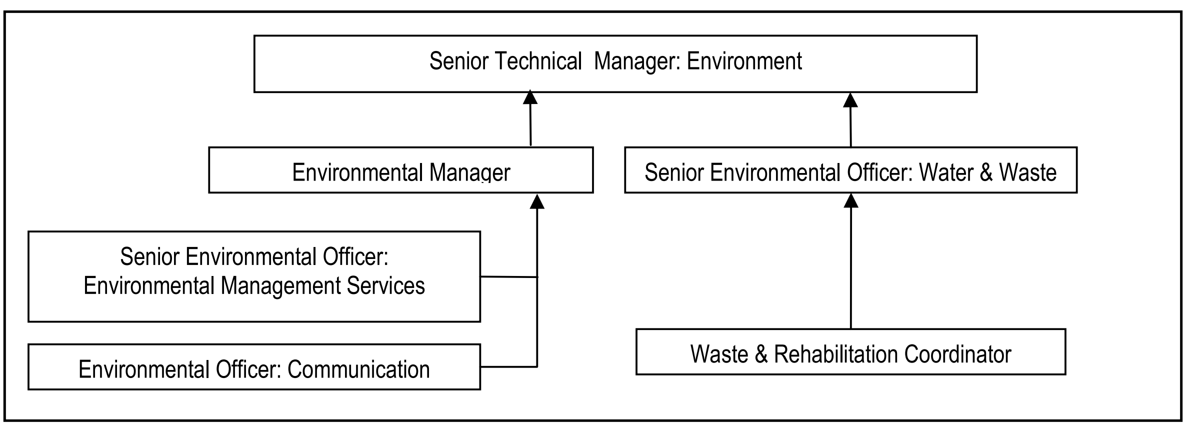


Figure 5.18: Departmental structure of the Impala Platinum Smelter.[2]

The Environmental Department is supported by Environmental Management Services Area Coordinators, which are engineers responsible for environmental matters in a demarcated area (*e.g.* concentrator, shaft) and meet once a month with the Environmental Department (Fig. 5.18)[2]. Task teams are responsible for different projects and meet monthly with the environmental department to discuss[2]:

1. Long term projects,
2. Operational issues (for the concentrators, shafts), and
3. Monitoring and reporting.

Publications produced by the department include "Envirotalk" (published once a month) and an Environmental, Health, Safety and Community Review that was published in 2001[2].

5.2.8 Environmental management plan

The environmental management plans (overall and specifically for air quality) as they were until the end of 2001 (historically) for Impala Platinum are examined.

5.2.8.1 Overall environmental goals

Impala Platinum has recognised that its activities, whilst contributing to an improved quality of life, does impact on the environment (Pulles *et al.*, 2000). It is Impala Platinum's vision to become a world-class leader in the management of environmental impacts and to achieve this an environmental policy has been formulated with specific objectives (Pulles *et al.*, 2000):

a. Complying with all relevant laws, policies and guidelines and where practicable, exceeding these standards;
b. Integrating environmental management into all aspects of business;
c. Conducting regular risk assessments to identify and minimise environmental impacts and to prepare emergency plans;
d. Continually improving environmental performance by encouraging innovation to promote the reduction of emissions and effluents, develop opportunities for recycling and using energy, water and other resources more efficiently;
e. Contributing to the development of sound policies, laws, regulations and practices that improve safety, health and the environment;
f. Training, education and encouraging employees and contractors to participate in environmental management so enabling them to conduct their activities in a responsible manner; and
g. Measuring and communicating environmental performance to stakeholders including employees, shareholders, the community and other interested parties.

5.2.8.2 Air quality management (particulate management)

In order to minimise potential impacts that may occur as a result of Smelter operations the following plans are implemented (Pulles *et al.*, 2000):

1. Comply with all relevant laws, policies and guidelines and where practicable bettering these standards;
2. Monitoring emissions both internally and externally to identify areas for improvement;
3. Continuously reviewing available technology;
4. Maintaining gas cleaning equipment and monitors;
5. Training and involving employees to pro-actively participate; and
6. Communicate and disclose relevant information to interested and affected parties.

The air quality management goal of the Impala Platinum Smelter is to ensure that particulate and SO_2 emissions do not pose a risk to public health and the environment or be a nuisance or aesthetically displeasing to the surrounding communities (Pulles *et al.*, 2000). In order to effectively manage environmental impacts that may arise as a result of the Smelter's activities, management options that conform to "Best Practical Environmental Option" (BPEO) and "Best (Proven) Available Technology Not Entailing Excessive Cost" (BATNEEC) are pursued (Pulles *et al.*, 2000).

The smallest of the three Platinum mines is Lonmin Platinum and in the next section the same information is supplied for this mine as was the case for the other two Platinum mines (Anglo Platinum and Impala Platinum). The first part focuses on the operation of the Smelter after which the management plans regarding particulate pollution control are described.

5.3 Lonmin Platinum

Lonmin plc is the third largest primary Platinum producer in the world and the only focused PGM producer with its primary listing on the London Stock Exchange (Hamann, 2003; Lonmin Platinum, 2002). The group has full management stake (73%) in Lonmin Platinum, and a 28% interest in Ashanti Goldfields (Lonmin Platinum, 2002). Lonmin Platinum is also listed on the Johannesburg Securities Index (Hamann, 2003). Over 90% of shares are owned by banks, nominees, and other corporate bodies (Hamann, 2003). In 2002 a total operating profit of R3 300 million was declared (Hamann, 2003). Lonmin Platinum exists of the Karee Mine and Western and Eastern Platinum Mines (about 20 000 employees and 5 000 contractors) to the east of Rustenburg with an annual production of approximately 760 000 oz (46 tonnes) of Platinum (Hamann, 2003). The annual turnover of PGMs is nearly R 6 300 million (Hamann, 2003; Lonmin Platinum, 2002).

5.3.1 Site description

The Lonmin Platinum Smelter operations form part of Western Platinum (Lonmin Platinum, 2001)[3]. The Smelter consists of 2 870 ha and together with Base Metal Refineries (BMR) is known as Metallurgical Services (Met. services) (Lonmin Platinum, 2001a)[3]. There are 350 people working in the Smelter (excluding contract workers responsible for expansions)[3]. A nearby village is Wonderkop[3].

5.3.2 Process description

Operations at Lonmin Platinum Smelter commenced in 1971 with various upgrades being made to the process over the years (Table 5.4) (Posnik, 2002).

Table 5.4: History of the Lonmin Platinum Smelter (Posnik, 2002)[3].

1971: Smelter and Converters were commissioned	1 x CCH drier Plant (Merensky)
1982: The UG2 drier and two furnaces were commissioned (Infurnco)	2 x Spray Drying Towers (UG2)
1989: The Davy Merensky Furnace was commissioned	1 x 6-in-line Merensky Furnace
1991: The UG2 plant was expanded to include a drier and 3 furnaces (Pyromet)	2 x Infurnco UG2 Furnaces
1992: The Davy Merensky Furnace was decommissioned	3 x Pyromet UG2 Furnaces
1997: The first UG2 drier was decommissioned	2 x Pierce Smith Converters
In 1999, the Smelter consisted of:	1 x Electrostatic Precipitator

The main function of the Lonmin Platinum Smelter is to extract a concentrate that is rich in Platinum Group Metals (PGM's) (Pulles *et al.*, 2001). The process employed consists of different sections, namely (Pulles *et al.*, 2001):

a. Concentrate receiving,
b. Concentrate drying,
c. Furnaces, and
d. Converters.

A schematic illustration of the Lonmin Platinum Smelter operations is found in Appendix B (Fig.5.19) with a detailed description of the process in Appendix D.

5.3.3 Permit requirements

Similar to Anglo Platinum and Lonmin Platinum, the Department of Environmental Affairs and Tourism through the Chief Air Pollution Control Officer (CAPCO) issued a provisional registration certificate for Lonmin Platinum Smelter (Lonmin Platinum, 2001a). Stipulations set out in the certificate that applied until 2001 included (Lonmin Platinum, 2001a):

a. Particulate concentration of the final emission from all the scrubbers must not exceed 120 $mg.m^{-3}$ ($0^{o}C$ and 760 mm Hg);
b. Off-gases from the submerged arc furnaces and from the Pierce converters must be passed through a settler followed by a precipitator before final emission through a 122 metre high stack;
c. Particulate concentration in final emission from stack must not exceed 120 $mg.m^{-3}$ ($0^{o}C$ and 760 mm Hg);

d. Total SO_2 emitted per day must not exceed 48 t;
e. A monitoring programme must be carried out to assess the impact of emissions on the environment;
f. All air cleaning equipment must have an availability at the prescribed efficiency of at least 96% of the time per month;
g. A report stating the availability of gas cleaning equipment, the causes and duration of non-compliance with any of the above requirements, must be submitted on a monthly basis; and
h. In the case of any expected long duration high emission episodes of particulates releases from any of the process, Directorate: Air Pollution Control must be informed immediately.

5.3.4 Air quality monitoring in / around the Smelter

Lonmin Platinum Smelter emits particulates from the Main and Flash drier stacks, the furnaces and converters as well as general plant fugitive emissions (Lonmin Platinum, 2001a). A number of different measurements are undertaken by the Smelter to monitor the SO_2 and particulate emissions from the plant (Table 5.5). These measurements are taken inside the Smelter as well as just outside the Smelter (on site) mostly on a continuous basis. Some of the measurements are only taken on a monthly basis (*e.g.* twenty positions on site) (Table 5.5).

5.3.4.1 Flash drier emissions

Lonmin Platinum makes use of two separate Drier stacks to dry the UG2 and Merensky ore (Lonmin Platinum, 2001a; Lonmin Platinum, 2001b) [3,4]. The particulate emissions are measured in-stack by a monitor, but due to instrumentation problems by the end of 2001 none of the measured data were captured or reported to CAPCO.[3] Particulate emissions from the Flash driers are minimised through baghouse filters[3]. After the drying process is completed, the ore is stored in Silo's where significant fall-out occurs that is controlled by dust catchers as well as baghouse filters (Lonmin Platinum, 2001a; Lonmin Platinum, 2001b)[3].

Table 5.5: Measurements undertaken inside Lonmin Platinum Smelter to monitor SO_2 and particulate emissions (Lonmin Platinum, 2001a).

Position	Measurement	Frequency of measurement	Data collection	Maximum guideline	Permit level
Smelter: Main stack	Particulates concentration	Continuous	Hourly average	120 $mg.nm^{-3}$	120 $mg.nm^{-3}$
	SO_2 concentration	Continuous	Hourly average	-	
	Flow	Continuous	Hourly average	-	
	Temperature	Continuous	Hourly average	-	
	Pressure	Continuous	Hourly average	-	
	SO_2 discharge $t.day^{-1}$ measurement	Continuous	Daily	48 $t.day^{-1}$	48 $t.day^{-1}$
	SO_2 discharge calculated	Monthly	Monthly	48 $t.day^{-1}$	48 $t.day^{-1}$
Smelter: Flash drier stack	Particulates concentration	Continuous	Hourly average	50 $mg.nm^{-3}$	
Ground level: two points	SO_2 concentration	Continuous	Hourly	300 ppb	
			Daily	100 ppb	
			Monthly	50 ppb	
			Annual	30 ppb	
Ground level: two points	Particulates concentration PM_{10}	Continuous	Hourly average	180 $mg.Nm^{-3}$	
			Annual average	60 $mg.Nm^{-3}$	
Twenty positions in Smelter	SO_2 concentration	Monthly	Monthly measurements	300 ppb	
Twenty positions on site	Particulates concentration	Monthly	Monthly Measurements	300 $mg.Nm^{-3}$	
BMR Ni crystalliser	Nickel concentration at plant perimeter	Once a month		1 $\mu g.m^{-3}$	

5.3.4.2 Furnace off-gas particulates to Main stack

The furnace area consists of Pyromet furnaces (unit no. 2, 3, 4 and 5) and Infurnco furnaces (unit 1). These furnaces are, similar to Anglo Platinum, regarded as the biggest source of particulate emissions. Emissions are controlled through baghouses and ID fans, and workers are required to wear a mask with a filter and ABEK cartridges to absorb the particulates and gases while working in the area (Lonmin Platinum, 2001a)[3]. Activities on the paste floor of the Merensky furnace are restricted to two-hour shifts[3]. No measurements are available for this area because of faulty instrumentation[3,4].

5.3.4.3 Converter off gas to Main stack

Precautions that are taken in the Converter area include extraction hoods that are used to limit the amount of particulate emissions by transferring it back into the Converters[3,4]. The biggest source of ambient particulate concentrations in this area occurs during tapping (Converters are tilted to throw the molten liquid into a stream of water for granulation; extraction hoods are then inactive)[3,4]. No measurements of particulate emissions are available for the converter area[3].

5.3.4.4 Overall main stack emissions

The process used by Lonmin Platinum differs slightly from that of Anglo Platinum and Impala Platinum since no Acid Plant is used. SO_2 and particulate off-gases from the Furnaces and Converters are routed through closed pipes to a common gas-mixing chamber from where it passes to the 128m high Main stack via one electrostatic precipitator (Pulles *et al.*, 2001)[3,4]. A SICK monitor is installed in the Main stack to measure particulate emissions in mg.m^{-3} (Lonmin Platinum, 2001b)[3,4]. The emissions are measured continuously, sent to the Smelter control room from where monthly summaries are sent to the Smelter Technical Manager[3].

Emissions from the Main stack were monitored for the period May 1999 to November 2002. Values recorded ranged between 21 tonnes and 52 tonnes per month until January 2002 (Fig. 5.20). In May 2002 the electrostatic precipitator in use exploded and the impact thereof can be clearly seen; levels of 558 tonnes for the month of June was recorded (Fig. 5.19) (further described in Chapter 6). Temporary measures were put in place and from August 2002 the emissions started to decrease. During the time when the precipitator was not working weekly Isokinetic sampling was conducted (Posnik, 2003). The values shown in Figure 5.20 are recorded as "calculated" because they are originally measured in mg.m^{-3} and are then converted to mg.Nm^{-3} and tonnes.month^{-1}.[3] Monitoring indicated that values from Isokinetic sampling differed significantly from the calculated values (Fig. 5.20).

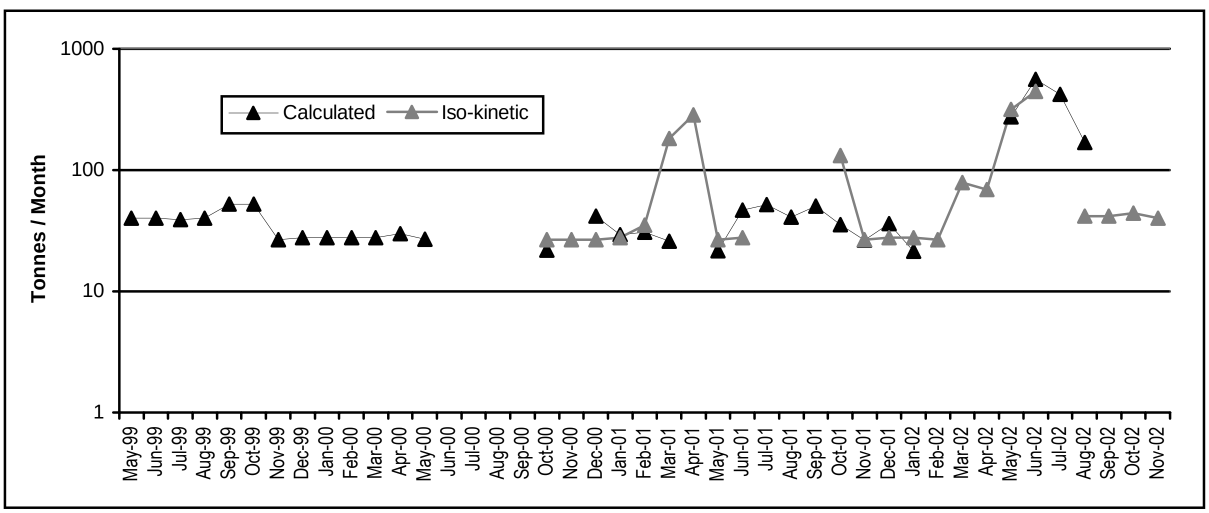


Figure 5.20: Main stack emissions from Lonmin Platinum Smelter (Lonmin Platinum, 2003)

5.3.4.5 Particulate measurements around the Smelter

Lonmin Platinum Smelter is the only Smelter to conduct measurements of particulate emissions in the direct vicinity of the Smelter. These measurements have been conducted since July 2001 (Lonmin Platinum, 2001a)[3]:

- Spot readings with Dusttrack Pro are conducted at 18 selected points with provision for two extra points (which have not been utilised). Monitoring is conducted manually (for periods of two minutes) and the time-weighted average of the readings at every spot is calculated in $mg.m^{-3}$. Instrumentation problems and time constraints have resulted in very few readings actually being recorded – only 33 measurements were done over the 18-month period (Fig. 5.21). During 2002 readings were conducted on a more regular basis, except for February and March when the equipment was sent to America to be calibrated. The readings for 2002 are at 15 of the 18 points higher than for 2001 with an extra measurement done for the new furnace (operational since 2002). The highest values were recorded in 2002 at the concentrate storage shed ($1.73 mg.m^{-3}$) and the ID fan area ($1.48 mg.m^{-3}$). For 2001 the highest value was $1.28 mg.m^{-3}$ recoded at the Smelter office area. The same pattern (only higher values) is followed for 2002 as 2001, except for the Pyromet slag and Smelter office where higher values were recorded for 2001.

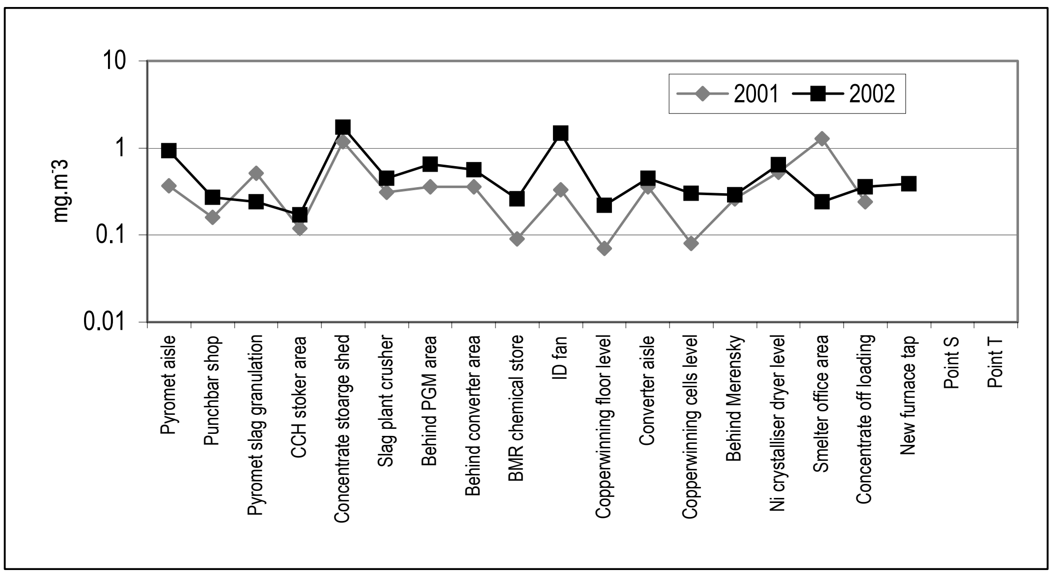


Figure 5.21: Spot readings with Dusttrack Pro conducted at 18 selected points around Lonmin Platinum Smelter (Lonmin Platinum, 2003).

- Particulate gravimetric sampling (static) was conducted for a 24 hour period once a month at four different sampling points around the Smelter / BMR complex. These readings started in July 2001 and were permanently discontinued in August 2001 due to instrumentation problems.

5.3.5 Fugitive emissions

Lonmin Platinum measures SO_2 as well as particulate emissions in the areas surrounding the Smelter (Lonmin Platinum, 2001b). Only two (mobile) stations with a weather station included are used to conduct the monitoring (Lonmin Platinum, 2001b).

5.3.5.1 Ambient SO_2 monitoring

The mobile station used for SO_2 monitoring is moved every three months to one of 14 different positions in the vicinity of the Smelter[4]. During 2001 the station was moved to near the Smelter to measure the influence of the new furnace commissioned (described in Chapter 6)[3]. A second mobile station measuring SO_2 and PM_{10} particulates was bought in August 2001 and has been moved around with a crane to different secure positions in the vicinity of the Smelter (*e.g.* farms, informal settlements and Mooinooi)[4]. The data are downloaded monthly by an independent company and processed by the Senior Environmental Officer (Central services) before it is sent to the Technical Manager of the Smelter who is responsible for the monthly reporting to CAPCO[3,4]. An additional weather station was installed at the end of 2001 near the Senior Environmental officer's office[3,4].

5.3.5.2 Ambient particulate monitoring

During 2001 and 2002 the second mobile station was located approximately 250 metres to the southwest of the Smelter (Lonmin Platinum, 2002). Data recorded at the station regarding particulate emissions (monthly mean) indicated that the highest value was recorded in August 2001 (181.2 $mg.m^{-3}$) and the lowest value in November 2001 (74 $mg.m^{-3}$) (Fig 5.22). No value was recorded for January 2002. Ten of the 16 values recorded are higher than 100 $mg.m^{-3}$, with the daily limit of 180 $mg.m^{-1}$ exceeded a total of 40 times during the 16-month period. The percentage data capture are also shown in Figure 5.21. From July 2002 the capture was between 98.5% and 100%; before that, it varied substantially, with the lowest values recorded for January 2002 (0%) and September 2001 (26%). According to Lonmin Platinum (2002) the data also reflects the influence of sources not connected to the Smelter.

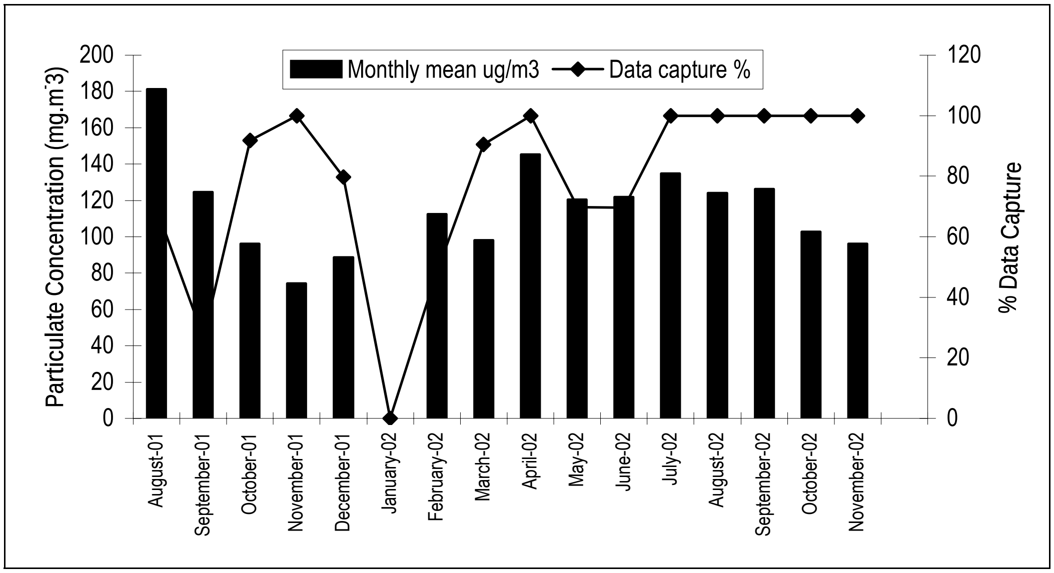


Figure 5.22: Fugitive particulate measurements: mobile station (Lonmin Platinum, 2003).

5.3.6 Gravimetric sampling

Similar to Anglo Platinum, a fingerprint study was conducted to assess the amount and content of particulate emissions workers in the Smelter is exposed to (Fig. 5.23)[3,4]. A total number of 26 elements were tested for over a five-day period[3]. Sampling for particulates took place on three of the five days under different conditions in the Smelter and in different areas of the Smelter (*e.g.* furnace, converter and Main stack area)[3]. The values for the different elements cover a wide range (0.1 $\mu g.m^{-3}$- 4010 $\mu g.m^{-3}$). Exceptionally high values (> 1000 $\mu g.m^{-3}$) were recorded for Lead (Pb) and high values (> 100 $\mu g.m^{-3}$) were further recorded for Calcium (Ca), Iron (Fe) and Copper (Cu) (Fig. 5.23). The report written by the company responsible for the measurements made no mention of any of these high values and offered no explanation for the high values. The same pattern is followed for the furnace and converter area and the main stack in the case of all the elements tested for.

The percentage value of a number of elements tested for was included in the fingerprint study (Fig. 5.24). The values are lower than that recorded for the same type of study conducted by Anglo Platinum and ranges between 0% and 2.5%. The highest value was recorded for Nickel (Ni) with high values also recoded for Iron (Fe) and Copper (Cu). The value for Platinum particulates is very low.

Information about the basic sampling techniques used as well as the sampling method and reporting procedure is included in Appendix F.

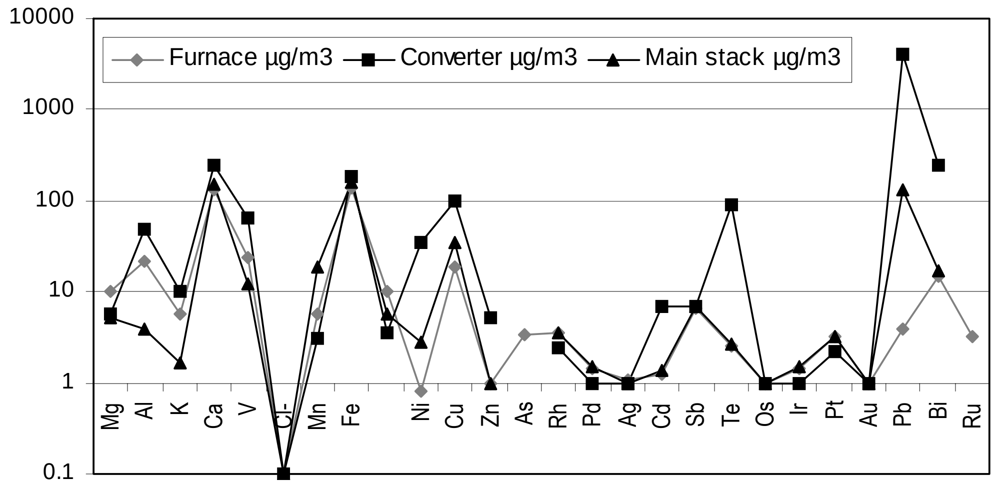


Figure 5.23: Elements present in analysis of particulate emissions from Lonmin Platinum Smelter (Lonmin Platinum, 2001).

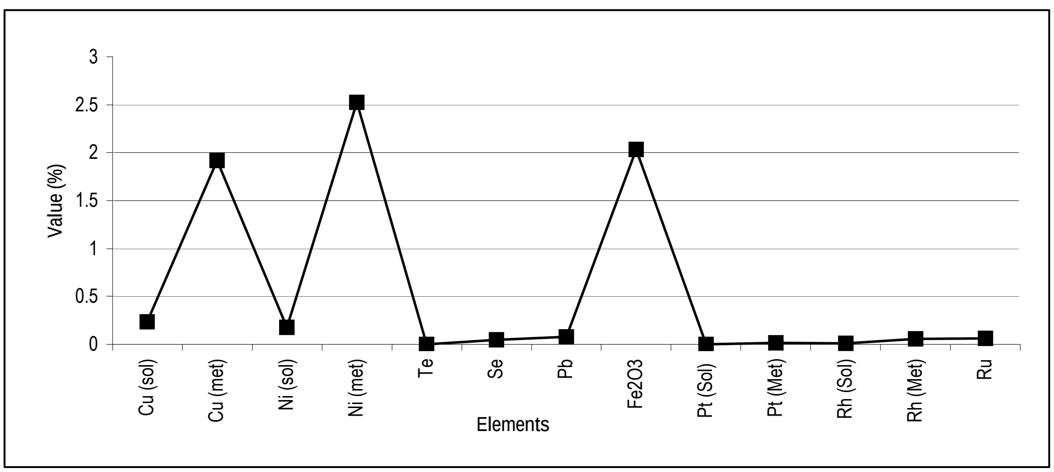


Figure 5.24: Percentage value of elements present in analysis of particulate emissions (Lonmin Platinum, 2001).

5.3.6.1 Analyses of samples

The results of gravimetric sampling conducted for the different sections of Lonmin Platinum Smelter is shown in Figure 5.25. Not much data were recorded until the end of 2002, with the most recordings taking place between December 1999 and December 2000. A very high value was recoded for January 2003 (9.377 $\mu g.m^{-3}$) (Fig. 5.25). Particulate control mechanisms were found to be inadequate during an occupational health and safety audit (Lonmin Platinum, 2001b). Excessive particulates levels resulted from practices such as using compressed air to clean walkways (Lonmin Platinum, 2001b). A summary of the particulate data further suggests that the air quality in the

Smelter / BMR Complex is frequently poor (Lonmin Platinum, 2001b). From the data recoded it can be seen that the nett mass of the samples is quite high and could potentially contribute to health impacts on employees as well as residents in proximity to the Smelter / BMR (Lonmin Platinum, 2001b).

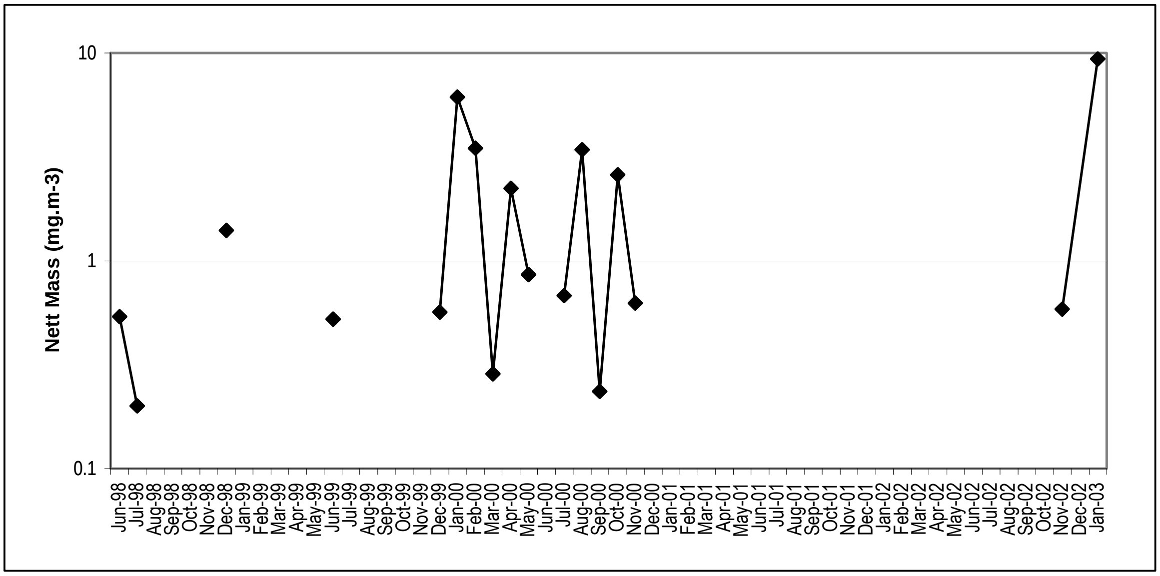


Figure 5.25 Results of analytical reports for the Smelter (Roving, Merensky furnace, Pyromet furnace and CCH combined) (Lonmin Platinum, 2003)

The final two sections focus on the management structures and plans in place at Lonmin Platinum Smelter to deal with particulate emissions.

5.3.7 Departmental structure

The Environmental department of the Smelter /BMR complex (Met. Services) has a staff compliment of two, namely[4]:

a. The technical manager who is also the environmental manager; and
b. The assistant environmental officer.

Central services has a further two environmental officers (Divisional Environmental Manager and Senior Environmental Officer) who work together with the environmental managers from each of the shafts and concentrators and are responsible for[4]:

a. Formulating and managing new projects,
b. Managing the Environmental Management Programme Report (EMPR) and Environmental Impact Assessment (EIA) procedures,
c. Executing the Minerals Act, and
d. Gravimetric sampling.

5.3.8 Environmental management system

There is a comprehensive environmental management system in place for the Smelter - all of which are easily accessible and formulated in procedures. The two main procedures, from which all other emanates, are the Environmental Assessment and Management Procedure (EA & MP) and Environmental Management Programme (EMP) (Lonmin Platinum, 2001b). The Lonmin Platinum: Safety, Health and Environmental Policy can be found in Appendix G. The environmental policy is implemented and maintained through an Environmental Management System, which complies with the requirements of the SABS ISO 14001 code of practice for Environmental Management Systems and are (Lonmin Platinum, 2001b):

1. Documented and controlled where necessary to ensure conformance to the EMS requirements, and
2. Made visible to suppliers and contractors where applicable to ensure that these are documented and controlled by them.

5.3.8.1 Overall goals

The Safety, Health and Environmental (SHE) Policy is displayed throughout the Smelter and can also be electronically viewed on the ISO 14001 Intranet page (Lonmin Platinum, 2001b). The SHE policy expresses the overall intentions and principles in relation to overall environmental performance and provides a framework for actions as well as for setting environmental objectives and targets (Lonmin Platinum, 2001b). Departmental managers are responsible to ensure that the policy is understood and supported in their departments through (Lonmin Platinum, 2001b):

1. Participating in the setting of environmental objectives and targets during monthly SHE meetings,
2. Deriving departmental objectives and targets from the environmental policy where appropriate,
3. Involving personnel in programs to achieve the objectives and targets, and
4. Conducting regular training and awareness sessions.

5.3.8.2 Management of particulates

Air pollution control is described in the Environmental Assessment and Management Procedure and includes prevention, management, mitigation and recommendations (Lonmin Platinum, 2001a; Lonmin Platinum, 2001b):

1. Procedure for environmental monitoring and measurement,
2. Procedure for air quality measurement,
3. Procedure for monitoring fugitive particulates (PM_{10}),
4. Procedure for inspection / maintenance of particulates catchers and bag house procedure, and
5. Procedure for inspection / maintenance of particulates in the electrostatic precipitator.

Chapter 6

Airborne pollutants in the Rustenburg area: The contributors and management from 2002

In Chapter 5 the contributions of the three Platinum mines to particulate emissions as well as the management practices to control the pollution are discussed for the period up to the end of 2001. Due to the situation described in Chapter 4 (section 4.4), major changes have been implemented in the Platinum mining industry to control and minimise the impacts of particulate pollution. The planning of these new measures started years before, but commissioning only took place from 2002. In Chapter 6 the most important new projects implemented by all three mines are discussed as well as other smaller projects, new management practices and new legislation implemented by the Air Pollution Control Officer (APCO) for North West province regarding registration certificates. The new projects of the different mines are discussed in the same order as in Chapter 5. In the last section of the Chapter, the other important roleplayers in the region (*i.e.* Rustenburg Air Quality Forum and North West Ecoforum) are discussed to ensure that a holistic picture of the region is depicted.

6.1 Anglo Platinum

Anglo Platinum has implemented a major new project that will contribute to the control of particulate pollution (ACP project). This project is discussed after which the new plans regarding management practices (new permit requirements, the implementation of a regional environmental department, preparations for ISO 14001 certification as well as the implementation of an Air Quality Management Plan for the Rustenburg operations) are focused on.

6.1.1 New projects

The Anglo Platinum Converting Process (ACP) project is by far the biggest and most expensive project implemented in the region at a cost of R1.6 billion (Anglo Platinum, 2002a; Anglo Platinum, 2000). Planning of the project started in 1996, but by 2003 the plant was still not fully operational (Table 6.1). The project consists of new imported converting technology, a high and low strength Acid Plant and re-engineered particulate and gas cleaning and capturing system (Anglo Platinum, 2002a; Anglo Platinum, 2001b)[5].

The project has the primary objective of reducing SO_2 emissions, while increasing Sulphur fixation (Table 6.2) (Anglo Platinum, 2002a; Anglo Platinum, 2001a; Anglo Platinum, 2001b). The project will further reduce particulate emissions from the Main stack by capturing and diverting fugitives from the furnace building to the new Acid Plant (Anglo Platinum, 2001a).

Table 6.1: Target dates set for the planning and commissioning of the Anglo Platinum Converting Process (ACP) project (Anglo Platinum, 2000).

	Target date	
	Early	Late
Select technology options	March 1996	June 1996
Start feasibility test work at research scale	December 1996	June 1997
Start Pilot plant operations	September 1997	December 1997
Commence with initial plant design	June 1998	December 1998
EMPR amendment	September 1999	June 2000
Project approval by Board	September 1999	June 2000
Plant commissioning	September 2001	September 2002
Plant fully operational	March 2002	June 2003

Table 6.2: Projected changes in emissions from the Anglo Platinum Waterval Smelter (Anglo Platinum; 2001a).

	2001	2005
SO_2	133 $t.day^{-1}$	20 $t.day^{-1}$
Noxious Emissions	78 $t.month^{-1}$ (2.6 $t.day^{-1}$)	127 $t.month^{-1}$ (4.23 $t.day^{-1}$)
Particulate Emissions	312 $t.month^{-1}$ (10.2 $t.day^{-1}$) 3740 tpa	Stage A: 97 $t.month^{-1}$ (3.12 $t.day^{-1}$) 922 tpa Stage B: 2. $t.day^{-1}$ 844 tpa
Sulphur fixation	55%	98%

The new Acid Plant is designed in such a way that it operates in two sections: a strong gas stream section accepting Converter off-gas and a weak gas stream section accepting Furnace off-gas (Anglo Platinum, 2001a). If problems occur in either of the sections in the Acid Plant, only the related production process needs to be appropriately managed (Anglo Platinum, 2001a). Appropriate instrumentation for real-time monitoring of particulates and flow rates was installed in the Converter and Acid Plant stacks (Anglo Platinum, 2001a).

Anglo Platinum further implemented a number of smaller projects in order to reduce particulate emissions. These projects include[5,7]:

a. The closing of the conveyor belts going into the Furnaces;

b. Extra ventilation throughout the Smelter;

c. Extra, improved capturing hoods for the Furnaces in the ACP section; and

d. The furnace is rebuilt every 10 years.

6.1.2 New permit requirements for Waterval Smelter

Along with the new ACP project, the North West Department of Agriculture, Conservation and Environment (DACE), through the Air Pollution Control Officer (APCO), issued a new provisional registration certificate (no 153/3) for the Waterval Smelter in December 2002 (replaced the provisional registration certificate issued in 1999)[7]. The provisional certificate expires in November 2003 and will be replaced with a permanent registration certificate only if particulate emissions from the Main stack are limited to 120 mg.Nm^{-3} (Anglo Platinum, 2003). In 2003 Anglo Platinum made a new commitment that all smelting and converting related fugitive emissions will be controlled (within legal limits) by 30 September 2004 (Anglo Platinum, 2003).

6.1.3 Regional environmental department

In 2002, a regional environmental department was established for the Rustenburg section of Anglo Platinum operations[5]. The new department includes specialists responsible for the management of air quality for the region as a whole (including the Smelter) (Fig. 6.1)[5].

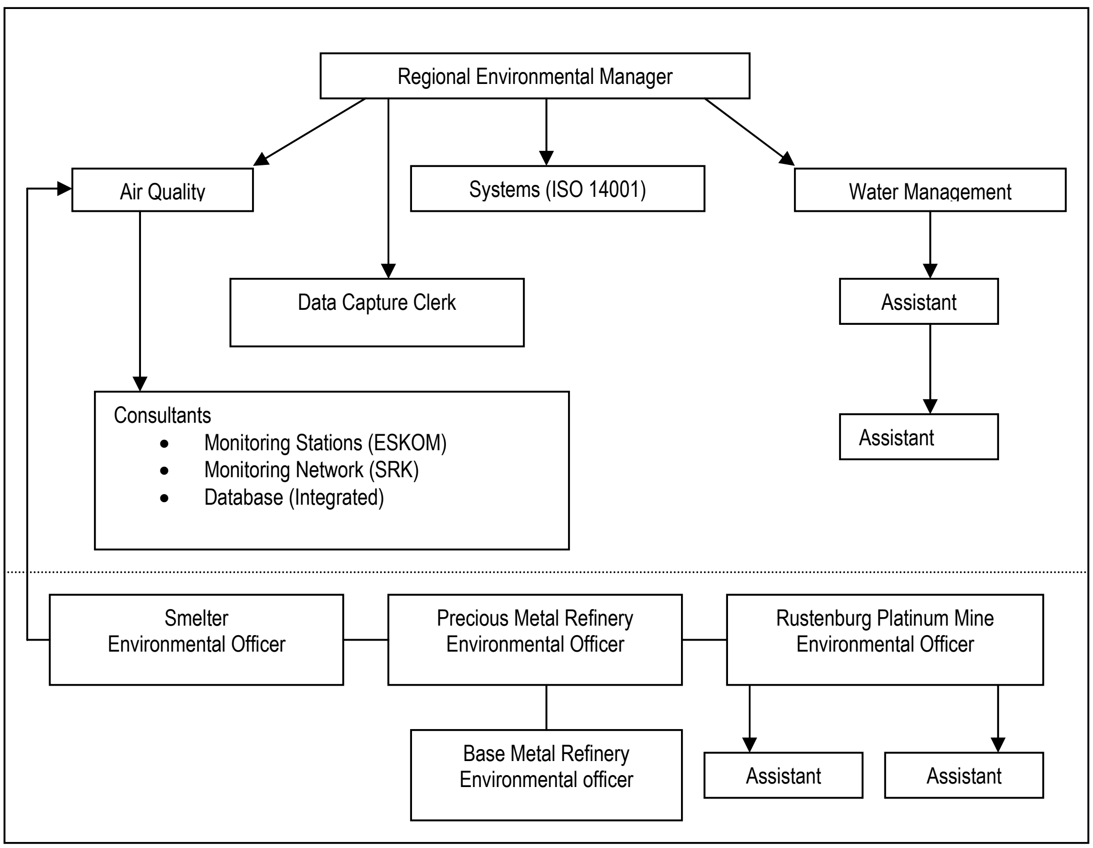


Figure 6.1: Structure of the regional environmental department for the Rustenburg section[5].

The regional air quality manager is supported by environmental officers for each Business Unit (*e.g.* Smelter, Base Metal Refinery) as well as a number of consultants responsible for the maintenance of the air quality monitoring stations, the downloading of the captured data and the functioning of the integrated database created as a result of the fugitive emission monitoring (Fig. 6.1).[5] A new addition has also been a Safety, Health and Environmental (SHE) manager appointed specifically to the Smelter to improve and better coordinate management efforts (Anglo Platinum, 2003).

6.1.4 ISO 14001 certification

Another new management tool implemented by Anglo Platinum that will help to control particulate emissions and improve air quality management is the implementation of ISO 14001. Anglo Platinum planned to apply for ISO 14001 certification by the end of 2003[5]. In order to achieve this, a Coordinator (Systems) was appointed to the regional environmental department, with a representative for every Business Unit (*e.g.* Smelter) to be responsible for implementation in that specific Unit (Fig. 6.1)[5].

6.1.5. Air quality management plan

Extensive planning has lead to the design of an Air Quality Management Plan (AQMP) for the Rustenburg section of the Anglo Platinum operations. The plan is based on three pillars, namely (Anglo Platinum, 2003):

a. A detailed source inventory;
b. Business Unit specific plans: assist Units in source identification, specific reduction plans and contingency measures, implementation of reduction plans, source specific monitoring; and
c. Consolidation of the plans from the different Business Units and monitoring: compile a consolidated AQMP, specify the regional performance indicators, and perform monitoring, liaison and reporting.

The plan comprises of 11 sections and include (Anglo Platinum, 2003):

a. Introduction: ambient air quality, aim of regional AQMP;
b. Framework: compilation of framework, design of AQMP;
c. Significant sources: Business Unit sources, combined sources;
d. Emission control: particulate emissions, SO_2 emissions;
e. Performance indicators: local guidelines, international guidelines;
f. Ambient monitoring: monitoring locations, monitoring methods;
g. Contingency measures: particulate emissions, SO_2 emissions;
h. Reporting and liaison: internal / external reporting, community liaison;
i. Inspections and audit (internal and external): internal auditing, external auditing;

j. Financial provision: physical implementation, monitoring and auditing; and
k. Appendices: Business Unit air quality management plans and the detailed source inventory.

The AQMP was completed in 2003 with implementation already starting on the tailings dams and process plants in 2002 (Anglo Platinum, 2003). Emission reduction targets are included for 2005, 2008 and 2010 (Anglo Platinum, 2003). The plan is dynamic and the idea is to update it on a regular basis as the changing situation requires (Anglo Platinum, 2003).

6.2 Impala Platinum

Impala Platinum also introduced several new projects to improve their air quality management and achieved ISO 14001 certification during the period.

6.2.1 New projects

A large project that has been implemented in the Rustenburg region was the installation of a Sulfacid plant by Impala Platinum at a cost of R55 million (Pulles *et al.*, 2000)[2]. The purpose of the plant is to clean the furnace off-gas with the result that no particulates are emitted through the Main stack anymore (except when the Sulfacid plant is off-line) (Pulles *et al.*, 2000)[2]. The Sulfacid plant further ensures that in the event of any individual electrostatic precipitator failure, the gas stream will still be free of particulates thereby increasing the plant's efficiency and decreasing the amount of maintenance required on the plant (Pulles *et al.*, 2000). The Sulfacid plant is situated after the three electrostatic precipitators and before the Main stack and has been operational since September 2002[2].

In November 2002 an additional Drier stack was installed. Since Impala Platinum made no data available for this study (Chapter 5), it is not possible to determine the impact of these new projects on particulate emissions. Theoretically, an extra Drier stack will lead to an increase in the particulate emissions.

Another new project initiated by Impala Platinum is the commissioning of three particulate monitors (TEOM instruments) that were installed in the ambient monitoring stations in May 2002[2]. The data from these stations are automatically transferred via radio links to a central computer in the control room from where it is distributed to the Intranet where it can be viewed by all workers as well as the Environmental department[2].

6.2.2 ISO 14001

The Rustenburg Operation (which includes the Smelter) of Impala Platinum achieved ISO 14001 certification in 2003[2]. The pre-assessment took place in 2002 and accreditation in 2003[2]. The Precious Metal Refinery (PMR) and Base Metal Refinery (BMR) in Springs were the first to implement the standard, and received ISO 14001 certification during May 2000 (Impala Platinum, 2001b).

6.3 Lonmin Platinum

The situation regarding particulate emission management at Lonmin Platinum has changed since 2001. A major new project was implemented in four different phases, ISO 14001 certification was achieved and work started on ISO 18001 certification. A new provisional registration certificate under which the Smelter has to operate was implemented (included new limits regarding particulate emissions) and an Air Quality Management Plan (AQMP) was designed.

6.3.1 New projects

Lonmin Platinum started in 1999 with the rebuilding of their Smelter in four different phases (Lonmin Platinum, 2003; Posnik, 2002):

a. Phase 1: Flash dryer;
b. Phase 2: Single, circular, large furnace;
c. Phase III – Third Converter; and
d. Phase IV – Sulphur Fixation Plant consisting of four main process units (Fig.6.2)
    1. Dust scrubbing,
    2. Sulphur dioxide scrubbing,
    3. Sodium regeneration, and
    4. Particulate and Sulphur dioxide handling.

The process differs from that described in Chapter 5 and Appendix D in that the existing tanker off loading facility at Lonmin Platinum deliver concentrate to an upgraded blending system where all the concentrates are mixed (Lonmin Platinum, 2001b). Two pressure filters remove excess moisture and the resultant cake is fed into a Flash drier (Lonmin Platinum, 2001b). The concentrate is stored and delivered pneumatically to the new Furnace (Lonmin Platinum, 2001b). Once the new Smelter is fully operational all the existing Furnaces and Drier plants will be decommissioned and retained as standby units on a care and maintenance basis (Lonmin Platinum, 2001b).

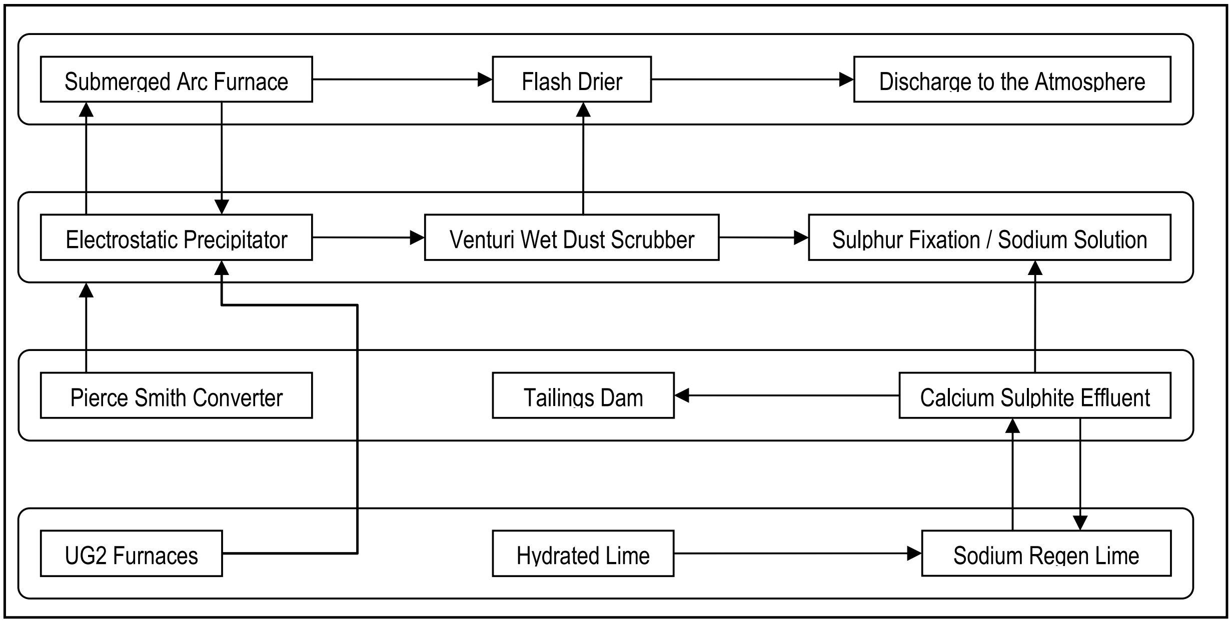


Figure 6.2 Sulphur Fixation Plant at Lonmin Platinum (Posnik, 2002)

The new Smelter process will assist the company to comply with the new permit requirements set by the APCO (see section 6.3.2) (Posnik, 2002). The commissioning of the new Smelter was planned to be completed by October 2001, but was delayed because of problems with the Furnaces in 2001 and 2002[3]. In 2003 all four phases of the Smelter was still not yet fully operational.

6.3.2 New permit requirements for Lonmin Platinum Smelter

The North West Department of Agriculture, Conservation and Environment (DACE), through the Air Pollution Control Officer (APCO), issued a new provisional registration certificate for Lonmin Platinum Smelter in December 2001 which was enforced from December 2002 (Fig.6.3)[3]. The provisional registration is valid for a year and requires the Smelter to comply with new, much lower SO_2 and particulate emission levels by the third quarter of 2003 (Lonmin Platinum, 2003).

Table 6.3: Provisional registration certificate for Lonmin Platinum Smelter (Posnik, 2002).

	Previous (until 2002)	Provisional (2002 –2003)	Future 2003 onwards
SO_2 to Stack	48 tons per day	56 tons per day 820 grams per second	6.5 tons per day
Dust to Stack	120mg.Nm^{-3}	120mg/Nm^3	50mg/Nm^3
S0$_2$ Ambient Monitoring	DEAT guidelines		
PM10 Dust: Ambient Monitoring	DEAT guidelines		

6.3.3 ISO 14001 certification and ISO 18001 certification

Lonmin Platinum's Smelter achieved ISO 14001 certification in October 2001 and was busy preparing for ISO 18001 certification in 2003[3]. The emphasis in ISO 18001 certification is on the integration of procedures - safety, health and environmental concerns of the Smelter will all be combined into one procedure that can be easily followed by everyone[3]. The process to integrate the Safety, Health and Environment departments in to one department started in 2002[3]. ISO certification ensures that all information is easy accessible and include[3]:

1. Aspect and impact identification,
2. Aspect register,
3. Planning of environmental projects (combined with the writing down of the procedures), and
4. Implementation.

Together with ISO certification, Lonmin Platinum is in the process of implementing the Occupational Health and Safety Administration System (OHSAS) – a SABS code similar to ISO 14001 that focuses on health and safety issues[3].

6.3.4 Air quality management plan

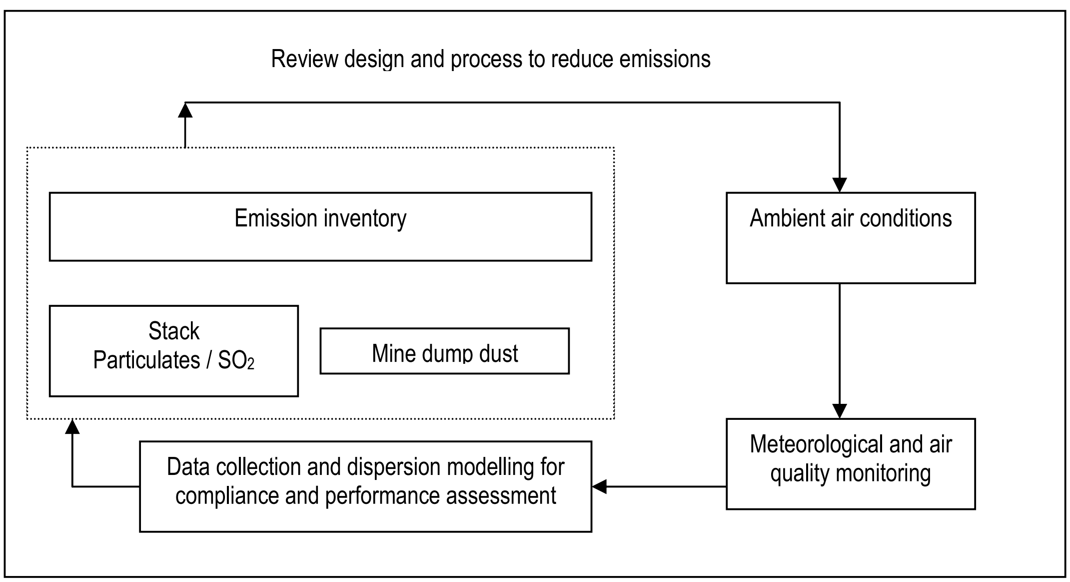


Figure 6.3: Components of the Lonmin Platinum air quality management strategy (Lonmin Platinum, 2002).

Lonmin Platinum has, similar to Anglo Platinum, initiated a process to design an Air Quality Management Plan (AQMP) for their Smelter operations (Fig. 6.3) (Lonmin Platinum, 2003). In 2002 components of the strategy were published and further developed during 2003 (Lonmin Platinum, 2002). The AQM plan contains the same basic elements as those of Anglo Platinum's AQM plan but not as much detail. Another difference is that the plan is just for the Smelter and not for all Lonmin Platinum's operations as is the case for Anglo Platinum.

6.4 Other role players in the Rustenburg region

The information included in Chapter 5 and Chapter 6 has focused on the contributions to particulate emissions and the management practices to control these emissions of the three Platinum Smelters in the Rustenburg region. Along with these mining companies, there are also three other important roleplayers in the region that affects the management of pollution in the region, namely the Air Pollution Control Officer (APCO), the Rustenburg Air Quality Forum (RAQF) and the North West Ecoforum (NWEF). These three important roleplayers will be discussed in the following section.

6.4.1 Air Pollution Control Officer (APCO)

The role and responsibilities of the Chief Air Pollution Control Officer (CAPCO) have already been described in Chapter 3. In the North West Province, where Rustenburg is situated, the role of CAPCO is slightly different. The Department of Agriculture, Conservation and Environment (DACE) appointed an Air Pollution Control Officer (APCO) specifically responsible for the North West Province in 2001[8]. The APCO has the delegated authority of the Minister (of the National Department of Environmental Affairs and Tourism) to enforce the Atmospheric Pollution Prevention Act in the Province, and very little power is still left with the national Department regarding the North West Province (RAQF, 2002a)[1,8]. As described in Chapter 3, the intention of the new National Environmental Management: Air Quality Bill is to delegate the responsibility regarding air quality management to the local level where it will fit in with the Integrated Development Planning (IDP) process[5]. For the purpose of this study it will mean that the Rustenburg Local Municipality will have an environmental department that will be responsible for managing the air pollution in the region (including mining activities, scheduled processes, vehicle emissions, boiler stacks and sporting activities)[5].

6.4.1.1 Air quality strategy for the North West province

Since APCO's appointment an ambient air quality objective for the North West provincial government was determined which states that the Province should have an ambient air quality complying with ambient air quality criteria for SO_2 and TSP/PM_{10} by 2005 (Posnik, 2002):

a. Industrial emissions, controls and management systems and/or budget provisions must be in place by 2003, and
b. The cumulative contribution from all industrial sources to the atmospheric pollution levels must be:

- Less than 70% of the guideline for 24h average
- Less than 30% of the guideline for annual average

The Provincial air quality strategy is based on the United States Air Quality Legislation as established by the Clean Air Act of 1970, and amendments (Fig. 6.4) and involves (Posnik, 2002):

1. Specifying air quality criteria and goals;
2. Devising and enforcing a set of emission control tactics to achieve the air quality criteria;
3. Quantification of emissions, emission rates and the way in which pollutants are being emitted;
4. Compilation of an inventory of source emissions;
5. Monitoring of air pollution concentrations and meteorological conditions; and
6. Devising emission control tactics through air quality modelling.

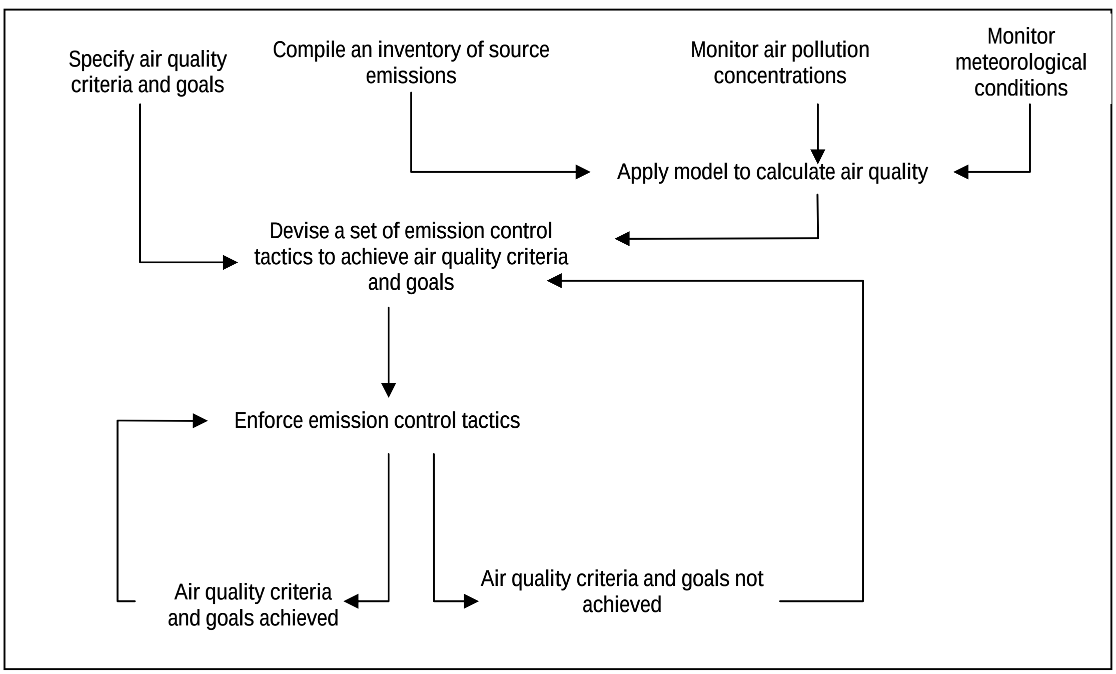


Figure 6.4: Air Quality Development Strategy (US Air Quality Legislation as established by the Clean Air Act of 1970, and amendments) (Posnik, 2002).

According to the APCO the above-mentioned objectives are achievable, although there are still areas of concern (*e.g.* dust from mine dumps) (Posnik, 2002). The provincial strategy has implications for industry and therefore industry needs its own co-objectives in order for the Province to reach its primary objective (Posnik, 2002).

6.4.1.2 Permit registration

The APCO is responsible for issuing registration permits to Scheduled processes (*e.g.* Platinum Smelters) as described in Chapter 3. The new provisional registration permits issued to Lonmin Platinum and Anglo Platinum is regarded as the first step in the system for the future (Posnik, 2002). The process for the provisional registration includes (Posnik, 2002):

1. Measuring,
2. Stringent guidelines,
3. Anticipated air quality standards, and
4. Specific requirements in the certificate.

6.4.2 Rustenburg Air Quality Forum (RAQF)

At the end of the 1990's and beginning of 2000's industries in the Rustenburg area came increasingly under pressure from the public to assess and manage air pollution in a transparent and co-ordinated manner (Pulles *et al*., 2001). Together with industry's acknowledgement of the cumulative impact arising from the wide variety of pollution sources, changing legislation that is increasingly holding polluters accountable for their actions, and the absence of clear-cut factual information with which to make regional assessments of air quality led to the formation of the Section 21 company, the Rustenburg Air Quality Forum (RAQF) in October 1999 (Pulles *et al*., 2001). The RAQF was requested and initiated by the Chief Air Pollution Control Officer of the Department of Environmental Affairs And Tourism and was founded by the Platinum (Anglo Platinum, Impala Platinum, Lonmin Platinum) and Chrome industries (Xstrata) and the Senior Air Pollution Control Officer responsible for the Rustenburg region at that stage (Pulles *et al*., 2001). The RAQF cannot replace the government function; it was formed to assist government with the monitoring and reporting function (RAQF, 2002b).

At the launch of the RAQF the objective was to involve all the major industries and, in a common forum (Anglo Platinum, 2001b; Pulles *et al*., 2001):

a. Assess the emission inventory from all industrial and non-industrial sources (phase 1),
b. Monitor the air quality of the receiving environment (phase 2),
c. Determine the carrying capacity of the receiving environment,
d. Develop the air management strategies for the Rustenburg area,
e. Liase with the public in the Rustenburg area on the aforementioned issues, and
f. Issue the monitoring results of the different companies in a single report, on a regular basis for the benefit of the community of Rustenburg. The public would then have information regarding the

air quality, as measured at these various stations to compare it with ambient air quality guidelines that were applicable in South Africa. The results would be available for interpretation or use for whoever was interested in such data. The first two phases of the objectives have been executed and are discussed below.

6.4.2.1 Phase 1

Through an analysis of other such bodies in the country it is apparent that the absence of a solid foundation of information can lead to inefficient use of funding, inappropriate monitoring and criteria establishment, and ineffectual air quality management (Pulles *et al*., 2001). Therefore, an initial baseline assessment study by an independent consulting firm was commissioned (published in April 2001) with the objective to (Pulles *et al*., 2001):

a. Compile a comprehensive data inventory of all identifiable point, diffuse and mobile sources of air pollution. These sources are to include industrial emissions, emissions from other human activities such as the burning of domestic fuels, and vehicle fuel combustion;
b. Identify the manner in which pollutants are discharged into the atmosphere (for example, the height, locality, and concentration of emissions);
c. Identify the conditions/reasons leading to the generation of air pollution by various sources, and the frequency of occurrence of these. This was mainly aimed at specific industrial processes, which have varying operational scenarios that lead to varying rates of air pollutant emissions;
d. Identify specific pollutants of concern;
e. Identify data sources of meteorological and air quality data;
f. Identify sensitive areas such as population groups and agriculture, their location and other data relating to these, which may be of future use; and
g. Develop a cost-allocation procedure for the corporate founder members of the RAQF such that the costs of funding the activities of the RAQF can be divided according to their relative air quality impacts.

The findings of the baseline study were designed as the platform from which the second phase of the study was initiated in 2002 (Pulles *et al*., 2001), but the objectives of phase one were not properly executed and the study lacked any real substance. More questions than answers followed the publication of the study.

6.4.2.2 Phase two

The report published following phase 2, defined the objectives of the phase as determining the state of emissions in the RAQF study area (Burger *et. al.*, 2002). All sources that significantly contribute to the air quality in the region were included in a database; the source parameters were determined as accurately as possible, however various degrees of success were obtained in this goal (Burger *et. al.*, 2002). The following aspects were examined (Burger *et. al.*, 2002):

a. The study area and land use;
b. Source inventory:
   1. Overview of sources, and
   2. Point, area and volume sources; small, other sources.
c. Pollutant identification;
d. Emission, meteorology and ambient air quality data inventory;
e. Results, namely:
   1. Impact assessment,
   2. Cost allocation procedure,
   3. Detailed source inventory,
   4. Analysis of the network,
   5. Monitoring requirements,
   6. Monitoring deficiencies,
   7. Data capture and communication, and
   8. Budget cost.
f. Conclusions and recommendations.

By 2002 the RAQF had been in existence for three years and no real progress was made regarding the original objectives as stated above. A strategic workshop was organised during which the structure and function of the RAQF was discussed (RAQF, 2002b). It was decided that the district municipality (Bojanala Platinum District Municipality) as well as affected communities surrounding Rustenburg and the National Union of Mine Workers (NUM) must be represented on the RAQF (RAQF, 2002b). The RAQF further approached the National Department of Environmental Affairs and Tourism (DEAT) for guidance regarding the future role of the RAQF (RAQF, 2002a). The APCO for North West province and the North West Ecoforum (see 6.4.3) was requested to reconsider their inactive participation in the structure and activities of the Forum[1]. The non-participation of these two entities was of great concern for the RAQF since it would affect their credibility as an organization reporting on the monitoring results of the various stations operated by them (RAQF, 2002a). The involvement of Non-Governmental Organizations (NGO's) in decision-making was seen as an integral component for the success of the RAQF (Pulles *et al*., 2001). The possibility of instituting an awareness campaign to inform the public about the work of the RAQF was investigated (RAQF, 2002b). By September 2003 no further progress was made and still not many of the original objectives had been achieved.

The last important role player in the region is the North West Ecoforum, which represents the public in the region.

6.4.3 North West Ecoforum (NWEF)

The North West Ecoforum (NWEF) is a Non-Profit Organisation founded in March 2000 by a group of concerned citizens in response to all the new mining developments in the Rustenburg region[1]. Branches are found in different parts of the province, but most of the activities are still in the Rustenburg region because of the environmental stress caused by the Platinum industry[1]. The objective of the NWEF is to aid in the creation of a healthier environment for all inhabitants of the North West Province, thus enabling a better quality of life and is achieved through[1]:

a. Attending Meetings: meetings regarding Environmental Impact Assessments and Environmental Management Programme Reports and Amendments are attended to ensure that the general public's interest are taken into account;
b. Scrutinising documentation relating to the above;
c. Giving inputs into the above processes;
d. Acting on complaints from the public, ensuring that government officials perform their duties correctly;
e. Continuously monitoring environmental compliance of industries in the area; and
f. Educating the public as to their environmental rights.

The North West Ecoforum has been involved in most of the environmental assessment processes related to expansions of current mining operations in the Rustenburg region[1]. The NWEF has been described as the most important key stakeholder in the region by the mines as well as a public participation consultant working in the region; their presence have led to a deeper discussion of the environmental problems currently experienced in the area, as well as a better understanding of the holistic environmental picture[10]. They have further managed to force the developer to improve the whole process regarding project implementation[10]. The influence of the NWEF has created extra costs on behalf of the developer but has also lead to more environmentally suitable projects[3].

Chapter 7

Review and synthesis of airborne particulate pollution management at Platinum Smelters in the Rustenburg region, North West Province

7.1. Introduction

In the previous two Chapters (Chapter 5 and Chapter 6) the contributors to particulate pollution in the Platinum industry (Anglo Platinum, Impala Platinum and Lonmin Platinum) have been described in detail. Other important roleplayers in the region (Chapter 6: section 6.4) as well as the management practices in use by the different roleplayers to control and minimise particulate pollution are described. Chapter 7 focuses on reviewing the information under a number of different focus areas, which include policies, formal procedures, technology used (old and new) and management practices. All this information will then be used to devise a regional management plan regarding particulate pollution in Chapter 8.

7.2. Safety, Health and Environmental Policy (SHE Policy)

Good management often starts with comprehensive policies. The policy that is relevant for this study is the Safety, Health and Environmental (SHE) Policy. All three mines have a SHE policy that recognises and acknowledges the impact that mining activities have on the environment (Chapter 5 and Appendix G). All three mines accept their responsibility and commit themselves to conduct business in a manner that is not detrimental to the environment. Similarities between the SHE policies of the three mines include:

a. A commitment to comply with guidelines and regulations;
b. Pollution must be prevented through planning, design of instrumentation and use of best practices;
c. The impacts of activities on the workers and environment should be minimised;
d. Education and training about environmental matters must be offered to workers;
e. All stipulated regulations apply to contractors;
f. Good relations and communication should exist with the public and surrounding communities; and
g. Environmental impacts are to be monitored.

The length and the detail of the policies vary. The policy of Anglo Platinum is the longest and most detailed. Only the policy of Lonmin Platinum makes reference to the use of environmental management systems and the handling of specific environmental problems (*e.g.* rehabilitation of slag dump). The issues included in the different policies will be discussed in this Chapter and the differences between company policy and practice will be reviewed. It is important that the mining companies not only make commitments in public to comply with legislation and policies, but employ the management plans (at ground level) to back up these commitments made (by head office).

7.3. Air quality management in the Environmental Management Programme Report (EMPR)

One of the most important public documents where the SHE policy can be tested is in the Environmental Management Programme Report (EMPR) written for the Smelter operations. Chapter 6 of an EMPR is legally binding and should include management plans regarding air pollution control for the entire lifespan of the mine (commissioning phase to decommissioning phase). A problem that is evident in all three the Smelter EMPRs is that few management plans are included that focus specifically on particulate emission control and the mitigation plans that are included are very general in nature (Pulles *et al.*, 2000: 9):

"The cumulative impact of all emission sources in the Rustenburg area on air quality has not been determined. Studies are underway, in co-operation with other industries in the area, to enable a comprehensive assessment of air quality in relation to pollution sources. Until such time as this study has been completed, it will not be possible to determine whether the Smelter emissions will be adequately curtailed through the expansion project. However, the management of impacts on air quality through continuous monitoring of emissions, weather conditions, and air quality in the area surrounding the Smelter will aid to ensure that air quality impacts are controlled to acceptable levels".

Information included in the above-mentioned paragraph are very vague and requires specification, for instance:

a. What are acceptable levels: according to South African legislation, international legislation?
b. For who are the levels acceptable: *e.g.* surrounding communities, workers in the Smelter, the environment?
c. "*continuous monitoring*": no indication is given of the monitoring frequency, locations, methodology, the ambient weather conditions, or the manner in which the information is to be processed.

More detailed information (*e.g.* Air Quality Management Plan) must be included in a Smelter EMPR to ensure that proper management plans are in place to control particulate emissions throughout the lifespan of the Smelter.

7.4. Formal procedures for management of particulate emissions

Management plans and procedures regarding particulate pollution identified in the EMPR then need to be further explained in detail in a number of procedures. These procedures need to cover all aspects of particulate emission control (*e.g.* the technology used, maintenance, operation under normal conditions, operation under upset conditions) and be in print. It is also important that the procedures must be made available to all Smelter employees (easy accessible) and updated on a regular basis. The best example is found at Lonmin Platinum where all the procedures are published internally in the company and updated on a regular basis. The ISO 14001 standard that has been implemented at Lonmin Platinum has promoted easy access to information within the company. While Anglo Platinum has formal procedures, they are not made available to the employees. Procedures used by Impala Platinum are not all written down or made available to Smelter employees. Investigations conducted for this study indicated that basic information about management practices was missing, difficult to access and not always easy understandable.

7.5. Permit requirements

South African legislation is an important aspect that will determine the management practices in place to control particulate emissions. For the Smelters the stipulations included in the registration certificates must be an important guideline as to how the pollution should be managed.

The original Permit requirements for the three Smelters is very difficult to compare since it do not contain similar information:

a. Anglo Platinum: limits are given for emissions from the Drier stack (50 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa) and Furnaces (50 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa);
b. Impala Platinum: a limit is given for emissions from the Drier stack (120 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa); and
c. Lonmin Platinum: limits are given for emissions from the Drier stack (50 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa) and Main stack (120 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa).

New provisional registration certificates were issued for Main stack emissions for Anglo Platinum (120 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa) as well as Lonmin Platinum (50 $mg.m^{-3}$ measured at $0^{\circ}C$ and 101.3 kPa) in 2002. These provisional certificates will only become permanent if all the stipulations are met. It is, therefore, important that all the new projects initiated by the Smelters (described in Chapter 6) are commissioned successfully and operational as soon as possible in order to meet the new more stringent limits.

7.6 Structure of environmental departments / relationships with other departments

The Environmental departments of the three Smelters have a significant part to play in the successful management of particulate emissions. These departments need to ensure that Smelter management are aware of all the environmental regulations and that these stipulations are enforced. All three Environmental departments have staff specifically responsible for air quality management and are supported by workers in the Smelter who have to report on environmental matters. Unfortunately, these workers do not always have the necessary qualifications or time to adequately fulfil these duties. For all three Smelters, it would be beneficial to appoint additional (properly qualified) environmental department employees to focus on air pollution management because of the seriousness of the problem. A shortage of staff was found to be a problem at all three industries.

The structure of the Anglo Platinum regional Environmental department has changed significantly with more personnel being responsible for air quality management since 2002 than before. The regional Environmental department work closely together with the Occupational Hygienists, but there is still room for improvement in the relationship (*r.e.* availability of information, co-ordination of efforts).

The Environmental department of Impala Platinum is smaller with only one person (environmental manager) responsible for the air quality management of all the operations (Smelter included). There is no one in the department that is solely responsible for air quality management of the Smelter. Closer co-operation with the ventilation department (responsible for gravimetric sampling) is needed, in order to ensure that problems are sorted out quickly and efficiently.

Lonmin Platinum has an Environmental department specifically responsible for the Smelter. The department is small and it is suggested that this department be expanded and work closer together with the Central Services Environmental department (responsible for gravimetric sampling).

7.7 Changes in technology used to control particulate emissions

The technology used to control particulate emissions (Anglo Platinum: ceramic candles, Impala Platinum and Lonmin Platinum: electrostatic precipitators) has been ineffective and outdated for a period of time, mainly because of the increasing volume of ore sent to the Smelters (described in Chapter 4: section 4.4) as well as equipment breakages. All three Smelters were built during the late 1960's and early 1970's with little modification of the pollution control equipment.

Since 2002, new technologies have been implemented by all three Smelters to minimise the particulates emitted (described in Chapter 6). Considerable amounts of time, money and research were invested in these projects, with environmental considerations taken into account from the planning stages of the projects. The projects commissioned by all three Smelters will, if successful, have a positive effect on reducing the amounts of particulates emitted in the region. All three projects are long-term developments, implemented in stages, with the results only visible a few years after their commissioning. Therefore, no definite conclusion about the success or failure of the technology could be made by the end of this study; two reasons being the problems experienced with measuring equipment (described in section 7.10) and the commissioning of the projects (longer than expected).

7.8. Additional control measures / management practices

All three Smelters have management procedures in place that focus specifically on particulate emission control. Lonmin Platinum's management procedures as well as those implemented by Anglo Platinum appear to be well developed while those available for Impala Platinum are not well developed at all.

In addition, all three Platinum Smelters have developed measures to help control particulate emissions from the Smelter area and minimise the impact on workers. Measures that have been implemented by all three Smelters included pneumatic transfer of ore throughout the Smelters, cemented areas and the use of a vacuum cleaning system to minimise the amount of particulates lying around.

Anglo Platinum and Lonmin Platinum have defined zones in the Smelter where respirators must be worn and the amount of time spent by workers in these areas is restricted. Automated shutdowns of parts of the Smelter when emissions reach a certain level is an option implemented with various success at the different Smelters. Anglo Platinum has only implemented it in the ACP section for SO_2 emissions while Impala Platinum has implemented it in the Spray dryers.

Despite these control measures, particulate emissions still seem to be very high. There is an apparent problem between the management practices designed and the implementation thereof.

7.9. Contingency plans

Contingency plans are as important as the changes in technology implemented, but were found to be deficient for all three Smelters. An example of where contingency plans were necessary, was when the electrostatic precipitator of Lonmin Platinum's Smelter exploded in May 2002[3]. The cause of the explosion was not immediately known and the electrostatic precipitator was beyond repair and had to be bypassed[3]. To replace the electrostatic precipitator could have taken up to a year[3], during which time all particulate emissions would have to be vented through the Main stack because no contingency plans were in place. A temporary baghouse was installed (June 2002) and the rebuilt precipitator was online by August 2002, but for 13 weeks all particulates were vented into the atmosphere (Lonmin Platinum, 2003). Another example of insufficient contingency measures can be found in the failure of ceramic candles installed by Anglo Platinum. The effectiveness of the control measures dropped to 75% for a period of 9 months (Anglo Platinum, 2002a). Despite all the research done and money spent, particulates were still vented in large quantities through the Main stack[5]. No contingency plans were in place that could help to reduce the particulate emissions and keep it within reasonable limits.

7.10. Monitoring particulate emissions

The monitoring of particulate emissions consists of two parts, namely monitoring inside the Smelter and monitoring of fugitive emissions (ambient monitoring).

All three Smelters measure emissions inside the Smelters in the same areas (*e.g.* Drier stacks, Main stack), because of reporting requirements set by the Air Pollution Control Officer for North West province (APCO). Not all three mines are equally successful in their measuring programmes. Anglo Platinum has the most comprehensive monitoring programme that covers all the different areas inside the Smelter. Although measurements are not undertaken on a monthly basis in all the regions, more data are available for Anglo Platinum than any of the other two Smelters. Some problems have been experienced with measuring equipment failure. It is not possible to review the monitoring programme of Impala Platinum since no data were made available for the purpose of this study. Pulles *et al.* (2000: 5.10) states, "*the Smelter Plant has significant emissions of sulphur dioxide. However, particulate emissions are low and well within guideline emission specifications for the processes giving rise to them.*" This claim cannot be substantiated because of the lack of data. Impala Platinum further claims that the people working in the Smelter will notice when emissions are over the limit[2]. This requires that people have to observe emissions on top of their usual workload. The argument is that it can be visually noticed when emissions are more than 50µg.m^{-3},[2] but the question that requires answering is whether it is possible to discern specific levels with the naked eye. Lonmin Platinum Smelter is the only one measuring emissions inside the Smelter as well as around the perimeter of the Smelter area. Problems with the measuring equipment have however lead to not much data being available for long periods from the different sections of the Smelter.

For monitoring to be effective, measuring equipment needs to be working continuously and calibrated correctly (Lonmin Platinum, 2003). In 2003 the APCO still did not regard the monitoring equipment as effective and the data as reliable (Lonmin Platinum, 2003). All measuring instrumentation and control equipment are manufactured and tested oversees under different circumstances[5]. In case of breakages, the instrumentation has to be sent back for repairs, which can take a very long time[5].

Another part of monitoring implemented by all three Smelters is visual monitoring where cameras are focused on the Main stack. This type of monitoring can be very useful, but needs further development and refinement in the case of all three Smelters.

Ambient monitoring in the Rustenburg region is still problematic. All three Platinum mines in the region regard monitoring as important, and conduct ambient particulate monitoring. The same pattern is followed as in the case of the monitoring inside the Smelters (most data available for Anglo Platinum and Lonmin Platinum, no data available for Impala Platinum). A problem that still needs to be resolved is whether it is possible to assign all emissions measured at a particular station to a specific Smelter. The data only show the measurement at a specific point at a specific time, it cannot be viewed as representative of the whole region or even a position a few metres away. A regional approach to monitoring is therefore needed (described in Chapter 8: section 8.3.4).

7.11. Gravimetric sampling

Particulate emissions in the Smelter area directly affect workers in the Smelter and are measured through gravimetric sampling (measurement of particulate emissions workers are exposed to during an 8-hour shift). The Department of Minerals and Energy (DME) has set out guidelines prescribing how gravimetric sampling should be conducted. All three mines applied these guidelines within the context of their specific situation with varying success. Not one of the Smelters had extensive data available for the purpose of this study, and the quality of the data was not sufficient. Anglo Platinum as well as Lonmin Platinum conducted fingerprint studies but it does not appear that these studies will be repeated in future or that the results are taken seriously. A new system has been implemented by all three Smelters (as designed by the DME) since 2002, which possibly will lead to more consistency and an improvement in the quality of data available.

As described in section 7.6 there is little co-operation (interaction) between the departments responsible for gravimetric sampling and environmental management, despite the two issues being closely related. The process appears to be very fragmented with separate departments having to take responsibility for issues closely related. The decision-making process becomes protracted.

7.12. Maintenance

It is important to conduct maintenance of the emission control equipment as well as the monitoring equipment. Regular maintenance undertaken properly can help to minimise problems before they become unmanageable. All three Smelters spent time and money on maintenance and regard it as important. Associated with maintenance is Isokinetic sampling, which ensures that correct measurements are taken.

Anglo Platinum contracts an independent company to conduct Isokinetic sampling on a regular basis. Maintenance is undertaken on the ceramic candles, computerised recording system and monitoring instrumentation. Impala Platinum conducts Isokinetic sampling on a monthly basis, but makes use of their own instrumentation. Once a year, an independent company is contracted to do the sampling. Maintenance on the electrostatic precipitators is also done on a regular basis, and because three precipitators are used simultaneously, there is little loss in efficiency. Lonmin Platinum has an extensive maintenance programme with very specific regulations that must be followed by employees as well as contractors. All particulate control instrumentation is included in the programme (*i.e.* dust catchers, baghouses and the electrostatic precipitator). A negative aspect is that no Isokinetic sampling is conducted. Although maintenance is done on a regular basis and is given high priority, major incidents, which lead to long downtimes, still occur at all three mines.

7.13. Quality and availability (accessibility) of data

The quality of the data regarding particulate emissions from the Smelters is an important consideration, because it is presumably used when making decisions worth millions of Rand about what instrumentation and control measures should be used and what management practices should be followed. In addition, the data are used for modelling purposes, which also helps with planning for future expansions and positioning of monitoring stations. The data are further reported to the APCO for North West province on a monthly basis and will influence under the new Air Quality Bill if the provisional registration certificate (which is needed to operate) becomes a permanent registration certificate. It is therefore essential that up-to-date information of a good quality is available.

With the quality and amount of data that were available at the end of this study, none of the above-mentioned options is possible. Some of the general problems experienced by all three Smelters include:

a. Problems with faulty measuring equipment, instrumentation (*e.g.* computers recording the data);
b. A time delay (weeks and sometimes months) before data are verified, analysed and available;
c. Co-ordination of information (*e.g.* lack of co-operation between environmental department and occupational hygienist leads to problems with gravimetric sampling);
d. Different types of information is available from each of the mines; and

e. Different measurements are done using different units over different periods of time (*e.g.* particulate emissions are measure in $tonnes.month^{-1}$, but are reported to the APCO in $mg.Nm^{-3}$).

A result of the above, is that it is very difficult to compare information from the three Smelters. Most often calculations are needed before comparisons can be made and sometimes the information differs just too much to draw any real conclusions.

7.14 Reporting

Reporting of information is a natural follow-up to measuring and monitoring of particulate emissions emitted. The reporting conducted by the three Platinum Smelters can be divided into three sections, namely:

a. Internal reporting to Smelter management,
b. External reporting to the APCO of North West, and
c. External reporting to the public and shareholders.

Anglo Platinum and Lonmin Platinum report internally on a monthly and yearly basis while Impala Platinum's internal reporting includes daily, monthly and yearly reports. All three mines have structures in place for internal reporting as well as for meeting the reporting requirements set by the APCO of North West province. The environmental departments of all three mines compile month-end reports, which include necessary information for internal reporting as well as satisfy the requirements of the APCO. Procedures exist to record environmental incidents and complaints and are reported internally and to the APCO.

Reporting to the public has been a problem, because little emphasis has been placed on ensuring that the interested public and more importantly, the public affected by the activities of the Smelters are properly informed. The perception created by the mines was that they are afraid of making too much information known to the public, as it would lead to more confrontation[10]. The public has also expressed doubts about whether the data made public reflect the true situation at the Smelters[10]. Through legislation, the mines were forced to interact more with the public (public participation meetings) and relationships started to improve. From 2000 onwards the situation started to change with more reporting to the public through local newspaper articles as well as community liaison meetings (by Anglo Platinum). All three Smelters have installed "hotlines" where the public can report environmental problems.

7.15. Training

To ensure that all employees working in a Smelter are aware of the importance of environmental management in general as well as environmental matters important for their specific job and what the consequences is thereof, training is required. Although the respective mines handle training slightly differently, the outcome has been similar: basic training is provided regarding environmental matters, but no real effort is made to ensure that Smelter employees understand the importance of environmental regulations that are enforced in the Smelter. The result is that there is not always the required urgency on the part of workers to report environmentally related problems because they do not understand that it is important. Training conducted by the three Smelters can be summed up as follows:

a. Anglo Platinum: an external company is responsible for training[5]. A training programme specific for the Smelter exists[5]. Environmental matters are included in induction training[5].
b. Impala Platinum: The training department is responsible for training[2]. In induction training, basic information about environmental issues is supplied[2]. Competency training is also done (job specific)[2]. Every time an upgrade is completed employees working in that area are re-trained[2].
c. Lonmin Platinum: The training department conducts training with basic environmental matters being included in the Safety, Health and Environment (SHE) induction[3]. For workers working in the Smelter itself, more specific training is given[3]. Re-training is also done every time there is a change in any of the procedures or instrumentation[3].

7.16. Closing

The topics discussed in Chapter 7 are examined further in Chapter 8 in which a regional management plan for the three Platinum Smelters is described. This regional plan forms the main focus of the study. Problems highlighted in Chapter 7 are discussed further with possible solutions given to the problem areas. Given the complexities of managing pollution in the Rustenburg area a plan is required that can be implemented inside a particular Smelter, while at the same time being beneficial to the region as a whole.

Chapter 8

Rustenburg regional air quality management plan

8.1 Introduction

Given the poor management of particulate air pollution (described in Chapter 7) that apparently extends into other forms of emissions (Chapter 1: section 1.1), a management plan for the control of air quality in the Rustenburg region was developed. The plan, called the Rustenburg Regional Air Quality Management Plan (RAQMP) was developed to manage particulate emissions from the three Platinum smelters and is described below. The RAQMP contains crucial elements of the management plans described in Chapter 2, but was further expanded to take into account the unique situation of the Rustenburg region as described in Chapter 4, 5 and 6 as well as the problems and positive aspects described in Chapter 7 to ensure that the plan will be suitable for use by the three Platinum mines. Protecting the environment and human health requires action at all levels, from broad policy development to local community initiatives (Green *et al*., 2000). As there is no single solution to complex environmental and health problems, there is an increasing need to develop integrated approaches that pool information, expertise and common resources to address environmental and health priorities (Green *et al*., 2000), an approach that is greatly needed to improve the pollution problems experienced in the Rustenburg region. The RAQMP contains theoretical knowledge as well as practical solutions to problems experienced inside all three the Smelters and for the region as a whole. The Plan focuses on the implementation phase of the Smelters, but can be expanded to include the construction and decommissioning phases if needed. The RAQMP plan consists of 12 sections and a summary is found in Figure 8.1, after which each section is described in detail.

8.2. Summary: Rustenburg Air Quality Management Plan

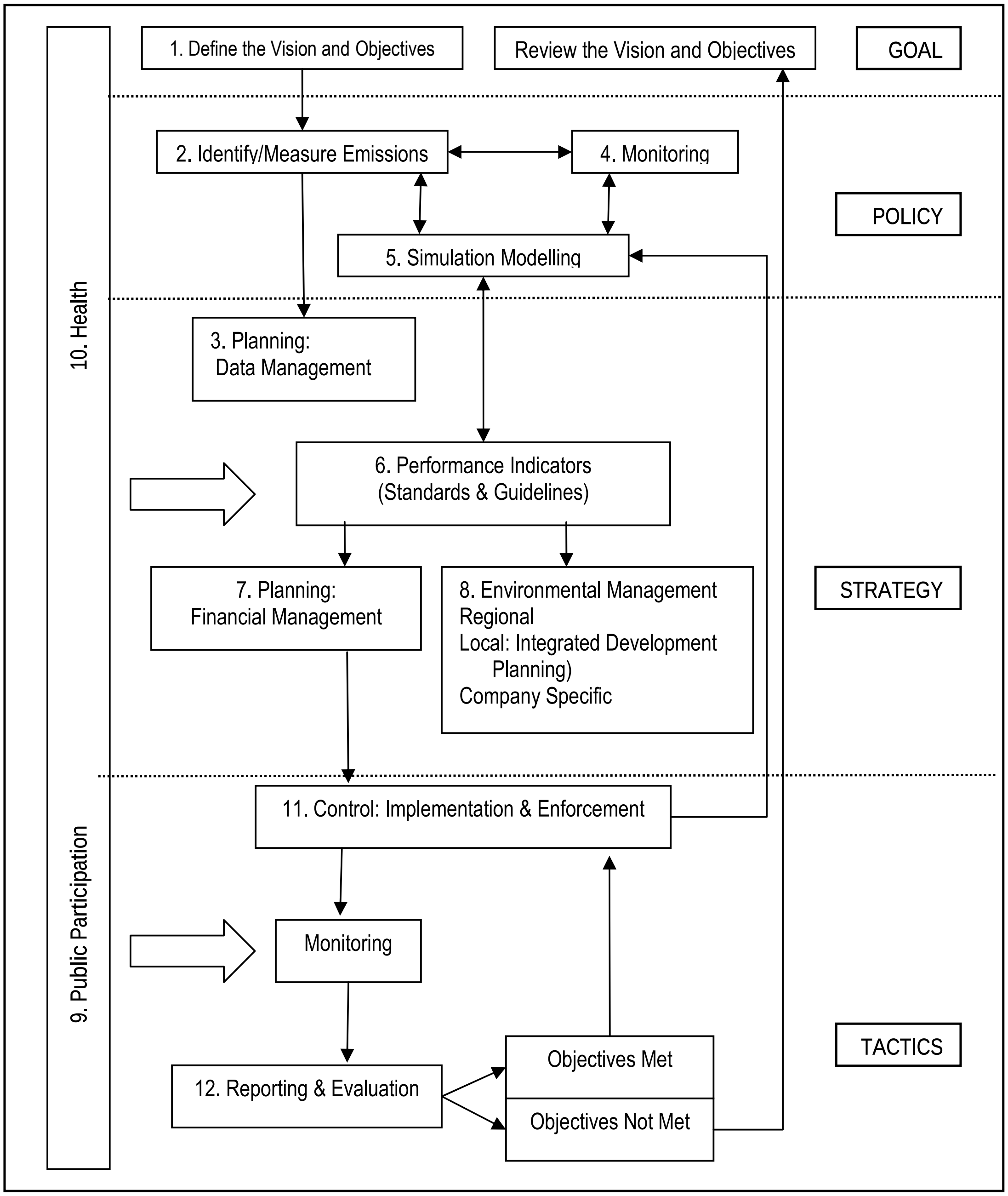


Figure 8.1: Summarised Rustenburg Regional Air Quality Management Plan.

8.3. Discussion of the Rustenburg Air Quality Management Plan (RAQMP)

Longhurst *et al.* (1996) states that a crucial component of any management plan is to identify clear goals. The first section of the RAQMP therefore focuses on defining a vision for the region regarding particulate pollution management as well as setting objectives that need to be met for the plan to be successful.

8.3.1. Goal: defining vision and objectives

The goals set for air quality management will mainly develop from the requirement to attain or maintain air quality standards and must be held throughout the various national, regional, and local sectors to help avoid the problems of conflicting policy development (Longhurst *et al.*, 1996). Furthermore, an AQMP must be an agreed procedure by which air quality goals are progressively, in the long term, achieved across a specified time period with specific responsibilities assigned (Scorgie, 2001b; Longhurst *et al.*, 1996).

For Rustenburg an initial review of the air quality is needed. The review should include economic, social and environmental impacts of air pollution as well as what information is available (*e.g.* research studies already conducted, Smelter EMPRs, available data, air quality control measures in place, management practices in place as well as the general state of the air). There is a feeling that sources (*e.g.* tailings dams, blasting and stockpiling) other than Scheduled processes (*e.g.* Smelters) are responsible for a significant part of particulate pollution in the region and this should be examined to determine the significance of these sources. Through the initial review the vision and initial goal for the region should become clearer. In the case of Rustenburg an initial goal would be to define and then create a quality of air that protects human health and welfare, without constricting development.

The objectives through which the initial goal can be reached, include:

a. Identify every role player (Chapter 4: section 4.4) and assign legal responsibility. Comprehensive consulting with all the role players must take place to ensure agreement on what the group of concerns in the region is and how it should be handled. A common goal ("*shared vision*") needs to be found;
b. Detailed quantification of air pollutant levels must be undertaken;
c. The Air Pollution Control Officer (APCO) in co-operation with the other roleplayers must determine initial legally binding standards regarding ambient concentrations specific for the region in accordance with international (and national) guidelines and standards. Determine the emission levels that can be permitted within the region, taking into consideration the current (and future) developments. The levels can be reviewed later (refer to 8.3.6) when the RAQMP is fully working and emission limits are achieved;
d. Identify initial emission quantities specific to every mine (taking into consideration the specific circumstances of the mine); and
e. Ensure effective operation of control measures in use (further described in Appendix H).

Defining the goal and objectives of the RAQMP is crucial to the success of the plan since it will form the basis for the rest of the plan. Once the initial goal is achieved, the quality of air should be maintained through the proper and effective implementation of the RAQMP.

8.3.2. Emissions inventory (identify / measure emissions)

Once the goal and objectives of the RAQMP are defined, it is necessary to establish an emission inventory, which requires the identification and quantification of all established sources of emissions (major industrial sources) (WHO, 2000). Without proper data, effective air quality management would be difficult and may lead to inappropriate or over-regulated emission control which is not in the interests of the general public or the industries subjected to control (Pulles *et al.*, 2001; WHO, 2000). An inventory procedure must be designed so that the greatest advantage is drawn from the data collected and that the data collected are of sufficient quality to meet the diverse needs of the interested user communities (Demerjian, 2000). Estimates of emissions can be used to develop emission inventories, but comprehensive, accurate and current measurements, on a continuous basis are necessary, to confirm the reliability of the estimate (WHO, 2000). The absence of information though, should not prevent the development of preliminary emissions estimates (WHO, 2000). The uses of an emission inventory include (Scorgie, 2001a):

a. Enforcement,
b. Emission reduction strategy development,
c. Land use planning,
d. Air quality modelling,
e. Identification of pollutants of concern,
f. Future emission projections, and
g. The provision of a basis for the planning of an ambient monitoring network.

It is unlikely that actual emission data will be available all the time, therefore, emissions from point and mobile sources must be estimated using a range of primary and secondary data sources (including general emission factors for point and diffuse sources) (WHO, 2000; Longhurst *et al.*, 1996). An AQMP will need to consider the range of sources at the local, regional, and national level that contribute to air pollution in a local area (Longhurst *et al.*, 1996). In addition to the more regular general quantification of emissions, spatially disaggregated emission estimations should periodically be made to identify particular problem areas for which specific policies can be developed (WHO, 2000; Longhurst *et al.*, 1996). Methods of emission inventories include (Scorgie, 2001a):

a. Gross estimation: this may primarily be a desktop study for a large geographical area where summary data could be used,
b. Rapid survey: field data should be collected from major point sources (sources contacted by questionnaire or telephone), and
c. Comprehensive emissions inventory: all “significant” point, area and line sources must be taken into account.

Distributing data by submitting it to a central archive that then serves as the vehicle for its dissemination has proved to be cumbersome and inefficient (Demerjian, 2000). The benefits of immediate open access to data through real-time processing and distribution are enormous; the process is technologically straightforward and has been demonstrated in meteorological networks around the world (Demerjian, 2000). Such a facility allows the accelerated identification of potential data quality problems, and the development of diagnostic tools and analysis approaches that will impact approaches to the air quality management process itself (Demerjian, 2000).

For the RAQMP, the establishment of an inventory will require three main steps:

a) *Identification and measuring of pollution levels*

- Identification of all particulate emission sources will require a comprehensive fingerprint study. Most of the sources have already been identified (*e.g.* roads, tailings dams, Smelters), but their contribution will have to be quantified. An emission audit can be used as a basis for the first stage of a process to provide information about the location and characteristics of pollutant sources. Used together with a map and local knowledge of the area the highest emission areas (air quality hotspots) can be identified.
- Proper, standardised measuring instrumentation (more than 99% availability of data) adaptable to local circumstances is needed. The equipment must be able to handle the particulate load in the Smelter and upgraded on a regular basis.

1. Proper placement of the instrumentation and measurement methodologies as follows:
    - Locations crucial to the monitoring of particulate emissions: inside the Smelter in the Drier stack, before the Main stack (measure furnace off-gas and converter off-gas), in the Main stack, and in the Acid Plant stack.
    - Monitoring around the perimeter of the Smelter to representatively measure particulate emissions (can include mobile stations, personal and small monitors).
    - Ambient monitoring must be done on a regional basis (See 8.3.4 and Table 8.2).
    - Gravimetric sampling according to guidelines set by Department of Minerals and Energy (DME, 2001).
    - Calibration standards should be set and instrumentation should be calibrated regularly with Isokinetic sampling conducted on a more regular basis.
    - For a start measuring should be done meticulously in all sections.

- All raw data must be kept for a period of one year and must be easy accessible.

b) *Data transfer to a database*

1. The recorded data from all three Smelters must be transferred to a single regional database (control room) via a computerised system that will conduct all the necessary calculations (*e.g.* $tonnes.month^{-1}$ to $mg.Nm^{-3}$). The data must be easy accessible and available for viewing at any

time. A person(s) should be responsible for all aspects relating to the data. The person will liase with each of the environmental departments which will be responsible to report all problems. The responsible person(s) must act as a link between the public, the mines, and the company responsible for the downloading of information (from the monitoring stations). The database must be updated on a daily basis and always contain the newest information, with detailed explanations included for problems. Reports that should be available:

- Internal: a daily report for use by all workers and responsible persons, and
- External: report to all interested and affected parties on a monthly basis.

2. The compilation on an emission inventory
   i. The emission inventory needs to be compiled with the help of a Geographic Information System (GIS). The inventory must contain certain standardised basic information for each identified pollution source that includes:
      - The quantity,
      - Percentage contribution (consider the range of sources that contribute emissions),
      - Height of emission,
      - Type of emission (point or mobile; point, area or volume),
      - Concentration of emissions over time,
      - Comparisons with previous time periods (*e.g.* day, month, year),
      - A set of standards that is built into the programme so that violations can be automatically identified,
      - The effects of the pollution (*e.g.* exposure and damage assessment, environmental and health risks),
      - The areas affected, and
      - A description of the types of measurements used.

c) Special circumstances for each individual mine must be taken into consideration and built into the process.

8.3.3. Planning: Data management

It is important that after the establishment of an emission inventory, the data are properly managed. Data management are one of the important aspects that have not received proper attention so far and have resulted in problems. Without proper data management it will not be possible to develop an RAQMP that will be of value for the region, because the situation cannot be assessed and therefore it would be difficult to make decisions. The data that are available must be incorporated in a proper structure to ensure that it can be utilised to the fullest. Recommendations about data management for the Rustenburg region have been made in section 8.3.2 and Table 8.1.

Table 8.1: Important sectors in data management (After Scorgie, 2001a).

Data quality objectives	Measurement accuracy and precision
	Traceability to metrology standards
	Temporal completeness
	Spatial representivity and coverage
	Consistency between sites and over time
	International comparability, harmonization
Data checks undertaken to flag erroneous data	Calculation of % data availability (missing data occurs due to power failure, instrument error, etc.)
	Time sequence trend analysis – identify outliers
	Stuck signal checks
	Specification of ranges for bearing measurements, ambient temperature
Data analysis and reporting	Calculation of period averages: facilities comparison with air quality guidelines and standards and dose-response thresholds
	Summary statistics of data set: including calculation of maximums, means, medians and standard deviations
	Frequency of occurrence of exceeding threshold values (guidelines, standards, dose-response thresholds, alarm thresholds)
	Frequency distributions (including cumulative frequency distribution plotting) and calculation of percentiles
	Time series analysis to identify temporal trends in concentrations: (e.g. diurnal, inter-annual)
	Overlaying of temporal trends for multiple pollutants: identify variations in ratios between different pollutants, useful for source identification purposes
	Isopleths plot generation through contouring of concentrations recorded at multiple stations: assess spatial variations
	Pollution rose generation: useful in determining likely location of sources in relation to monitoring sites
	Plotting of pollutant concentrations against meteorological parameters of importance in terms of atmospheric dispersion / stagnation and pollution removal potentials, e.g. atmospheric stability, wind speed, precipitation

8.3.4. Monitoring

Parallel to the establishment of the emission inventory a monitoring program needs to be devised. A monitoring program is often the most developed part of an AQMP with the longest history (Demerjian, 2000; Larssen, 1998 cited in Fenger *et al.*, 1998: 299). Monitoring emissions is necessary to assess the air quality and the impacts of policy implementation and mitigating strategies (Scorgie, 2001; Longhurst *et al.*, 1996; Boubel *et al.*, 1994). As part of the AQMP plan, monitoring aims and objectives should be defined prior to any sites being selected or equipment being procured (Scorgie, 2001; Sweeney *et al.*, 1997; Longhurst *et al.*, 1996).

The next important step would be the development of a monitoring network. The principal requirement of sampling is to obtain a sample representative of the atmosphere at a particular place and time that can be evaluated as a mass or volume concentration to determine (Sweeney *et al.*, 1997):

a. Compliance with guidelines,

b. Health impacts on people in built up areas, and

c. Where the highest concentration occur.

For the Rustenburg region it is important to remember that each of the mines participating in the study already has a monitoring network (described in Chapter 5), but that no coordinated network for the region exists. Because of the relative close proximity of the Smelters and all the particulate emissions in the region (*e.g.* Smelters, tailings dams, roads, background emissions, domestic coal burning), it is not always possible to assign results from a monitoring station to a specific mine. Therefore, it would be better to devise a combined monitoring strategy for the Rustenburg region. In order to achieve this, a common goal has to be defined over and above the interests of the individual mining companies. The RAQMP will need to determine the objective of the monitoring network, and according to that monitoring stations should be located. The existing monitoring provision of an AQMP needs to be evaluated in the light of the aims of the new plan and should not dictate the form of the plan although resource constraints may prohibit an enhanced level of monitoring (Longhurst *et al.*, 1996).

The following recommendations on where particulate pollution monitoring should be undertaken were made by a study conducted on behalf of the RAQF in 2002 (Burger *et. al.*, 2002):

a. On site at about 10m above ground,
b. On site at about 50m (depending on stack height) above ground,
c. Fence line monitoring, and
d. Ambient stations further away.

Multiple stations are required for the ambient monitoring due to the differences in meteorological conditions that occur even within a relatively short distance (Burger *et. al.*, 2002). The mountainous area bordering the study region will have significant local impacts on the wind direction and speeds that are not fixed and constantly varying (Burger *et. al.*, 2002). Even long term-averaged data may show changes, thus it would be impossible to predict a "best" site location for all weather conditions (Burger *et. al.*, 2002). With the above in mind, it must be determined if the existing stations adequately serve the monitoring requirements or if they should be moved to a new location (Burger *et. al.*, 2002).

The monitoring objectives applicable to Rustenburg include:

a. Determining the ambient air quality for compliance with air quality standards;
b. Evaluating the impact of a new air pollution source during the preconstruction phase;
c. Monitoring human exposure;
d. Researching atmospheric, chemical and physical processes;
e. Determining the maximum concentrations, background concentrations, and changes in air quality over time (start during preconstruction). Not everyone agrees that the natural PM_{10} concentration should be monitored and where the stations should be placed. There is a feeling that the air is already so saturated, it would not help to measure the natural conditions because it is not representative of the area; and

f. Determine air quality during maintenance, downtimes due to breakages, and other emergency situations.

Included in Table 8.2 are the different aspects that need to be examined when devising a new monitoring network and the sectors that need to be taken into account, such as how to establish the monitoring network, locations, cost, and other sectors.

Table 8.2: Different aspects that should be considered for management of a monitoring network for Rustenburg (Scorgie (2001); Demerjian (2000); Sweeney *et al.* (1997); Boubel *et al*. (1994)).

Establishment of a monitoring network	1. Monitoring objectives (project specific, mine specific, regional) determined by needs of data users	2. Available resources (Funds, manpower, existing Monitoring facilities)	3. Legal requirements (Local, regional, national, international)	4. Available technology (equipment, techniques)	5. Operational criteria (economic, social, legal, cost-effectiveness) Consider tradable pollution credits	6. Operational responsibility (Security, power supply)	7. Location, height, duration of release, amount of pollutant released
After the objectives of the study are defined, the following issues should be considered		1. Optimum number of monitoring sites	2. Standardise type of sampling methodology (Pollutant(s) to be measured; sampling duration; averaging period)		3. Standardise measurement requirements (Including visual monitoring)	4. Choice of representative locations	5. Network performance & assessment must be evaluated
Locations of individual sites	1. Must be situated in a generally open area		2. Samplers must not be mounted directly onto a surface		3. Each sampler must be uniquely identified and careful records maintained (effective screening of data to detect and correct equipment faults or other problems)		
Total cost of operating the instrument		1. The level and costs of after-sales support		2. Ease of operation	3. Reliability	4. Results of type approval	
Other factors to consider regarding the selection of infrastructural equipment			1. Auto-calibration devices	2. Sample manifold systems	3. Chart recorders	4. Provision of meteorological data	
Operation and maintenance program	1. Equipment and record system with equipment information, warranties, instruction manuals, etc.	2. Lubrication and cleaning schedules	3. Planning and scheduling of preventive maintenance	4. A storeroom and inventory system for spare parts and supplies	5. Listing of maintenance personnel	6. Costs and budgets for operation and maintenance	7. Storage of special tools and equipment
Important characteristics for all ambient air-sampling systems	1. Collection efficiency	2. Sample stability	3. Recovery	4. Minimal interference and an understanding of the mechanism of collection		5. Data produced are only as good as the QA/QC system employed	

8.3.5. Simulation modelling

Central to any AQMP is the ability to assess current and potential future air quality in order to enable informed policy decisions to be made (Longhurst *et al.*, 1996). Current emissions and monitoring data can be used to forecast future changes based upon a range of "what if?" scenarios (Longhurst *et al.*, 1996). Modelling has relatively high capital costs, requires technical staff, and must be updated on a regular basis (Longhurst *et al.*, 1996). Standardization of models and other guidelines issued is important to ensure accuracy and comparability of model outputs in relation to an AQMP (Longhurst *et al.*, 1996). In the plan developed for Rustenburg, the following are considered to be important:

a. A consultant with knowledge of the local situation and previous work experience in the region should be employed by the Rustenburg Air Quality Forum (RAQF) and made responsible for modelling on behalf of the region. It is necessary to conduct modelling for the region as a whole, because of the number of mining developments in the region. The cumulative impact has to be modelled to ensure that future developments are planned more responsibly.

b. If any extra modelling is required by the individual companies the modelling should be standardised and done according to collectively determined guidelines set for the region by the APCO):
   1. The modelling must apply to air quality and meteorological data, and
   2. Short term as well as long-term modelling should take place on a regular basis (decided upon by RAQF and the APCO). This modelling should relate to the deadlines set by the APCO for new standards to be met (*e.g.* 2003, 2005 and 2008).

c. Dispersion modelling can be used to
   1. Assess the current / future exposure situation in order to make informed decisions;
   2. Determine performance indicators (standards and guidelines that will be implemented);
   3. Identify source-exposure relations;
   4. Estimate the relative importance of various air pollutants;
   5. "What if?" scenarios: the modelling should provide advance warning of possible problems, and then contingency measures should be implemented to stop the forecast materializing by modifying emissions in consultation with other managers. Such modelling can also be used to test and improve contingency measures;
   6. Calculate air quality when data are missing (develop an agreed procedure that is understood by all and updated on a regular basis);
   7. Determine the main impact zone (can be used in future to determine the proper position of the monitoring stations).

8.3.6. Performance indicators: standards, guidelines and legislation

Air quality management in its traditional form is entirely driven by the question "Is there an air pollution problem?" (Seika & Metz, 1999). The decision whether there is, or not, is based on a comparison between measurements and air quality standards (Seika & Metz, 1999). Standards should form the basis of any AQMP and should reflect concentrations of chemical compounds in air that would not pose any hazard to the human population (Seika & Metz, 1999). Governmental bodies, through legislation, specify national air quality standards and goals and thereby form the foundation for all other levels of legislation (WHO, 2000). The decentralisation of air quality management to regions, local areas is necessary, especially in areas with a unique situation (Longhurst *et al.*, 1996). In recognition of the relatively lengthy timescale over which the plan will be implemented, the local decision maker would be advised to set local standards or targets that are at the leading edge of wider scale policy recommendations for air quality standards and to make provision for standards revision as the plan progresses (Longhurst *et al.*, 1996). To initiate any quality standard setting process, it is necessary to take into consideration (WHO, 2000; Seika & Metz, 1999; Longhurst *et al.*, 1996):

a. General environmental trends, international trends and air quality management at other levels;
b. Basic principles (*e.g.* Agenda 21 – precautionary principle, polluter pays);
c. Technical, social, economic and political factors of the country or region for which it is meant;
d. Interconnected policies (*e.g.* development, transport, energy, planning and environment) must be compatible, coordinate responses to an issue;
e. A standard usually only fits a certain part of the population, for the others it is either too low or too high; and
f. Guidelines and standards must be dynamic (new classes can be introduced) and must be re-examined on a regular basis according to international guidelines.

When developing standards it should be decided if the standards are to reflect the need to protect human health and the environment, even if it is unlikely to be achieved in the short- to medium-term with the resources available, or if it are to be set at realistically attainable levels (given the prevailing conditions), even though it may not be consistent with the levels needed to fully protect human health and the environment (WHO, 2000). Over time, air quality standards may also change as conditions within a nation change (scientific relationship between air quality, the health of the population and the quality of the environment becomes better understood) (WHO, 2000). There are considerable differences between the "classic" air pollutants such as SO_2, particulates and the "non-classic" air pollutants and different approaches may be needed to develop standards for the two types of air pollutants (WHO, 2000).

The "individual response" to a given concentration of air pollution varies considerably and air quality standards can therefore only serve a certain part of the population (Seika & Metz, 1999). For the remainder, the standards are either too low or too high and mean that the 'one standard fits all' strategy, essential to the traditional AQM process, should be regarded as a pragmatic approach rather than an ideal one (Seika & Metz, 1999). As ambient levels are decreasing to a stage where present standards are only rarely exceeded, the question arises of whether the traditional AQM process is capable of delivering continuous long-term improvement (Seika & Metz, 1999). When ambient levels fall below standard, there are usually two scenarios that are possible (Seika & Metz, 1999). The first one would be to tighten the standard and thereby create a new "virtual" air quality problem, while the second option would be to reduce the overall activity of the AQM process (Seika & Metz, 1999). As both scenarios are not ideal, there is a growing demand for a more advanced version of air quality management that (Seika & Metz, 1999):

a. Considers the various routes of personal exposure (*i.e.* domestic activities, indoor and outdoor concentrations, occupational exposure, refuelling, passive smoking);
b. Accounts for numerous possible individual combinations;
c. Considers the different individual responses to chemicals (*e.g.* child with pre-existing lung diseases vs. a healthy adult); and
d. Allow for continuous improvement (*i.e.* the process should be able to cope with varying real world concentrations such as steadily improving long-term air quality).

In reality, a limit value is usually not a distinction between good and bad and any illusion should be avoided that it is possible to condense a very complex situation in reality down to a simple figure without assumptions (Seika & Metz, 1999). Air quality standards are often a best estimate for what could be a good and achievable target to aim for, which, depending on national circumstances can differ significantly (Seika & Metz, 1999).

To implement proper standards (and not just guidelines) for the Rustenburg region, a substantial amount of information is needed. It will be necessary to complete all the steps of the RAQMP to get an idea of what proper standards will be for the region and how they should be implemented. While the new Air Quality Bill has not yet become official legislation, internationally recognised standards will have to be the main indicator and must be accepted by all mines in the region. It is important that preliminary (interim) performance indicators with a realistic starting point must be designed by the APCO. These interim measures must be reasonable enough to be attained by the mines (Smelters) and still be satisfactory to the public (Interested and Affected Parties). Public participation is essential to the process. After a worthwhile database is available (at least 2 years' data), performance indicators for the region (as a whole) as well as the individual mines can be designed which must include short, medium and long-term environmental targets. Threshold levels must be revised on a regular basis (rapid response to a changing situation is needed). Multiple levels of standards are needed; for example, limit values, target values, and alert thresholds. Air quality standards must be flexible so that changes can be made as conditions change.

The strategy developed for the region will have to indicate the direction the region will go in, in future (what standards must be achieved by when and how). The air quality standard setting process for the Rustenburg region must include all aspects as discussed above, with the overall goal to achieve mutually agreed goals and a shared vision for the region that will be beneficial to all the mines as well as the public. From the public perspective, the perception is that the area already has too many developments that cause particulate pollution (and all other pollution) and that all future developments should be stopped, until the pollution is within reasonable limits. The mining companies feel that new developments must still proceed, since it will be beneficial for them and bring economic growth to the region. The mines further feel that the particulate pollution is under control with the installation of new control measures. Between the above two extremes a compromise needs to be found. An assessment is therefore needed of how much development the region can tolerate (with and without future plans included). If developments are already more than the region can tolerate, the strategy (and therefore the standards) will focus more on reduction after which properly controlled development must still be possible. If the region can tolerate more developments it will have to be strictly controlled through suitable standards. Enforcement must be through each mine's permit as well as the Environmental Management Programme Report (EMPR Chapter 6) in which a full AQMP must be included.

8.3.7. Planning: Financial management

The total cost of air quality management is of economic importance and as air pollution management moves forward, economics can have a major role in reducing pollution (Boubel *et al*., 1994; Roos, 1993). When considering remedial measures, it is important that their benefits and costs are evaluated so that the preferred (optimum) air quality management measures can be identified where a balance is achieved between the protection of human and environmental health, and the imposition of unacceptable social and economic costs associated with remedial strategies (Mitchell *et al*., 2000; Roos, 1993). Two opposing economic forces determine how air pollution should be managed (Roos, 1993):

a. The cost of control: the higher the costs, the cleaner the air will be; and
b. The cost of air pollution damage: the dirtier the air the higher the costs to clean up.

A range of financial considerations is required in any AQMP (Table 8.3). For the Rustenburg region, more emphasis needs to be placed on financial issues; a section of the RAQMP should focus on the financial side of the management plans implemented. A Cost Benefit Analysis (CBA) is a good example of a strategy that can be followed and should be combined with a prioritisation of strategies. For the regional plan it should be determined what the best strategy would be to follow to reduce particulate pollution and what would be the costs associated with it? The technical feasibility of each option should be explored to ensure that the socio-economic impacts be limited to the minimum. The different options considered should be included and explained, along with the option chosen and the reduction of emission concentrations as a result of the implementation of the strategy. A system should be devised which would make it possible to determine the exact reduction of concentrations and the costs associated with it - often the mines cannot tell what amount of a new development was spent on environmental measures.

Table 8.3: Important financial aspects that should be considered in the RAQMP

A	Cost-benefit analysis and prioritisation of strategies.
1.	Source characteristics (percentage contribution, height of emission, exposure index).
2.	Reduction of ambient concentrations as a result of implementation of each strategy.
3.	Technical feasibility.
4.	Socio-economic impacts (balance between human and environmental health and annoyance of unacceptable social, economic costs of remedial strategies).
5.	Identify environmental targets.
6.	Examine short and long-term control measures.
B	Following final evaluation of strategies, recommend the most cost-effective strategies (beneficial)

8.3.8. Environmental management

The management of air quality needs to be investigated (and implemented) at various levels, namely regional, municipal level and company specific. The various levels will be considered separately in the following discussion.

a) Regional

An air pollution liaison committee needs to be established that will be responsible for the air quality management of the mining industry in co-operation with the APCO. In the Rustenburg region the Rustenburg Air Quality Forum (RAQF) is functioning. The RAQF (as structured in 2003) can form the basis, but changes will have to be made to ensure the proper functioning:

1. Composition: Include all role players: mines (all mines in the area must be included, not only those with a Smelter); governmental bodies (the APCO, DACE, DEAT, DME, Bojanala Platinum District Municipality); NGO's and Community Based Organisations (*e.g.* North West Ecoforum, Luka Environmental Committee, Chaneng Conservation Club); any interested and affected parties from the general public. For the plan to succeed all roleplayers will have to contribute actively in the writing and implementation of the plan. This Forum must work more closely together with the APCO. Both party's role and responsibility must be clearly defined and legal responsibility must be assigned to ensure that the decisions taken can be implemented.
2. Objectives: It is very important that the RAQF should define their objectives in relation to the duties of the APCO. To create and maintain a quality of air that protects human health and welfare, without constricting development would be a starting point. To achieve this, the current mandate of monitoring and reporting will have to be expanded.
3. Functions would include:
   i. Development of an AQMP for the region,
   ii. Enforcement of the AQMP in close co-operation with the APCO, and
   iii. Development and approval of new projects beneficial to the region, which fit in with the long-term strategy for air pollution control in the region.

b) Municipal level: Integrated Development Planning (IDP)

Each municipal council must, within a prescribed period after the start of its elected term, adopt a single, inclusive and strategic plan for the development of the municipality which (Government Gazette, 2000):

1. Links, integrates and co-ordinates plans and takes into account proposals for the development of the municipality;
2. Aligns the resources and capacity of the municipality with the implementation of the plan;
3. Forms the policy framework and general basis on which annual budgets must be based;
4. Complies with the provisions of Chapter 5 (Municipal Systems Act, 2001); and
5. Is compatible with national and provincial development plans and planning requirements binding on the municipality in terms of legislation.

Within 14 days of the adoption of its IDP, each municipality must give notice to the public of the adoption of the plan and publicise a summary of the plan, which reflects (Government Gazette, 2000):

1. The municipal council's vision for the long term development of the municipality with special emphasis on the municipality's most critical development and internal transformation needs;
2. An assessment of the existing level of development in the municipality that must include an identification of communities which do not have access to basic municipal services;
3. The council's development priorities and objectives for its elected term, including its local economic development aims and its internal transformation needs;
4. The council's development strategies which must be aligned with any national or provincial sectoral plans and planning requirements binding on the municipality in terms of legislation;
5. A spatial development framework which must include the provision of basic guidelines for a land use management system for the municipality;
6. The council's operational strategies;
7. Applicable disaster management plans;
8. A financial plan, which must include a budget projection for at least the next three years; and
9. Key performance indicators and performance targets.

The RAQF will have to examine the plans implemented in the IDP written for Bojanala Platinum District Municipality to ensure that a common vision for the region is ensured. Closer co-operation between these two bodies is necessary with regular meetings and necessary information exchanged.

c) Company specific

1. Air Quality Management Plan

It is necessary for the environmental departments of each of the mines in the region to design an AQMP that will link up with the RAQMP. The plan should focus on managing pollution problems (particulate and others) in the specific mine and should further be to the benefit of the region as a whole. The plan should be made available to all employees and included in training. The various Environmental departments should formulate specific goals (short- and long term) and it should be made known if the goals were achieved or not and the reasons why (Table 8.4). An Environmental report should be published on an annual basis that contains all the necessary information (*e.g.* summary of AQMP, goals, current activities, emission data, new projects, problems experienced and how they were resolved, explanation of technology used).

Table 8.4: Example of targets set for Anglo Platinum for 2000 (Anglo Platinum, 2001a).

Goal	Objective	Target	Target met / not met
Training and awareness	Make all employees aware of environmental issues	Incorporate environmental issues into induction training	Target met
Legal registers	Ensure legal compliance	Formulate an environmental legal register	Target met
Eco-efficiency indicators	Formulate a list of indicators	Identify Eco-efficiency indicators	Target met
Environmental management system	Formulate a management system	Implement document control as a basis for a good management system	Target not met (50%)
Improve internal reporting	Formulate communication channels	Clearly define all reporting structures	Target met
Improve incident reporting	Ensure that all incidents are reported efficiently	Formulate definite procedures and formats on incident reporting	Target met
Improve waste management	Initiate the proper management of waste	Formulate acceptable waste management strategy	Target not met (50%)
Proper storm water management	Improve storm water control	Upgrade the existing storm water structure	Target met
Pro-active air quality monitoring	Incorporate real-time monitoring	Install air quality modelling software	Target met
Ongoing performance assessment	Performance assessments for continual improvement	Formulate an assessment structure for continuous improvement	Target not met (50%)

An Industry's Environmental department's structure may not appear to be an important issue, but it can have a definite effect on the effective implementation of the AQMP if the department mainly responsible for implementing the plan is not operating efficiently. An evaluation of the departments is needed to ensure that enough people are available and properly qualified to create and implement the AQMP. Closer co-operation is further needed with the department responsible for Occupational Hygiene to ensure that problems can be efficiently solved. In addition, communication between individuals in the departments must be improved (*e.g.* employees in one department have different explanations for procedures, calculations, why something is done, etc). Employees responsible for air quality management needs to be trained in environmental management and have a basic understanding of engineering in order to ensure effective decision making.

8.3.9. Public participation (Air Quality Information System - AQIS)

The success of many industries, particularly those of the primary sector, depends largely upon the contribution and input from stakeholder parties, and the cooperation of surrounding communities (Hilson & Murck, 2000). An industry usually goes through three stages before realising the importance of the public's participation (Gerrans, 1993). The first of these stages, which is usually an unmitigated disaster, is the "Stonewall Stage" where industry refuses to talk to the public on the basis that there is general ignorance and that the media and environmental activists are orchestrating the campaign against industry (Gerrans, 1993). In the "Missionary Stage" an attempt is made to educate the public and to emphasize the benefits that had been brought (Gerrans, 1993). Though well intentioned, it still has little success (Gerrans, 1993). Simply telling people seldom works; a more ambitious approach, which involves the public directly, is called for (Gerrans, 1993).

The "Dialogue Stage" involves listening to what people have to say about their fears, what offends them, and what they think should be done to bring about improvements (Gerrans, 1993). In this third stage, image projection, and consultation are replaced by negotiation and the needs of Interested and Affected Parties (I&APs) are accounted for through appropriate corporate policies (Hilson & Murck, 2000; Gerrans, 1993). When mining, a number of cultural, aesthetic and natural resources critical to the well being of a society can be negatively impacted, and then it is crucial that the needs of these parties are addressed from the outset (Hilson & Murck, 2000). If mine management is socially active with all I&APs from the exploration to the closure stage, a mine community and external stakeholder parties are more likely to accommodate operations (Hilson & Murck, 2000).

The public should be informed in accessible ways of the development of the AQMP, its success (or failure) in improving air quality and how to complain about air quality (Longhurst *et al.*, 1996). The public must receive effective information which allows them to make an informed judgment of the air quality situation and thereby make personal decisions about undertaking certain activities and actions and further help them to become involved in identifying problems and implementing solutions (Figure 8.2) (Longhurst *et al.*, 1996).

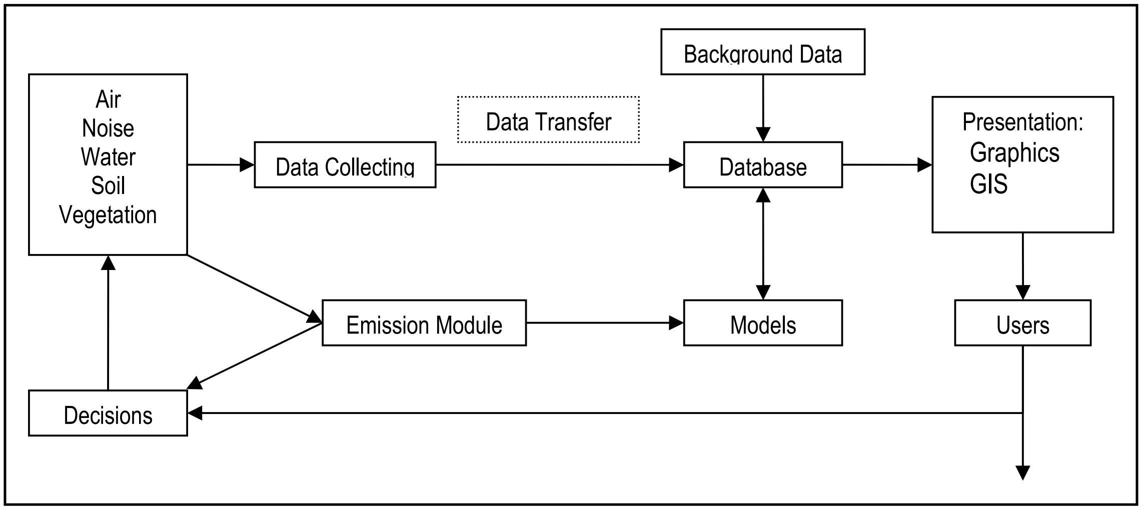


Figure 8.2: A principal structure of a modern environmental surveillance and information system (Larssen, 1998, cited in Fenger *et al.*, 1998:315).

An information centre in Rustenburg (funded and coordinated by the RAQF) must be established that consists of the following sections:

a) Supplying information (hard copies and electronic transfers)

1. Measurements (inside the Smelter, around the Smelter, ambient monitoring) must be automatically and continuously transferred from each mine to a website on the Internet which can be accessed by all interested and affected parties (I&APs). Access to data must be immediate and open.
2. Automatically created daily reports containing information from all three Smelters.
3. Copies of monthly reports send to the APCO along with the comparative data of the previous month and previous year.
4. Information must be supplemented by graphs, Geographic Information Systems (GIS), packaged analysis, visual display of routine information (summary) in public places (*e.g.* Library, Waterfall Mall), presentations (public meetings, community liaison meetings). Other information that should be included is maximum concentrations, population exposure, source impacts, background concentrations, and changes in air quality over time. The information must be in a format that is easy understandable for the general public as well as technical specialists.
5. Poor air quality alert: the public must be made aware of Smelter downtimes, when maintenance is planned and unforeseen problems through the Internet, email, SMS, and public notices in communities.
6. Information must be displayed about new projects planned, progress, commissioning dates, *etc.*

b) Complaints, comments, suggestions and questions

1. A call centre (hotline) should be established that could be phoned to report problems, make comments and suggestions, according to a formalised procedure (all complaints must be recorded using the same format). The numbers of the information centre (telephone, email, fax) must be widely advertised and available 24 hours a day. It is further important that the public must be informed exactly how to lodge a complaint or suggestion. Feedback need to be timely and effective; if no answer is available, the person complaining must still be phoned back and a reason must be supplied.
2. In formalising the external lines of communication, community liaison protocols must be established which take into account:
   i. The driving force must be the customer (public);
   ii. Public can be involved in identifying problems, setting goals, deciding whether exposure levels are acceptable or not and implementing solutions;
   iii. Involvement of the public can be at different levels; a combination of measures must be appropriate for local circumstances; and
   iv. Special care must be taken to ensure that local communities are included in the process and that all the important information reaches them efficiently and effectively (*e.g.* language barriers, lack of understanding of technical issues, poor infrastructure and problems with travel must be provided for).

c) Research and education

1. Research about issues that have a direct influence on the public and environment and apply to the region as a whole must be initiated from this centre (use can be made of post-graduate students from Universities as well as consultants that have worked in the region on a regular basis). The public must be educated about the basic issues of particulate pollution (the causes, management and control measures) through workshops, short courses, and newsletters. By educating the public a more constructive discussion about the future of the region can be initiated.

8.3.10. Health

Another basic issue that must constantly be taken into consideration in the RAQMP is the health impacts of the pollution on the public. Air quality management could be expected to improve the public health in the area where it is applied (Seika & Metz, 1999). Although the correlation between health problems and particulate pollution is difficult to prove, certain basic steps need to be taken in the Rustenburg region, especially since complaints have been received by the public and no studies are available for the region. Health studies can be divided into (Mitchell *et al.*, 2000):

a. Exposure-response relationships (mostly epidemiological studies)
b. Disease-burden estimation method (relies on the assumption that the exposure data conform to a predictable distribution) which consists of:

1. Identification of pollutants with health effects, and their concentration in the ambient air;
2. Assessment of the likely exposure of relevant populations of these levels;
3. Definition of a pollutant exposure-population response relationship that describes the health effects arising from changes in air quality; and
4. Application of the pollutant concentration values and exposure-response relationship to the relevant population to quantify an overall health effect.

In order to estimate the disease burden associated with particulates, an exposure-response relationship is required (Mitchell *et al.*, 2000). Numerous epidemiological studies have been conducted in an attempt to identify such relationships (Mitchell *et al.*, 2000). Other methods that can be used include (Ayres, 1997):

a. Challenging patients or normal subjects with individual pollutants or combinations of pollutants in defined exposures for specified times,
b. Animal work can help define mechanistic aspects of the health effects of air pollutants,
c. In-vitro work of isolated cell cultures or lavage fluid obtained from the nose or the lung, and
d. Computer modelling for personal exposures to specified pollutants, which can be extremely difficult to measure directly.

The Rustenburg region requires a baseline assessment to determine if pollution associated with mining activities (SO_2 and particulates) really is responsible for health problems in the region. The sensitive part of the population (*e.g.* people living in close proximity to a Smelter, the very old and very young, people who already has health problems that are exacerbated by particulate pollution) needs to be evaluated first. If evidence is found of pollution related diseases, the study needs to be expanded and continued over a number of years. Information can be obtained from mines, hospitals and medical practitioners as well as portable monitors and questionnaires. Health warnings should be given to the public (linked to standards and guidelines). Further, it is important to remember that:

a. There are various routes of exposure with possible individual combinations (many variables),
b. People have different responses to emissions and these must be investigated,
c. There will have to be a trade-off between development and the health effects it causes, and
d. The role of air pollution in initiating disease and exacerbating disease needs to be clarified.

A problem regarding particulate pollution is that particulates smaller than 10 µg (PM_{10}) might not be the measurement most representative of the fraction of the ambient aerosol that is responsible for its harmful effects on health[9]. Evidence has accumulated that this toxicity may lie in a finer fraction, perhaps below $PM_{2.5}$[9].

8.3.11. Control: Implementation and enforcement

Air quality control measures are an important component of management practice and although many and varied, legally binding emission limits and land-use planning remain dominant (Mitchell *et al.*, 2000; WHO, 2000; Anon, 1997).

The most powerful and cost-effective air quality management options occur during the planning stages of a new facility, whereas options involving changes in existing production processes or pollution control technology are more limited in scope (WHO, 2000). Planning options involve careful site selection to maximize dispersion, and location of the proposed facility away from sensitive receptors, such as residential areas or areas of natural or commercial sensitivity (WHO, 2000). While land-use planning can make relatively little contribution to immediate improvements in air quality, over a longer term the development planning system is central to policies (Mitchell *et al.*, 2000; Annegarn & Scorgie, 1997). Landuse planning is needed for future developments planned for the region. For Rustenburg a detailed map showing the location of all the current activities (as well as new developments planned) must be linked to the emission inventory (section 8.3.2). Overlays are needed of residential areas (including informal settlements), vegetation, farms as well as future town planning.

Three steps are necessary for designing a control structure that will be suitable for Rustenburg (Table 8.5). The evaluation of control options must take into account technical, financial, social, health and environmental factors, as well as the promptness with which they can be implemented and how practical it is (WHO, 2000).

8.3.11.1 Air quality alert (poor air quality)

A distinct short-term component of an overall AQMP is the establishment of a set of procedures and well developed lines of communications to deal with the occasional acute occurrence of very poor air quality (Table 8.6) (Longhurst *et al.*, 1996). An incremental response (alert system) to a developing problem should be activated by a number of threshold concentrations through a procedure that sets out the nature and priority of responses (Longhurst *et al.*, 1996). The air quality and meteorological monitoring of routine management will, it is assumed, provide advance warning of the likelihood of an adverse pollution episode (Longhurst *et al.*, 1996). The response of the air quality manager must be an attempt to stop the forecast materializing by modifying emissions of air pollutants both within the local area and over a wider scale by cooperation with other air quality managers (Longhurst *et al.*, 1996). Should this fail, attempts could be made to minimize the peak concentration and the duration of poor air quality by progressively more stringent (previously agreed) restrictions on emissions (Longhurst *et al.*, 1996). Simultaneously, a series of health warnings must be issued to provide general advice to the public at large as well as advising sensitive individuals of actions to take to minimize their personal risk (Longhurst *et al.*, 1996).

Table 8.5: The three aspects of control required in the RAQMP.

A. Proposals & Assessment	1. Decide if there is a problem: compare measurements and standards (best estimate for what could be a good and achievable target to aim for)
	2. Evaluate the technology used - position, type, efficiency (more than 99%), availability (100%). The new technology discussed in Chapter 6 will impact positive on the region, but there is still old technology in use that is a really big problem.
	3. List and describe strategies considered (change from source-based to receiving environment approach). To determine strategies integrated planning and management of all sources is needed. The role and control ability of air quality managers must be described.
	4. Investigate short and long term control strategies and evaluations. Indicate the effect of future emissions from growth and development on ambient air quality and demonstrate how compliance will be maintained.
	5. Additional structure (and source)-specific objectives must be designed (e.g. use of best available technology; trade-offs within company; non-compliance penalties)
	6. Plan the production processes (nature and priority of procedures to be carried out must be decided). Explain the implementation of each measure.
	7. Emission quota stipulation must be included. Targets may not be achievable because of the background concentrations.
	8. Control efficiency must be measured / proof. This is not always possible; it is easier to calculate it. Decide on the efficiency and work backwards what is necessary to get to that efficiency.
	9. Develop an air quality alert, which can assess the situation and choose the appropriate responses. Source-specific contingency measures may have to be included, but they need only be implemented should the recommended control strategies not be successful in achieving and maintaining compliance within a required time period. Must decide at which threshold concentration the alert system must be triggered.
	10. Standardization of procedures is important to ensure accuracy and comparability. All decisions must be practical and able to implement. It must be able to reduce the emissions and better the situation, but still be reasonable enough so that the mines can implement it.
B. Policy Implementation	1. Enforce emission and reduction control
	2. Continued enforcement if achieved (continuous improvement needed)
	3. Emission control tactics must be revised if air quality standards are not achieved. Different responses can be followed: Emission reduction by direct prevention Altering spatial distribution Provision of less polluting alternatives (e.g. area in Smelter must be cemented, hosed down, vacuum cleaned on a regular basis, look at vegetation options, make sure all pipes are closed, enough fans are installed, precipitators, ceramic filters)
C. Evaluation (Auditing)	1. Ongoing assessment of progresses (against performance indicators) and efficiency of pollution abatement.
	2. Internal inspections and external auditing protocols

Table 8.6: Important factors that should be included in an air quality alert (Longhurst *et al*, (1996))**.**

Possible response strategies	On-site emergency plan that can be viewed by all (include an estimation of):
Emission reduction by direct prevention of emissions	Total result in case of explosion
Altering the spatial distribution of emissions away from the worst affected areas through the modification of polluting activities	Effects of thermal radiation in case of fire
Reducing emissions through the provision of less polluting alternatives	Concentration effects of toxic releases
	Potential effect of major incident on public
	Suitability of on site emergency plan

8.3.12 Reporting and evaluation

Reporting constitutes the final section of the RAQMP and is responsible for evaluating the success or failure of the plan (targets met or not met) and communicating it:

a. Internally

1. The creation of daily, weekly, monthly and yearly reports with relevant information (*e.g.* graphs, comparison to previous data, reasons for compliance failure, indicate downtimes and reasons). Data must be available in $mg.m^{-3}$, $mg.Nm^{-3}$ as well as $t.month^{-1}$ to make comparisons easier. All conversion factors, calculations must be explained in a written procedure (must be available, kept updated at all times).
2. Data spreadsheets must be updated on a regular basis.
3. Reports must be circulated not only to management, but also be easy accessible to all personnel (*e.g.* through the Intranet, displayed within Smelter area).

b. Externally: Interested and Affected Parties

1. Reporting to the Interested and Affected parties (I&APs) and how it should be handled has been discussed in detail under Section 8.3.9.

c. Externally: Regulatory authorities (APCO, RAQF)

1. All emissions monitored must be reported to the APCO on a monthly basis,
2. Reasons for each instance of non-compliance must be supplied,
3. The information (and the format thereof) reported by all three mines must be standardised, and
4. Major incidents must be reported, and described in terms of:
    i. Estimated probability,
    ii. Potential effects on public, and
    iii. Events that took place.

After the initial implementation of the RAQMP, an ongoing process is needed to ensure the constant evaluation and updating of the plan (Table 8.7). If the objectives set for each section are met, enforcement must continue, but if the objectives are not met re-evaluation is needed (Figure 8.1).

Table 8.7: Elements that must be included in an environmental system (Lonmin Platinum, (2001b))**.**

Before implementation	Implementation and operational phases	Procedure applicable	Effective operation is maintained through
Environmental aspects	Structure and responsibility	Procedure for environmental roles, responsibilities and authorities	Monitoring and measurement
Legal and other requirements	Training, awareness and competence	Procedure for environmental training	Non-conformance and corrective and preventive action
Objectives and targets	Communication	Formal internal communication: Procedure for SHE forums	
Environmental project programs to achieve environmental targets must be launched and managed			

8.4 Closing

From discussions in Chapter 5 and 6 it is evident that particulate emissions are a significant problem in the Rustenburg region and has only recently (in the last three years) received the deserved attention. A number of issues still require clarification before any real progress can be made to reduce levels of particulate emissions[9]:

a. How do PM_{10} levels vary across the Rustenburg area?
b. What is the natural background pollution level?
c. How much of the particulate pollution can be controlled?
d. How long will it take to reduce levels of particulate pollution?
e. To what level do emissions need to be reduced to protect human health? and
f. Should new developments be discouraged until all questions are answered and/or emissions have been reduced to within acceptable levels?

These questions can only be answered through the implementation of the AQMP as described in Chapter 8. The success of the plan and the future of the region would depend on the support and co-operation received from all the roleplayers in the Rustenburg region.

Chapter 9

Concluding remarks

The economy of the North West Province is relatively small (4.9% contribution to the national Gross Domestic Product) with the main contributor being the mining (predominantly gold and Platinum) and agricultural sectors (NW DACE, 2002). This study has shown the importance of the Platinum industry for North West province as well as the Rustenburg region in helping to alleviate poverty through providing work to a considerable number of people (NW DACE, 2002). Platinum mining will, however, always be contentious as it impacts on human emotions and raise issues that cannot be easily answered. Platinum mining especially in the Rustenburg region has a negative impact through (NW DACE, 2002):

a. Degradation of soil, vegetation and water resources;
b. Air, water and soil pollution from mine drainage and industrial emissions;
c. Over-utilisation of natural resources such as water, soil and vegetation, and
d. Overcrowding, leading to the spread of communicable diseases and epidemics.

Air pollution, and specifically for this study particulate pollution, cannot be allowed to continue uncontrolled because the impact on the environment and humans is significant. Particulates and SO_2, both of which are dominant pollutants in the Rustenburg area, are documented to act synergistically in adversely affecting human health (Harrison, 1990 cited in Burger & Scorgie, 2000: 3-7; Harrison, 1990 cited in Burger & Scorgie, 2000b: 5; Egenes, 1999). Particulates act as a carrier taking SO_2 to the lower parts of the respiratory system, which it would not reach alone due to adsorption on the walls of the upper respiratory tract (Burger & Scorgie, 2000b). In the Rustenburg region it is especially important to find a balance between development on the one hand and pollution prevention on the other hand, although it involves a number of difficult questions (Ross, 1972):

a. How does one measure the value of an improved quality of life?
b. What trade-offs are individuals in specific areas willing to make?
c. How safe is safe?
d. How to attain acceptable levels of air pollution at minimum public and private expense,
e. What are the acceptable levels of air pollution?
f. How do the air pollution hazards compare with the risks to which we voluntarily expose ourselves each day?

Since 2000 there have been attempts by the mining industry in Rustenburg to control particulate pollution. Awareness of the problem increased and vast amounts of money were spent on upgrading control measures and developing management practices to limit the amount of particulates emitted from the Smelters. Despite all these efforts, a number of problems still exist that hampers the efforts:

a. Technology: Problems were experienced with the slow commissioning of new technology as well as the inefficiency of the technology already in place to minimise the amount of particulates emitted. Problems further exist with the monitoring equipment which means that the data available for the region are inadequate.
b. Legislation: Outdated South African legislation along with limited powers of the Air Pollution Control Officer responsible for the region has lead to a situation where the mining companies did not experience any pressure to improve on their performance. Lack of proper data makes it further impossible to enforce registration permit conditions.
c. Management practices: Proper environmental management practices are not in place or updated on a regular basis. A further problem is that Smelter management does not take environmental management seriously enough and often the policies set by top management (head office) are not enforced at ground level in a Smelter. To control particulate pollution effectively, it may sometimes be necessary to cut back on production - very difficult for an industry that is profit driven in very favourable economic conditions.
d. Interaction with the public: From the side of the mines, the thinking is that the particulates have no real effect (it is only visible pollution) and only because it can be seen do people assume that it causes a problem. The view from the side of the public is that all sinus / asthma problems are a result of the mining activities. Only proper communication between the two parties will lead to a situation of increasing trust where a solution may be found that is acceptable for both parties.
e. Competitiveness: A very high Platinum price along with a favourable exchange rate has created a highly competitive situation. Vast quantities of Platinum are mined by three companies in a relatively small area; therefore the smallest advantage one company have over another can have a significant impact in the profits made. Equipment and processes used along with management practices are all kept confidential and joint projects regarding environmental matters are not really regarded as an option.

For the region to move forward (continued profitable mining without loss of life) a solution will have to be found where all the mining companies can work together to solve air pollution problems in the region. An important step in this process would be the creation and implementation of a regional Air Quality Management Plan (AQMP). There is some movement in the direction of a regional plan, but not all mines agree on this.

For the purpose of this study an AQMP has been devised for the Rustenburg region (RAQMP). The plan consists of 12 sections which focus on all the important aspects that need to be addressed to ensure that particulate pollution (and pollution in general) is properly controlled and minimized. Theoretical knowledge is included which is characteristic of management plans designed for similar circumstances worldwide as well as practical solutions to problems experienced inside all three the Smelters and for the region as a whole. The Plan is flexible and will change over time as implementation has started.

To be sustainable, mine management must not use environmental legislation as the only guidance but be proactive in their environmental management; they are required to perform beyond regulatory demands and integrate a number of environmental management tools into operations (Hilson & Murck, 2000). Further, because regulatory frameworks vary significantly throughout the world, performing in line with legislation does not necessarily translate into sound environmental practice (Hilson & Murck, 2000). Sustainable development in the corporate mining context, therefore, calls for a company to use best practices when addressing important environmental and socio-economic issues (Hilson & Murck, 2000). Another essential element of sustainable development is extended socioeconomic responsibility, which requires industrial operations to address the needs of all stakeholder groups throughout the various stages of operation (Hilson & Murck, 2000). There is now a growing expectation for corporations to operate in accordance with community groups that are potentially affected by industrial operations, and to address the needs of stakeholder parties when devising corporate policies (Hilson & Murck, 2000).