

Appendix C

Existing air quality management plans for atmospheric Pollution control for the Rustenburg region

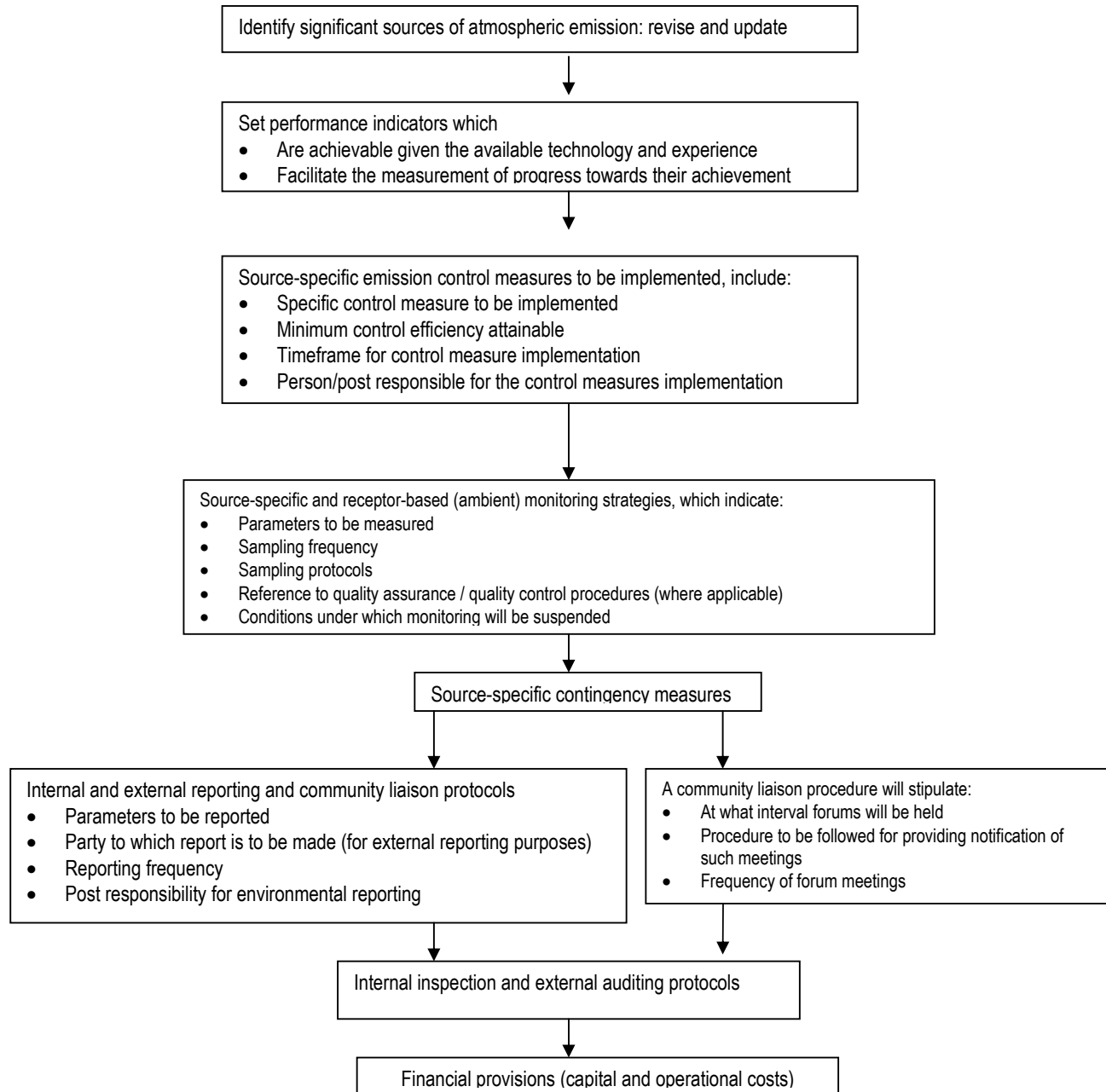


Figure C.1: Framework for Air Quality Management plan development for the Rustenburg region (Scorgie, 2001b)

Ms. Yvonne Scorgie, an independent consultant with experience working in the Rustenburg region, proposed both of the plans featured in this App. endix in 2001. The purpose of the plans was to try and devise a regional management plan that can be implemented by all the large industries in the region. This was a first attempt since no such plans existed previously. As discussed under section 4.3 (Chapter 4) large industries are responsible for 96.2% of total emissions in the region (Table 4.2; Table 4.4 and App. endix B: Fig. 4.7) (Pulles *et al.*, 2001; Burger & Scorgie, 2000a). Therefore, these industries had to be targeted first.

Both of the plans contain detailed information with a number of sections and sub-sections included. The plan featured in Figure C.1 contains more steps than the plan featured in Figure C.2. Both of the plans are linear and no reiterations occur.

Significant differences occur between the two plans with different types of information included. Where similar information is included, it is in a different order. The plan in Figure C.1 is a framework for the development of an AQMP and concentrates more on public participation and reporting of results (internal and external). Provision is made for internal inspection as well as external auditing. The plan in Figure C.2 is an AQMP for the region and focuses more on identifying the pollutants to be controlled as well as devising the most effective strategies to reduce the emissions. It further includes dispersion modelling while the plan in Figure C.1 focuses more on monitoring and no modelling is included. Figure C.2 fits more in with the Air Quality Management Plans (AQMPs) described in Chapter 2.

Elements that are included in both plans are contingency measures as well as financial provision. More detail is included in Figure C.2 about financial matters and more specifically Cost-Benefit Analysis (CBA). The second plan (Fig. C.2) further includes the technical feasibility of the different strategies considered and the socio-economic impacts of each strategy.

Both of the plans would require the co-operation of all the major industries in the region and it would take a considerable time to fully implement and ensure the efficient working. None of the plans would however work without a comprehensive emission inventory that must include more information than is currently available. Because of the particular situation present in the Rustenburg region (section 4.4: Chapter 4) more planning would be needed before any plan can be implemented (feature of Figure C.2) and after that, tight controls are needed with input from all the interested and affected parties (feature of Figure C.1) in the region to ensure the success of the regional plan.

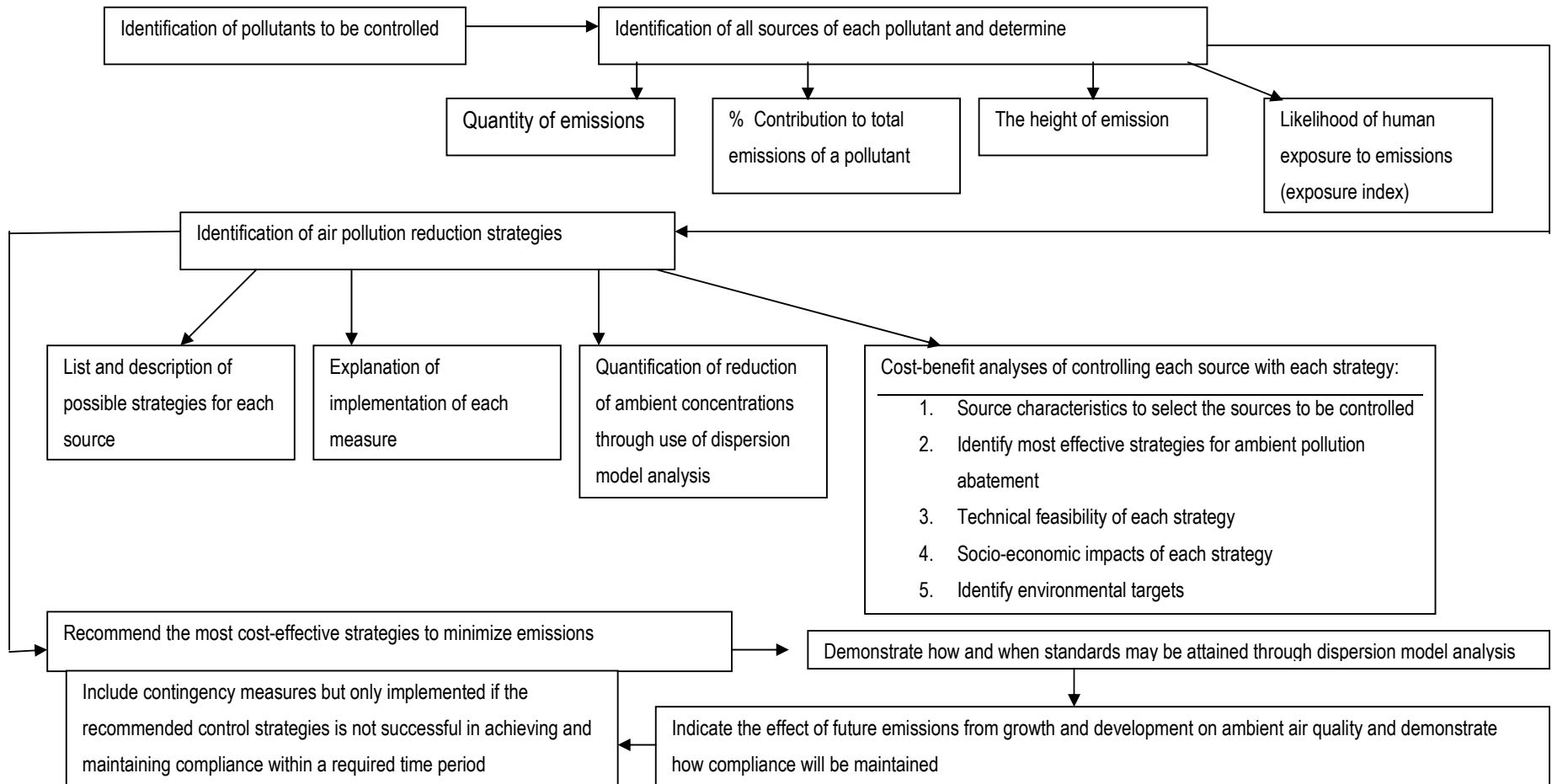


Figure C.2: Regional air quality management plan (Scorgie, 2001).

Appendix D

Smelter process description

D.1 Anglo Platinum

D.1.1 Concentrate receiving

Ore is mined from a number of shafts in the vicinity of the smelting operation and is transported to the concentrator plants (Waterval, Frank, Klipfontein, Amandelbult, Lebowa and Potgietersrus) where it is milled (Anglo Platinum, 2001a; Pulles *et al.*, 2001). The milled ore is introduced to flotation banks where particulates containing precious metals are separated as a concentrate (Pulles *et al.*, 2001). Non-valuable tails are deposited onto tailings dams (Pulles *et al.*, 2001). The concentrate is then pumped to the Smelter plant as slurry, where it is off-loaded by means of overhead cranes at the concentrate receiving shed (storage capacity is 7000 tons) (Anglo Platinum, 2001a).

D.1.2 Concentrate drying

There are four Flash driers at Waterval Smelter with the purpose of drying the wet concentrate (Anglo Platinum, 2001a; Pulles *et al.*, 2001). A Flash drier consists essentially of a vertical drying column into which wet concentrate is fed, along with hot gas generated by the hot gas generator that uses coal as a heat source (Anglo Platinum, 2001a; Pulles *et al.*, 2001). The exhaust gases from the cyclones are passed through a multi-clone and baghouse before it is vented to the atmosphere through the Drier stack (Pulles *et al.*, 2001). The concentrate collected in the baghouse, multi-clone and cyclones is pneumatically transferred to the product bins at each Flash drier and then blended with a predetermined quantity of lime to aid in the Furnace slag management (Anglo Platinum, 2001a). The final blend is pneumatically conveyed to the 2500 tonne silo from where the concentrate is pneumatically conveyed to either Furnace when requested by the Furnace control room (Anglo Platinum, 2001a).

D.1.3 Furnaces

Waterval Smelter has two Furnaces (Pulles *et al.*, 2001). Concentrate is fed into the Furnaces, which use electrical energy to melt the concentrate (Pulles *et al.*, 2001). Lime is blended with the concentrate, which lowers the melting point of the slag to create a fluid slag at normal operating temperatures (Anglo Platinum, 2001a). The matte (denser than the slag) settles at the bottom of the Furnace and consists of Nickel, Copper, Iron and Cobalt Sulphides and Platinum Group Metals (PGMs) (Anglo Platinum, 2001a; Pulles *et al.*, 2001). The matte is tapped from the Furnaces periodically while the slag is tapped virtually

continuously through water-cooled copper blocks and is granulated using a high flow water stream (Anglo Platinum, 2001a; Pulles *et al.*, 2001). Converter slag is also returned to the Furnaces to recover any matte entrained in the Converter slag (Anglo Platinum, 2001a). Furnace off-gas is fed to the ceramic filters to remove entrained particulates and then vented to the atmosphere via the Main stack (Anglo Platinum, 2001a). There are 12 ceramic modules (6 per Furnace) each containing 864 ceramic candles (Anglo Platinum, 2001a). Particulates are returned to the Furnaces via air slides and tails are pumped to the slimes dam (Anglo Platinum, 2001a; Pulles *et al.*, 2001).

D.1.4 Converters

There are 6 Pierce-Smith Converters (Pulles *et al.*, 2001). The Furnace matte is charged to the Converters through the mouth of the Converter and air is blown through the molten bath (Anglo Platinum, 2001a; Pulles *et al.*, 2001). The oxygen reacts exothermically with the Iron Sulphide thereby supplying the heat for the Converter (Anglo Platinum, 2001a; Pulles *et al.*, 2001). Silica slag is added to the Converter to produce a fayalite slag (Anglo Platinum, 2001a). The slag produced is periodically skimmed off and fresh Furnace matte charged until the matte level in the Converter is sufficient for casting in the slow cool section (Anglo Platinum, 2001a; Pulles *et al.*, 2001). The slag is then returned to the Furnaces and the matte is sent to the Base Metal Refinery (BMR) for further processing (Pulles *et al.*, 2001). During the converting process large amounts of SO₂ are produced (Pulles *et al.*, 2001).

D.1.5 Slow cooling

The matte from the Converter section is transported to the slow cool section in refractory lined ladles (Anglo Platinum, 2001a). It is then poured into the refractory lined moulds aiding the slow removal of heat (Anglo Platinum, 2001a). By placing a lid over the mould the cooling process is slowed down (Anglo Platinum, 2001a). The ingots are then lifted and crushed to ± 3 cm before transportation to the Rustenburg Base Metal Refinery (RBMR) (Anglo Platinum, 2001a). The slow cooling process ensures that the sulphur deficient matte forms magnetic plates enabling the PGM's to be separated from the Base Metals at the BMR (Anglo Platinum, 2001a).

D.1.6 Slag milling

The granulated Furnace slag is separated from the bulk of the granulating water by rake classifiers (Anglo Platinum, 2001a). Classifier product is conveyed to the Slag Mill storage silo while the classifier water overflow is pumped to a dedicated thickener for further treatment (Anglo Platinum, 2001a). Slag is fed from the Silo to a ball mill with a closed circuit cyclone to achieve a product for flotation feed with a particle size of between 50 to

65% passing 75 micron (Anglo Platinum, 2001a). The flotation circuit consists of two rougher banks, and one scavenger bank of flotation cells (Anglo Platinum, 2001a). Concentrate pulled from the rougher cells is sent to the concentrate shed via a dewatering system, while concentrate from the scavenger cells is returned to the flue dust thickeners (Anglo Platinum, 2001a). The tails from the scavenger bank are pumped to a tailings dam (Anglo Platinum, 2001a).

D.1.7 Acid plant

During the process of converting, SO₂ and particulates are generated as unwanted by-products (Anglo Platinum, 2001a; Anglo Platinum, 2000). In order to prevent this release into the atmosphere SO₂ gas is used to make H₂SO₄ in a Single Absorption Sulphuric Acid plant (Anglo Platinum, 2001b; Pulles *et al.*, 2001). The Acid plant must be available 96% of the time according to permit requirements (Anglo Platinum, 2001b). Availability is defined as the percentage of time in a given month during which the Acid plant could produce acid, given a gas supply (Anglo Platinum, 2001b). Utilisation is defined as the percentage of time (available or total) that the Acid plant was actually producing acid (Anglo Platinum, 2001b).

The coincidence of scheduled and unscheduled Acid plant downtimes with poor dispersion potentials have been noted to coincide with significant increases in ambient SO₂ concentrations when compared to long-term means (Burger & Scorgie, 2000a). The sources of downtime can be defined as (Anglo Platinum, 2001b):

1. Major events: blower failures, catalyst degradation, flow constrictions; and
2. Chronic downtime: solids in weak acid circuit, acid leaks, instrumentation.

D.2 Impala Platinum

D.2.1 Concentrate receiving

Ore is mined from a number of shafts in the vicinity of the Smelter and is transported to two concentrator plants (Merensky and UG2) where it is milled (Pulles *et al.*, 2001). Concentrate is pumped to the Smelter as slurry, where it is received in large thickeners (Pulles *et al.*, 2001). The thickeners partially dewater the slurry and the dewatered slurry is then introduced to the driers (Pulles *et al.*, 2001).

D.2.2 Concentrate drying

Concentrate drying is effected by means of Spray driers (Pulles *et al.*, 2001; Pulles *et al.*, 2000). The principle of the operation is to nebulise (break up into small particulates) the partially thickened concentrate in the presence of hot gas (generated in a hot gas generator) (Pulles *et al.*, 2001; Pulles *et al.*, 2000). Water is rapidly vaporised from the wet concentrate

and passes together with some of the dry dust into electrostatic precipitators (one for every Spray drier), where the dust is recovered with less than one percent moisture content (Pulles *et al.*, 2001; Pulles *et al.*, 2000)². Drier off-gas contains small amounts of particulates and gases typically evolved through the combustion of coal (Pulles *et al.*, 2001; Pulles *et al.*, 2000).

D.2.3 Furnaces

Dry concentrate is pneumatically transferred to the Furnaces (App. endix B: Fig.5.3 and Fig. 5.13) (Pulles *et al.*, 2001; Pulles *et al.*, 2000). Furnaces use electrical current, discharged through large electrodes placed in the Furnace bath, to melt the concentrate (Pulles *et al.*, 2000). The smelting of concentrate in the Furnaces is the first of two beneficiation processes (Pulles *et al.*, 2001; Pulles *et al.*, 2000). The Furnaces in use are the No. 4 and No. 5 Furnaces, the old No. 3 Furnace was demolished and replaced with a new No. 3 Furnace in December 2000 (Pulles *et al.*, 2000). The off gas passes through three electrostatic precipitators to remove particulates before being discharged through the Main stack (Pulles *et al.*, 2001; Pulles *et al.*, 2000)².

D.2.4 Converters

Furnace matte is collected in ladles from Furnace tap holes and an overhead crane transports the full ladles across the aisle into the open mouth of a Converter (App. endix B: Fig.4.17) (Pulles *et al.*, 2001). The Converters are cylindrical in shape and are known as Pierce-Smith Converters (Pulles *et al.*, 2000). When sufficient Furnace matte has been loaded, the entire Converter rotates so that an extraction hood covers the open port (Pulles *et al.*, 2000). During the conversion process, fugitive gases and particulates may escape from the Converter hoods (Pulles *et al.*, 2001; Pulles *et al.*, 2000). Two new Converters were commissioned in October 2000, which have double the capacity of the Converters used up to then (Pulles *et al.*, 2000). These Converters are designed to have improved gas capture efficiencies and larger material handling capacities (Pulles *et al.*, 2000). The older Converters are used as spare capacity and provide more operational flexibility by decreasing the reliance of the Converter operations on those of the Furnaces (Pulles *et al.*, 2000).

D.2.5 Acid plant

Converter off-gas is the feed gas for the Acid plant and cannot be vented directly to the atmosphere due to the high SO₂ concentration (Pulles *et al.*, 2000). The function of the Acid plant is primarily to remove SO₂ from the Converter off-gas stream (Pulles *et al.*, 2000). The feed gas is routed through a wet scrubber that largely removes SO₃ and particulates from the gas stream before entering the Acid plant (Pulles *et al.*, 2000). SO₂ is catalytically

converted to SO_3 in a single stage conversion, which is then dissolved in water to form H_2SO_4 (Pulles *et al.*, 2000). Unconverted gas is discharged to the atmosphere through the Acid plant stack (Pulles *et al.*, 2000). An availability of 90% is required for the Acid plant². The Acid plant was upgraded in October 2000 and includes (Pulles *et al.*, 2000):

- i) A 60-meter stack;
- ii) A new wet scrubber (as part of the SulfAcid plant);
- iii) A four-bed Converter to accommodate increased Converter capacity;
- iv) An increase in conversion efficiency to 96%;
- v) A new absorption tower;
- vi) Rebuilding of the drying tower;
- vii) A strong-acid storage tank, which will minimise emissions during start-ups; and
- viii) An upgrade of the pre-heaters, which aids in the reduction of emissions during start-up.

Acid plant shutdowns occur once per annum for a period of approximately five weeks, generally within the period of July to October (Pulles *et al.*, 2000). Under normal operating conditions, the intensity of impacts is considered as medium with medium significance; under conditions where the Acid plant is not available and production levels remain unchanged, the intensity of the impact is regarded as having the potential to be high, with associated high significance (Pulles *et al.*, 2000). The sources of downtime are the same as those defined by Anglo Platinum (D.1.7).

D.3 Lonmin Platinum

D.3.1 Concentrate receiving

Ore is mined from shafts within the Western Platinum, Karee Mine, and Eastern Platinum mines (Lonmin Platinum, 2001b; Pulles *et al.*, 2001). Concentrate is received at the Smelter by truck from the Merensky, Rowland, 1 Shaft, Karee, and E.P.L. concentrators located in the mine lease area (Lonmin Platinum, 2001b; Pulles *et al.*, 2001).

D.3.2 Concentrate drying

Merensky concentrate is dried in a rotary kiln, and UG_2 concentrate is dried in a Flash drier (Lonmin Platinum, 2001b; Pulles *et al.*, 2001). The Flash drier replaced Spray driers in 2000 (Pulles *et al.*, 2001).

D.3.3 Furnaces

The ore goes to the Furnaces where it is smelted to remove gangue materials (predominantly silica) (Pulles *et al.*, 2001). The Merensky and UG_2 concentrates are smelted

through their own Furnace, each designed to handle the particular ore type (Lonmin Platinum, 2001b). The Smelter consists of six Furnaces; one of these Furnaces is a six-in-line submerged arc electrode Furnace used for the smelting of Merensky concentrate (Fig.D.1) (Pulles *et al.*, 2001). The other five are circular Furnaces used for the smelting of UG₂ concentrate and consist of three Pyromet Furnaces and two Infurnco Furnaces (Fig.D.1) (Pulles *et al.*, 2001).

The concentrate together with a suitable flux (limestone) is smelted in the Furnaces where all but two (Sulphur and Iron) of the major undesirable gangue constituents are removed as slag (Lonmin Platinum, 2001b). Slag from the Furnace operations is milled and floated to recover entrained PGMs in the form of a concentrate, which is recycled through the process (Pulles *et al.*, 2001). Slag tails are disposed on the mine tailings dams (Pulles *et al.*, 2001). The remaining PGM, Gold, Nickel, Copper, Cobalt, Sulphur and Iron are removed from the Furnaces as molten Furnace matte (Lonmin Platinum, 2001b). The Nickel, Copper and Iron Sulphides are heavier than the gangue materials forming the slag and sink to the bottom of the Furnace (Lonmin Platinum, 2001b). This gravity separation forms means of separating the unwanted gangue material (slag) from the metal sulphides (Furnace matte) (Lonmin Platinum, 2001b). The Furnace slag is tapped from the Furnace at a relatively high elevation from one end to the other end at a low elevation (Lonmin Platinum, 2001b).

D.3.4 Converters

At the Furnace matte stage the products of the Furnaces are combined in one of the two Pierce-Smith Converters, which is used to remove Sulphur and Iron and produce a matte, which is the final product (Lonmin Platinum, 2001b; Pulles *et al.*, 2001). This is achieved by blowing air through the molten matte, which oxidizes the Fe to FeO₂ (Lonmin Platinum, 2001b). By adding a suitable flux (silica sand) a slag is formed which is then removed (Lonmin Platinum, 2001b). Likewise some of the Sulphur is oxidized to SO₂ gas, which is disposed of in the atmosphere via the Main stack (Lonmin Platinum, 2001b). After slag removal, the molten product from the Converter (Converter matte) is granulated by pouring a steady stream of matte into a cold jet of water which is sprayed at a rate of approximately 14 000 liters per minute (Lonmin Platinum, 2001b). The granulated matte is then weighed, bagged and sent to the Base Metal Refinery (Lonmin Platinum, 2001b; Pulles *et al.*, 2001).

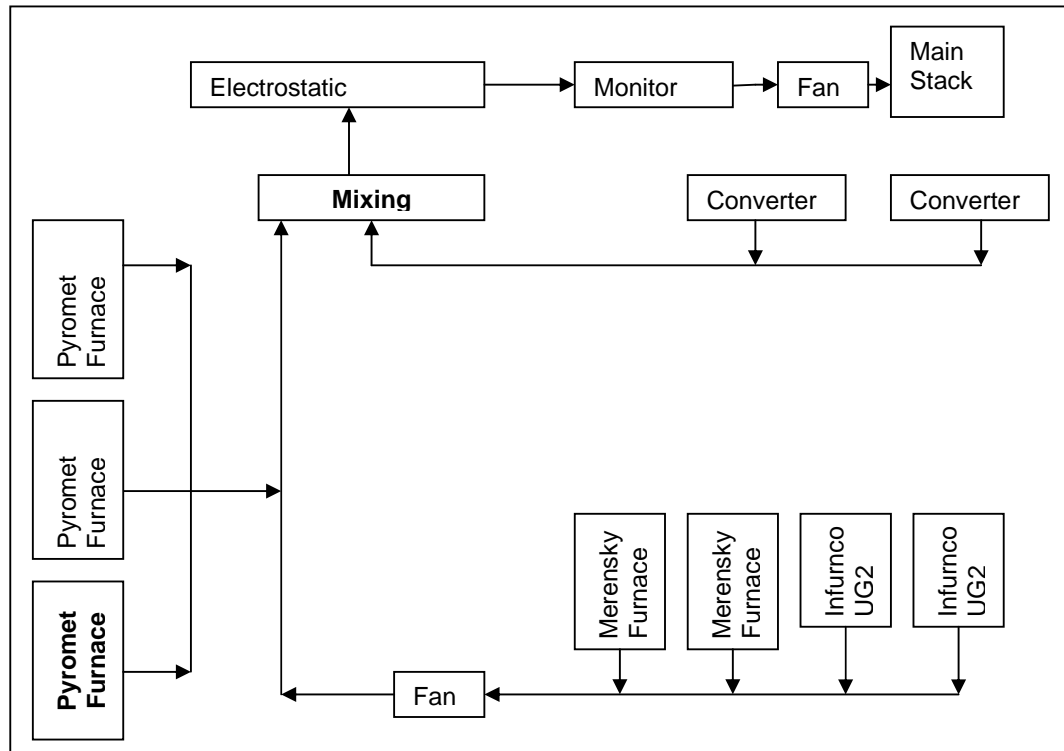


Figure D.1: The layout of a section of the Lonmin Platinum Smelter³

D.3.5 Acid plant

Lonmin Platinum does not have an Acid plant, because most of the concentrate used in the Smelter is UG₂ ore, which has much less Sulphur in than ore from the Merensky reef.⁴ Therefore, the amount of SO₂ vented through the Main stack is less, even though there is no Acid plant⁴. A Dual Alkalize Scrubber Plant was installed in 2002 (Pulles *et al.*, 2001)³.

Appendix E

Calculations

Table E.1: Calculations relating to atmospheric particulates (Boubel *et al.* (1994); Bridgman, (1990); SRK (1997))

parts per million (pp. m)	Quantity of a gaseous pollutant present in the air
1 pp. m	1 volume of gaseous pollutant / 10^6 volumes (pollutant + air)
	0.0001 percent by volume
$\mu\text{g.m}^{-3}$	Mass of a pollutant is expressed as micrograms of pollutant per cubic meter of air.
Basic relation between $\mu\text{g.m}^{-3}$ and pp. m at 1atm and 25°C	$\mu\text{g.m}^{-3} = \text{pp. m} \times \text{molecular weight} \cdot 24.5 (10^{-3})$
To convert from units of pp. m (vol) to $\mu\text{g.m}^{-3}$, it is assumed that the ideal gas law is accurate under ambient conditions. A generalized formula for the conversion at 25°C and 760 mm Hg	<p>Example: $\text{SO}_2 = 1 \mu\text{g.m}^{-3} = 0.35\text{pp. b}$</p> <p>1 pp. m (vol) pollutant = 1 liter pollutant. 10^{-6} liter air = $(1 \text{ liter} / 22.4) \times \text{MW} \times 10^6 \mu\text{g.gm}^{-1} / (10^6 \text{ liters} \times 198^\circ\text{K} / 273^\circ\text{K} \times 10^{-3}\text{m}^3 \cdot \text{liter}^{-1})$ = $40.9 \times \text{MW} \mu\text{g.m}^{-1}$ (MW equals molecular weight)</p> <p>Example for October 2001 for Lonmin Platinum: $148 \text{ mg.m}^{-3} \times 56.7 \text{ m}^3\text{s}^{-1} \times 3600 \times 720$</p> <p>----- 1000 000</p>
$\mu\text{g.m}^{-3}$ to t.months^{-1} :	actual mg.m^{-3} x flowrate x seconds in a hour x hours in a month / $1000 \times 1000 \times 1000$

Appendix F

Gravimetric sampling procedure

F.1 Introduction

The Gravimetric sampling procedure was designed to determine the amount of particulates and gases workers are exposed to during a normal 8-hour workday (DME, 1999). Every manager of a mine must implement a Code of Practice for Occupational Hygiene programmes where significant hazards have been identified (DME, 1999). The criteria for a significant hazard is (DME, 1999):

- a. Airborne pollutants: $\geq 10\%$ of the occupational exposure level,
- b. Thermal stress: heat $\geq 27,5^{\circ}\text{C}$ wet bulb and $\geq 37^{\circ}\text{C}$ dry bulb; cold $\leq 6^{\circ}\text{C}$ dry bulb,
- c. Noise: 82 dB (A), and
- d. Radiation: $\geq 1 \text{ mSv}\cdot\text{a}^{-1}$.

F.2 Guideline for the compilation of a mandatory Code of Practice for an Occupational Hygiene Programme

The guideline replaced the Guideline for the Gravimetric Sampling of Airborne Particulates for Risk Assessment in terms of the Occupational Diseases in Mines and Works Act No. 78 of 1973 (DME, 1999). The guideline does not stipulate requirements for specific circumstances but sets out a basic system for managing the risk to health (DME, 1999). When undertaking an occupational hygiene programme the following steps must be included (Burger & Scorgie, 2000b; DME, 1999).

F.2.1 Risk assessment

- a. List the significant airborne pollutants to which employees are being exposed,
- b. List health effects associated with the significant airborne pollutants identified,
- c. The Occupational Exposure Levels (OELs) for each hazardous airborne pollutant must be identified (TableF.1). Legally binding OELs are available for the assessment of exposures,
- d. List the key operations and activities that pose the greatest potential for exposure to pollutants,
- e. Availability and use of material safety data sheets for significant airborne pollutants identified, and
- f. The risk assessment process used must be briefly described.

Table F.1: Occupational exposure levels for various elements (Lonmin (2001b); DME (2001))

Elements	Threshold Limit Value	Elements	Threshold Limit Value
Al (salts)	2 mg.m ⁻³	Ni (soluble compounds) Ni (insoluble compounds)	0.1 mg.m ⁻³ 0.5 mg.m ⁻³
Al (metal) Inhalable particulate Respirable particulate	10 mg.m ⁻³ 5 mg.m ⁻³	Pb (fume)	0.15 mg.m ⁻³
Cr metal, Cr [II] and Cr [III] compounds	0.5 mg.m ⁻³	Pb (dust)	0.15 mg.m ⁻³
Cr [VI] compounds	0.05 mg.m ⁻³	Pt (soluble) Pt mine dust respirable particulate <5% crystalline quartz / silica >5% crystalline quartz / silica	0.002 mg.m ⁻³ 3.0 mg.m ⁻³ 0.1 mg.m ⁻³
Rh (metal fume and dust)	0.1 mg.m ⁻³	Pt (metal)	5.00 mg.m ⁻³
Rh (soluble)	0.001 mg.m ⁻³	Cu (fume)	0.2 mg.m ⁻³
Ni (metal)	0.5 mg.m ⁻³	Cu (dusts and mists)	1 mg.m ⁻³
Rest	10 mg.m ⁻³	Mg Inhalable particulate Fume and respirable particulate	10 mg.m ⁻³ 5 mg.m ⁻³

Threshold Limit Values (TLV) are the limits set for almost all chemicals, minerals and dusts to which healthy persons (aged 18 to 65) are permitted to be exposed for periods of up to 8 hours per day (Table F.1) (Strauss & Mainwaring, 1984). Three categories of TLVs are defined in order to account for acute and sub-acute exposures (Burger & Scorgie, 2000b):

a) Threshold Limit Value - Time Weighted Average (TLV-TWA)

Represents the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

b) Threshold Limit Value - Short-term Exposure Limit (TLV-STEL)

Represents the concentration to which workers can be exposed continuously for a short period of time without suffering from

1. Irritation,
2. Chronic or irreversible tissue damage, or
3. Narcosis of sufficient degree to increase the likelihood of accidental injury, impair self rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded.

c) Threshold Limit Value - Ceiling (TLV-C)

The concentration should not be exceeded during any part of the working exposure.

F.2.2 Determination of homogeneous exposure groups

The second step in the procedure would be to identify Homogeneous Exposure Groups (HEG) (Table F.2) (DME, 1999). Four different categories were identified.

Table F.2: Classification band (DME, 1999)

Classification bands	
Category	Personal exposure level
A	Individual exposures \geq the OEL or mixtures of exposures ≥ 1
B	Individual exposures $\geq 75\%$ of the OEL and the OEL or mixtures of exposures between ≥ 75 and 1
C	Individual exposures $\geq 50\%$ of the OEL and $< 75\%$ of the OEL or mixtures of exposures between ≥ 0.5 and < 0.75
D	Individual exposures $\geq 10\%$ of the OEL and $< 50\%$ of the OEL or mixtures of exposures between ≥ 0.1 and < 0.5

F.2.3 Gravimetric sampling monitoring

After the determination of the HEGs Gravimetric sampling monitoring is to be conducted on an annual cycle period (1 January – 31 December) (DME, 1999). It is imperative that correct, meaningful and representative results are obtained (DME, 1999). For a given HEG, samples must be randomly assigned covering all shifts (different employees on different days over the monitoring time period) (Table F.3) (DME, 1999). The exposures measured for any individual employee for individual pollutants are allocated to the medical record/s of that specific employee and to all the other employees within that HEG (DME, 1999). Medical surveillance must be initiated once 10% of the OEL of a pollutant is exceeded (DME, 1999). The mine must draw up a sampling strategy including a monitoring programme (consisting of methodology, design and implementation) for each HEG, for the cycle period, and keep a record thereof (DME, 1999).

Table F.3: The mandatory frequency of sampling (DME, 1999)

Category	Frequency
A	Sample 5% of employees within a HEG on a monthly basis with a minimum of 5 samples per HEG, whichever is the greater
B	Sample 5% of employees within a HEG on a 3 monthly basis with a minimum of 5 samples per HEG, whichever is the greater
C	Sample 5% of employees within a HEG on a 6 monthly basis with a minimum of 5 samples per HEG, whichever is the greater
D	Sample 5% of employees within a HEG on an annual basis with a minimum of 5 samples per HEG, whichever is the greater

F.2.4 Sampling and analysis methodology

The sampling methodology to be used is dependant on the pollutant to be monitored and in accordance with internationally compatible best practice methodologies (DME, 1999). The relevant methodology chosen for each significant pollutant identified must be stated in the Code of Practice with a Quality Assurance (QA) programme implemented (DME, 1999). When sampling for particulates, the respirable fraction of airborne particulates based on the “Johannesburg Curve” for size distribution (*i.e.* particle aerodynamic diameter <7.0 micron) is to be used in the sampling methodology (DME, 1999).

The South African Bureau of Standards (SABS) is recognised by the Department of Minerals and Energy (DME) to approve analysis methods (DME, 1999). Companies who supply analysis services must have their laboratory approved by the SABS and supply their clients with a copy thereof (DME, 1999). The laboratory’s own operating procedures and quality control practices must be documented in the Code of Practice (DME, 1999). Analysis of samples must be as per recognised internationally compatible best practice techniques and must be stated in the Code of Practice (DME, 1999).

F.2.5 Reporting and recording

The following mandatory reports are required (DME, 1999):

- a) Quarterly personal exposure report signed by the manager and kept for record purposes at the mine. The report must reach the office of the DME: Occupational Hygiene Directorate for their action / records no later than 30 days subsequent to the end of the sampling quarter: March, June, September, and December.
- b) Occupational exposure assessment reports and records (to be kept at the mine).

F.2.6 Control measures

If there is found to be significant risk, a hierarchy of control measures is implemented (DME, 1999)⁷:

- a. Elimination, substitution and isolation;
- b. Engineering controls: *e.g.* extra ventilation, enclosures;
- c. Administrative controls: *e.g.* people work in shorter shifts in a problem area – only a few hours in furnace, then moved to another section;
- d. Personal protective equipment (*e.g.* respirators); and
- e. Ensure the use of:
 1. Information, instruction, training;
 2. Rules and procedures; and
 3. Supervision

In the following sections the Gravimetric sampling procedures used by the three Smelters participating in the study are discussed.

F.3 Anglo Platinum

F.3.1 Basic sampling techniques

A portable battery operated sampling pump calibrated before use is attached to a worker (Anglo Platinum, 2001b). A membrane filter, pre-weighed on a microbalance, is placed in a filter cassette holder, which in turn is placed into a small cyclone that will separate the respirable fraction from the coarser dust (Anglo Platinum, 2001b). The respirable fraction is collected on the membrane filter, whilst the non-respirable fraction is collected in a small container at the bottom of the cyclone (Anglo Platinum, 2001b). The filter cassette-cyclone combination is clipped onto the worker's lapel, with the device within 300 mm from the nose (a piece of connecting tube is fitted between the pump and the filter cassette) (Anglo Platinum, 2001b). When the pump is switched "on" the time is noted and again when the pump is switched "off"; therefore the total sampling duration is noted and by multiplying the latter with the calibrated flow-rate, one can calculate the total volume of air sampled (Anglo Platinum, 2001b). The pre-weighed filter is weighed again and the mass of particulates sampled is determined by subtracting the pre-weight from the post-weight (Anglo Platinum, 2001b). The concentration of the particulates is expressed as μg respirable particulates per volume of air sampled (m^3) (Anglo Platinum, 2001b).

F.3.2 Sampling method, reporting and analyses

Waternet Smelter is subdivided into 13 sampling areas (*e.g.* Furnace, Flash dryer and Engineering) with each sampling area subdivided into activity areas (*e.g.* Furnace upper level and furnace lower level) (DME, 1999)⁷. Each activity area consists of HEGs (*e.g.* Furnace tapper, operator)⁷. Anglo Platinum makes use of the sampling frequency described in Category B (Table F.3, Table F.4 and Table F.5) (DME, 1999)⁷. Samples are analysed twice a year by an independent consultant (DME, 1999)⁷.

Table F.4: Example of a gravimetric sampling schedule: January 2001) (Anglo Platinum, 2001b)

Week	Date		Monday	Tuesday	Wednesday	Thursday	Friday		
1	01 to 05	S	P						
		S A							
		S P							
2		S			D	D			
		S A			3	3			
		S P			3:1	3:2			
3		S		M	M	A	A	N	N
		S A		1	1	4	4	1	2
		S P		1:2	1:3	4:1	4:2	1:4	2:1
4		S	M	D	M			D	M
		S A	2	3	1			3	1
		S P	2:2	3:3	1:1			3:4	1:5
5		S							
		S A							
		S P							

Legend to be used:
S = shift to be sampled
S.P = statistical population number
S.A = sampling area number
Date = weekly period (e.g. 01 – 07)
M = morning shift
D = day shift
A = afternoon shift
P = public holiday

Table F.5: Example of how statistical populations are described (Waterval Smelter: January to June 2001) (Anglo Platinum, 2001b)

Number	Area	Number of persons	No of samples to be taken	% of persons sampled for the 6 months cycle
1:1	Furnace area – lower levels	72	5	6.9
1:2	Converter area	67	5	7.4
1:3	Crane drivers	12	5	41.7
1:4	Slow cool area and WCM crushing and conveying	18	5	27.8
1:5	Furnace area	36	5	13.8
	Flash dryers and flux reverts section			
2:1	Flash dryers	61	5	8.2
2:2	Flux reverts	7	5	71.4
	Engineering			
3:1	Hot metals Boilermaker workshop and fitter workshop	75	5	6.7
3:2	Charge preparation workshop	32	5	15.6
3:3	Vehicle maintenance, electrical and instrumentation workshops	59	5	8.5
3:4	Masons workshop	32	5	15.6
	Wet chemical processes and rowing occupations		5	
4:1	Wet chemical processes (acid plant and slag mill)	37	5	7.8
4:2	Rowing occupations	76	5	6.6

A monthly report is sent to the Smelter Business Manager and the committee responsible for Health and Safety matters at the Smelter with a comprehensive report compiled once a year⁷. The Occupational Hygienist is responsible for conducting projects to improve equipment and administrative controls if the emission levels are unacceptable high⁷. Proposals must first be referred to the Environmental officer or the Business Manager of the Smelter⁷.

F.4 Impala Platinum

F.4.1 Basic sampling techniques

The sampling techniques used are the same as those described above for Anglo Platinum.

F.4.2 Sampling method, reporting and analyses

Impala Platinum Smelter is classified as an activity area and is subdivided into sampling areas, which is further divided into Homogeneous Exposure Groups (HEG)². The Occupational Hygienist identified 14 HEGs for Impala Platinum Smelter:¹¹

1. Acid Plant,
2. Converter,
3. Converter Aisle,
4. Converter Blower,
5. Converter Skimmer,
6. Dryer,
7. Furnace,
8. Furnace Smelter Services,
9. Furnace Tapping,
10. Smelter Roving,
11. Toll Business Lab/Sampling,
12. Toll Business ACR,
13. Toll Business Bunker, and
14. Toll Business Catalyst.

Samples are taken on a daily basis, and batched on a quarterly basis and sent for analyses at a SANAS approved Laboratory¹¹. The results are sent to the Occupational Hygienist after which it is determined if any action is needed¹¹. The results are further sent to employees in writing with comments from the Ventilation Officer included¹¹. Management receives reports on a monthly, quarterly and yearly basis¹¹. Impala Platinum implemented a new report structure in December 2002 because the previous structure was found to be inadequate¹¹. The objective is to use the database as a live action plan to assist management to comply with the Health Regulations¹¹.

F.5 Lonmin Platinum

F.5.1 Basic sampling techniques

Lonmin Platinum ascribe to the same Department of Minerals and Energy (DME) procedure as used by the other two Platinum mines³ (described above). The procedure are explained to workers to ensure they understand the importance thereof (Table F.6).

Table F.6: Information given to workers of Lonmin Platinum Smelter to explain the gravimetric sampling procedure (Lonmin Platinum, 2001b)

Most people have an idea of what dust is: soil blown about causing a dust storm, and household dust. In the work environment, dusts are an ever-present nuisance and often a health hazard. It is caused by such activities such as polishing, drilling, sifting or handling of materials, especially in powder form. The term airborne particulates are often used when referring specifically to dust particles floating around in the air in a working environment. The human being's lungs are able to deal with the dusts breathed in by coughing it out of the body, but breathing in a lot of hazardous dust which may happen at the workplace, overburdens the lungs and leads to a state of disease. The extensive accumulation of dust in the lungs, together with the lungs' reaction to its constant presence is called Pneumoconiosis. This word is derived from the Greek words 'pneumo' and 'konios' meaning "lung" and "dust". In order to detect if the worker is being excessively exposed to airborne particulates, the worker needs to wear a personal sampling pump for measuring the exposure level of the worker, taking into consideration the time the worker may be exposed. This is done in the identified 'dusty' areas of the plant.

Lonmin use gravimetric pumps to measure this. The little pumps suck in the air, which is passed through a special filter (cassette). The dust, which may be breathed in by the worker, accumulates on the filter. This filter with the dust is analysed at the lab to detect for hazardous dust. It is important that the worker does not interfere with the pump or filter, as the lab technician may not be able to detect if the worker is being exposed and a wrong exposure level can result. Once at the lab they detect that the worker is being exposed to hazardous dust, and then the problem at the workplace can be sorted out.

To check if the worker is over exposed or not, the lab technician / analyser does a scientific calculation, taking into consideration: the airflow rate through the sampling instrument; the sampling period; the mass of the dust collected on the filter; the amount of people working in the area and the legal limit of the concentration of dusts. If this figure is = or > 1, then there is a problem and the limit has been exceeded. If it works out to less than 1, then there is no problem and the limit has not been exceeded. It is important that the blue or red 'plug' on the filter cassette is removed before the pump is started – if this is not done, the pump will flash a red error light. The foreman, who records the exact time the pump began and stopped, fills in the field sheet. This field sheet and the pump that has been switched off at the end of the wearer's shift, as well as the filter cassette, are returned to the Gravimetric Department for weighing. The results of the sampling exercise will be put on the notice board.

F.5.2 Sampling method, reporting and analyses

Sampling is conducted on a monthly basis using a personal air sampler (Gillian Pump with cellulose filters) (Lonmin Platinum, 2001b). The Lonmin Platinum Smelter is classified as an activity area and is subdivided into sampling areas (Assay Laboratory and Smelter / BMR complex), which is further divided into HEGs (e.g. furnace and converter).⁴

The Assistant Environmental Officer of the Smelter is responsible for the sampling and also takes the final responsibility for the data⁴. The samples are sent to the the Senior Environmental Officer (Central Services) which sends it for analysis on a yearly basis. Results are obtained 3 months later.⁴ Every six months the Assistant Environmental Officer has the opp. ortunity to change the HEG's, in order to include important communities that may be left out⁴. The Senior Environmental Officer reports the results back to the Assistant Environmental Officer of the Smelter⁴.

Appendix G

Policy Statements

G.1 Anglo Platinum: Safety, Health and Environmental Policy (Anglo Platinum, 2001b)

Anglo American Platinum Corporation Limited, as the world's leading primary producer of platinum group metals, commits itself to the creation of a safe and healthy environment for all our employees and the citizens of the communities with which we interact.

1. Aims

In order to give practical expression to our commitment and to measure our progress we have the following aims:

1. Safety and health
 - i. Prevent or minimise workrelated injuries and health impairment of employees and contractors, and
 - ii. Contribute to addressing priority community health issues.

2. Environment
 - i. Conserve environmental resources;
 - ii. Prevent or minimise adverse impacts arising from our operations;
 - iii. Demonstrate active stewardship of land and biodiversity;
 - iv. Promote good relationships with, and enhance capabilities of, the local communities of which we are a part; and
 - v. Respect people's culture and heritage.

2. Management principles

All our Business Units are required to adhere to the following principles in a systematic and comprehensive fashion, and actively encourage implementation by business partners. Further all contractors are obliged to comply with the provisions of this policy.

a. Commitment

Hold senior line managers within each Business Unit accountable for safety, occupational health and environmental issues. Allocate adequate financial and human resources to ensure that these issues are dealt with in a matter that reflects their high corporate priority.

b. Competence

Ensure workforce competence and responsibility at all levels through selection, retention, education, training and awareness in all aspects of safety, health and the environment.

c. Risk assessment

Identify, assess and prioritise the hazards and risks associated with all our activities.

d. Prevention and control

Prevent, minimise or control priority risks through planning, design, investment, management and workplace procedures. Prepare and periodically test emergency response plans. Where accidents or incidents do occur, take prompt corrective action, investigate root causes and take remedial action. Actively seek to prevent recurrences and disseminate experiences learned.

e. Performance

Set appropriate goals, objectives, targets and performance indicators for all our operations. Meet all applicable laws and regulations as a minimum and, where appropriate, apply international best practice.

f. Evaluation

Monitor, review and confirm the effectiveness of management and workplace performance against company standards, objectives, targets and applicable legal requirements. Key to this process is a system of appropriate audits and progress reports to senior management coupled with regular reporting to the Board of Directors of Anglo American plc.

g. Stakeholder engagement

Promote and maintain open and constructive dialogue and good working relationships with employees, local communities, regulatory agencies, business organisations and other affected and interested parties, to increase knowledge and enhance mutual understanding in matters of common concern. Report on progress towards the achievement of our aims.

h. Continual improvement

Foster creativity and innovation in the management and performance of our businesses, and our approach to solving the challenges facing our enterprises. Support

research and development into safety, health and environmental issues, and promote the implementation of international best practices and technologies where appropriate.

G.2. Impala Platinum: Environmental Policy Statement (Impala Platinum, 2001b)

We recognise that our activities, whilst contributing to an improved quality of life, do impact on the environment. These impacts affect each and every stakeholder, including our employees, shareholders and local communities. It is therefore our vision to become world class in the management of environmental impacts. To realise this vision Impala Platinum is committed to:

- 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 our 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 our environmental performance to stakeholders including employees, shareholders, the community and other interested parties.

This policy will be regularly reviewed to ensure that it adequately reflects our commitment to continual improvement through better systems and greater environmental efficiency. The Board of Directors will ensure that resources are made available to meet these commitments.

G.3 Lonmin Platinum Safety, Health and Environmental Policy (Lonmin Platinum, 2001b)

We realise our operations have the potential to expose employees and surrounding local communities to safety, health and environmental hazards. Therefore, it is our responsibility towards our employees and the environment to conduct our core business of Smelting and Base Metal Recovery in a manner non-detrimental to all. With this as our objectives, we commit ourselves to:

- a. Compliance with relevant safety, health and environmental legislation and other requirements guiding responsible practice;
- b. Use best available technology, where economically viable, to minimise the health and safety risks and prevent pollution at source; and
- c. Continual improvement of our safety, health and environmental management systems and performance, illustrating our commitment towards responsible practice.

To ensure that we meet our objectives, we shall focus on:

- a. Implementing management systems to identify, manage and monitor the safety, health and environmental aspects of Metallurgical services' activities, products and services;
- b. Continuously strive to reduce the air emission and water effluents of our operations;
- c. Reduce, re-use and re-cycle waste and ensure the legal and safe disposal thereof;
- d. Manage all chemical, including oil, through the responsible purchasing, storage and clean-up of spillage;
- e. Inform, train and develop our people on the importance of safety, health and environmental management as well as on their roles and responsibilities;
- f. Open and transparent communication to interested and affected parties on safety, health and environmental matters;
- g. Rehabilitate the slag dump to minimise the safety, health and environmental impacts thereof; and
- h. Optimise the consumption of resources to ensure the sustainability of our operations and long-term benefits to stakeholders.

The 2000 Safety, Health and Environmental Policy was reviewed and has been refined to reflect the company's new thinking (Lonmin Platinum, 2002).

Vision

Lonmin's vision is to be the safest, most cost-effective producer of PGMs whilst providing above-average returns for our shareholders. Sustainable development is a challenge which we have accepted and will work towards in all our operations.

Commitment

In order to meet this vision, Lonmin is committed to:

- a. Implementing and maintaining effective safety, health and environmental management systems that drive continual improvement through regular, objective review;
- b. Ensuring employee knowledge of the safety, health and environmental risks by effective assessment and training;

- c. The reduction, re-use and recycling of waste to minimise final disposal and promote the efficient use of natural resources;
- d. Preventing and reducing all forms of pollution by employing effective technologies to control emissions to air and pollution of land and water;
- e. Maintaining transparent, consultative relationships with all stakeholders through effective communication channels;
- f. Contributing to the long-term social, economic and institutional development for our employees and the communities within which our operations are located; and
- g. Complying with applicable legislation and other relevant industry norms.

App. endix H

Control equipment

H.1. Inertial collectors

Inertial collectors (cyclones, baffles, louvers, or rotating impellers) operate on the principle that the aerosol material in the carrying gas stream has a greater inertia than the gas (Boubel *et al.*, 1994). Since the drag forces on the particulate are a function of the diameter squared and the inertial forces are a function of the diameter cubed, it follows that as the particulates diameter increases, the inertial (removal) force becomes relatively greater (Boubel *et al.*, 1994).

H.2. Filters

Filtration is one of the oldest and most widely used methods of separating particulates from a gas (Johnson, 1998). A filter removes particulate matter from the carrying gas stream as the particulate impinges on and then adheres to the filter material (Boubel *et al.*, 1994). With time passing, the deposit of particulate matter becomes greater and the deposit itself then acts as a filtering medium (Boubel *et al.*, 1994). When the deposit becomes so heavy that the pressure necessary to force the gas through the filter becomes excessive, or the flow reduction severely impairs the process, the filter must either be replaced or cleaned (Boubel *et al.*, 1994). Industrial filtration systems are varied, but the most common type is the baghouse (Boubel *et al.*, 1994).

H.3. Electrostatic precipitators

The Electrostatic Precipitator (ESP) works by charging dust with ions and then collecting the ionized particulates on a surface consisting of either tubular or flat plates (Johnson, 1998; Boubel *et al.*, 1994)⁴. For cleaning and disposal, the particulates are then removed from the collection surface, usually by rapping the surface (Boubel *et al.*, 1994)⁴. A DC field of at least 30kV (high enough that a visible corona can be seen at the surface of the wire) is established between the central wire electrode and the grounded collecting surface resulting in a cascade of negative ions in the gap between the central wire and the grounded outer surface (Boubel *et al.*, 1994). Any aerosol entering this gap is both bombarded and charged by these ions that then migrate to the collecting surface because of the combined effect of this bombardment and the charge attraction (Boubel *et al.*, 1994)⁴. When the particulates reaches the collecting surface, it loses its charge and adheres because of the attractive forces existing and stays there until the power is shut off and it is physically dislodged by rapping, washing, or sonic means (Boubel *et al.*, 1994)⁴.

H.4. Scrubbers

Scrubbers, or wet collectors, have been used as gas-cleaning devices for many years (Boubel *et al.*, 1994). The process has two distinct mechanisms resulting in the removal of the aerosol from the gas stream (Boubel *et al.*, 1994). The first mechanism involves wetting the particulates with the scrubbing liquid (Boubel *et al.*, 1994). The particulates are trapped when it travels from the supporting gaseous medium across the interface to the liquid scrubbing medium (Boubel *et al.*, 1994). Some relative motion is necessary for the particulates and liquid-gas interface to come in contact (Boubel *et al.*, 1994). In the spray chamber, the droplets are sprayed through the gas so that they impinge on and make contact with the particulates - the smaller the droplet, the greater the collection efficiency (Boubel *et al.*, 1994).

The second mechanism is removal of the wetted particulates on a collecting surface (a bed or simply a wetted surface), followed by the eventual removal from the device (Boubel *et al.*, 1994). One common combination follows the wetting section with an inertial collector, which then separates the wetted particulates from the carrying gas stream (Boubel *et al.*, 1994). The ultimate scrubber in this respect is the venturi scrubber (operates at extremely high gas and liquid velocities with a very high pressure drop across the venturi throat) (Boubel *et al.*, 1994).

Classical dedusting and wet scrubbing techniques are rapidly being displaced by advanced filtration and dry scrubbing technologies (Otto, 1995). Dry scrubbing uses a dry absorbent to collect organics, SO₂, HF and HCl producing a stable by-product, which is realized in a “contact device” (venturi reactor) followed by a “separation device” (bag filter) where an all dry stable by-product is produced (Otto, 1995).

H.5. Other measures

Contaminants can also be removed from industrial waste air by (Chitwood *et al.*, 2000):

a) Thermal treatment

Thermal treatment includes direct flaring or catalytic oxidation and is effective when the concentration of the organic pollutant is high enough to provide the majority of the energy required (Chitwood *et al.*, 2000). However, it becomes too costly when concentrations are low because a secondary fuel has to provide the majority of the energy required to oxidize the contaminant (Chitwood *et al.*, 2000).

b) Biological treatment systems

Biological treatment systems provide ecologically sensitive as well as cost effective options because they mimic natural processes, require less resource intensive operation and maintenance, and reduce or eliminate the need for additional treatment of end products (Chitwood *et al.*, 2000). These systems also meet the need for an economical method for treating and controlling (Chitwood *et al.*, 2000):

1. Low contaminants concentrations in waste air,
2. Odour removal,
3. Hazardous air pollutants,
4. Volatile organic compounds, and
5. Smog precursor emissions

c) Activated carbon adsorption

Compounds are adsorbed onto the surface of carbon producing a very clean effluent (Chitwood *et al.*, 2000). However, the amount adsorbed per unit mass of carbon is related to the concentration of the contaminant in the air (Chitwood *et al.*, 2000). Low concentrations cause a low adsorption rate; therefore, the amount of carbon required per unit mass of contaminant becomes too large as concentrations decrease (Chitwood *et al.*, 2000).

d) Clean technology

The ideal way to avoid the emission of pollutants is a complete recycling of all materials in the complex ecosystem encompassing the whole world, but so far technology does not allow for this (Figure H.1) (Johnsson, 1998).

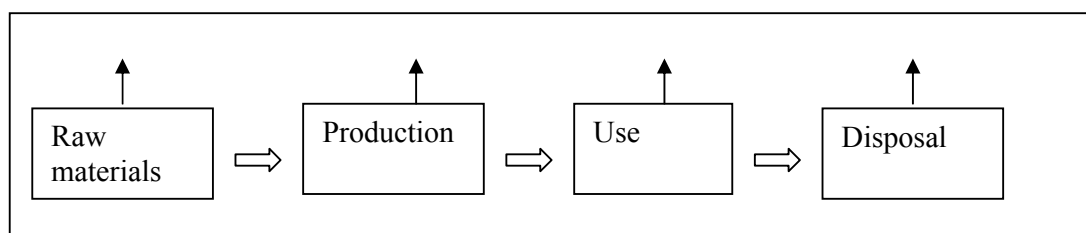


Figure H.1: Traditional production process with emissions to the atmosphere (Johnsson, 1998).

Further, the energy consumption for a 100% recycling of material may be very high, giving rise to high emissions from energy conversion processes and consequently an increase

in total emissions (Johnsson, 1998). However, it is possible to reduce pollution emissions from production, use and disposal of products by proper planning of the production processes (Johnsson, 1998). The ultimate way to reduce emissions would be to recirculate all waste and close the process completely or to use all waste and byproducts in other production processes (Figure H.2) (Johnsson, 1998).

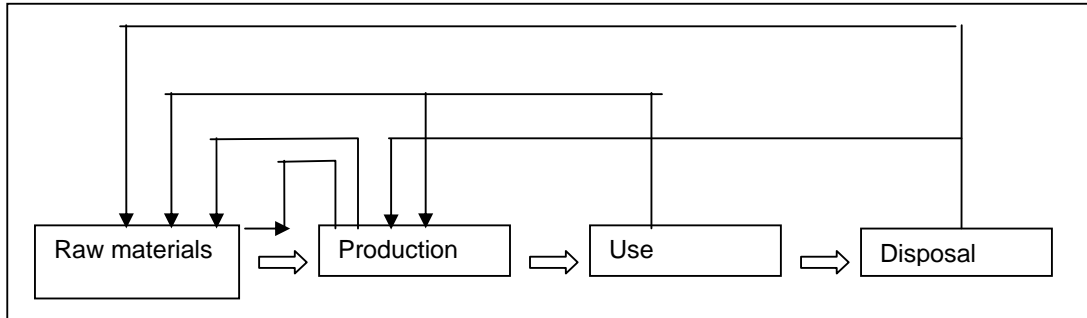


Figure H.2: Clean technology, recirculation of waste materials (Johnsson, 1998).