TITLE AND DESCRIPTIVE ABSTRACT

FORTUNE METALIKS SA (PTY) LTD

REPORT 0513-P008-FOR

AMBIENT AIR QUALITY IMPACT STUDY FOR A PROPOSED STEEL RECYCLING AND PROCESSING FACILITY IN NIGEL

This report documents the results and findings of an air quality impact investigation pertaining to the proposed manufacturing of form steel products by Fortune Steels at 12 Johnson Road, Nigel Industrial Area, Ekurhuleni Metropolitan Municipality.

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TECHNICAL VERIFICATION

All results and related data have been obtained through careful and precise execution of recognised methods of evaluation and are related only to the scope of work covered in this report and of prevailing conditions at the time of the assessment. The opinions and interpretations are embraced through judgment, discernment and comprehension to the best of available knowledge.

Fieldwork and report compilation performed by:

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1 April 2014

Date

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1. INTRODUCTION

1.1. TERMS OF REFERENCE

Environmental and Health Risk Consulting (Pty) Ltd (EHRCON) was retained by Fortune Metaliks South Africa (Pty) Ltd (Fortune) to perform an ambient air quality impact assessment in support of the proposed Fortune Steels recycling and processing facility.

The proposed steel plant will be situated at 12 Johnson Street, Nigel Industrial Area, within the Ekurhuleni Metropolitan Municipality (see **Figure 1**).

In accordance with the Listed Activities and Minimum Emission Standards identified in terms of Section 21 of the National Environmental Management: Air Quality Act (Act 39 of 2004) (NEMAQA), Fortune Steels must submit an application for an Atmospheric Emission Licence (AEL) to operate the proposed steel plant. The steel plant will incorporate a 6MVA induction furnace, a Radius Continuous Casting Machine to produce mild steel billets and a rolling mill.

The scope of this study was based on the requirements of the NEMAQA for AEL applications as well as specific conditions outlined by Mr G Bansal of Fortune Steels.

The objectives of this study were to describe the ambient emissions from the process and to assess the impact on the health of the receiving community. The findings of the study are aimed at providing Fortune Steels, the Ekurhuleni Metropolitan Municipality and other stakeholders with scientific data required in terms of present and future air quality management systems.

Potential sensitive receptors associated with this project include industrial and commercial receivers up a distance of 2km from the operation. No formal residential areas are located within the study area.

Figure 1: Location of Fortune Steels (red polygon)

The assessment of emissions from the steel plant comprised the following terms of reference:

- A review of the legislative framework, ambient air quality standards and guidelines as well as relevant health criteria (Chapter 2).
- A process description and baseline emission inventory (Chapter 3).
- A description of the local climate and meteorology (Chapter 3).
- An overview of available data on criteria air pollutant concentrations in the area (Chapter 4).
- Assessment of the potential for human health and environmental impacts based on comparisons of modelled pollutant concentrations with relevant guidelines and standards (Chapter 4).
- Assessment of the incremental contribution of the process and the cumulative outcome on selected future air quality parameters in the study area (Chapter 4).

1.2. METHODOLOGICAL OVERVIEW

The establishment of an emissions inventory formed the basis for assessing the impact from the process. The inventory comprised the identification of sources of emission and the quantification of each source's contribution to ambient air concentrations. In the emissions inventory, dispersion simulation and impact assessment, reference was made to routine emissions from production processes.

Process emission rates were obtained from emission factors which associate the quantity of a pollutant to the activity associated with its release. Due to the absence of locally generated emission factors, use was made of the comprehensive set of emission factors published by the United States Environmental Protection Agency (US-EPA) in its AP-42 document *Compilation of Pollution Emission Factors*.

The simulation of emissions was performed through the application of the ISC-AERMOD View Model. AERMOD is a steady-state plume model, applicable to rural and urban areas, flat and complex terrain, surface and elevated releases, and multiple sources (including, point, area and volume sources). In the stable boundary layer (SBL), the concentration distribution is assumed to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal

distribution is assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function. Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate.

Ambient pollutant concentrations were simulated to ascertain highest hourly, daily and annual averaging levels to facilitate comparisons with air quality guidelines.

1.3. KEY FINDINGS

The study, aimed at describing emissions from the proposed steel plant of Fortune Steels in Nigel, concludes the following:

- Criteria pollutants account for less than 1% of atmospheric emissions from the facility. The greenhouse gas, carbon dioxide, is the major pollutant emitted from processes and particulate matter, the criteria pollutant of significance.
- Emission estimation based on similar, existing operations in Europe and the USA, indicate that gaseous and particulate emissions will probably not exceed national emission limits for secondary steel production and combustion processes.
- The smelting and combustion processes are the dominant sources of ambient pollution, discharging more than 99% of the total emission load. Less than 1% of the atmospheric pollution load can be attributed to fugitive emissions from housekeeping and vehicle movement.
- Dispersion of emissions from the facility was modelled using the ISC-AERMOD View model based on the standard Gaussian solution.
- The results present the spectrum from maximum ground level concentration to maximum impact area, and accounts for hourly, daily and annual averages.
- Average ground level concentrations were predicted for atmospheric conditions based on local meteorological data for the period January 2008 to December 2013.

- During the construction phase of the project, dust deposition rates in excess of the non-residential standard are predicted at the nearest receivers north and east of the site respectively. These receivers are within 100m of operations. During extreme dry and windy spells, deposition rates as high as 4 000mg/m^2/day may be recorded.
- Daily exceedence of the 24-hour standard of 75µg/m^3 as a result of the process is estimated to remain below 25% of the standard. The impact is limited to industrial receivers up to a distance of 300m from the process boundary.
- It is unlikely that the process independently, would result in annual average PM_{10} concentrations above the national standard of 40µg/m^3 at the nearest receivers.
- Ground level concentrations of all gaseous pollutants are likely to be below the respective lower assessment thresholds for all the relevant reference periods.
- Controlled emissions can be effectively reduced through application of best available industrial control measures and sound environmental management principles. A reduction in emissions of up to 99% can be achieved.
- Process emission testing as indicated in *GN 893 of November 2013* should be performed annually to proof compliance and to assist effective air quality management both for the applicant and the licensing authority.

2. AIR QUALITY ASSESSMENT CRITERIA

2.1. AIR QUALITY DESCRIPTORS

The following words or expressions form the basis of the Act, existing guidelines and SANS standards and will be used in this report-

a) **acceptable** to the authority administering this standard or to the parties concluding the purchase contract, as relevant.

b) **air pollution** means any change in the composition of the air, caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.

c) **air quality standard** comprises limit values based on health risk or environmental risk (or both) and associated averaging periods indicative of exposure durations, in addition to the following criteria:
   - monitoring and data management protocols for air quality assessment and reporting;
   - permissible frequencies of exceeded limit values within defined time frames; and
   - time frames for achieving compliance in non-attainment areas

d) **agglomeration** area with a population of 250 000 or more inhabitants or, where the population is less than 250 000 inhabitants, a population density per square kilometre that justifies the need for ambient air quality to be assessed and managed.

e) **alert threshold** level beyond which there is a risk to human health from brief exposure and for which priority action is required.

f) **ambient air** means outdoor air in the troposphere, excluding work places, were air quality is determined in accordance with SANS 1929:2005.

g) **assessment** method used to measure, calculate, predict or estimate the level of a pollutant in the ambient air.

h) **assessment threshold**
   - **lower assessment threshold** level below which modelling or objective estimation techniques alone may be used to assess ambient air quality; and

- **upper assessment threshold** level above which monitoring is mandatory, and below which a combination of measurements and modelling techniques may be used to assess ambient air quality.

i) **atmospheric emission** or **emission** means any emission or entrainment process emanating from a point, non-point or mobile source that result in pollution.

j) **national** authority national authority responsible for air quality.

k) **provincial authority** provincial government department tasked with air quality management under the National Environmental Management: Air Quality Act.

l) **local authority** local government department tasked with air quality management under the National Environmental Management: Air Quality Act.

m) **averaging period** over which average value is determined.

n) **level** concentration of a pollutant in ambient air or the deposition thereof over a given time.

o) **limit value** level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health or the environment as a whole (or both), to be attained within a given period and not to be exceeded once attained.

p) **margin of tolerance** percentage of the limit value by which this value may be exceeded, subject to the conditions laid down in SANS 69:2004.

q) **natural events** geothermal activities, bush fires, high winds or the atmospheric re-suspension or transport of natural particles from dry regions.

r) **pollutant** substance introduced directly or indirectly by man into the ambient air and likely to have harmful effects on human health or the environment as a whole (or both).

s) **priority area** identified and proclaimed as a priority area by the Minister of Environmental Affairs and Tourism or any member of the executive committee (MEC), by notice in the Gazette and after consultation with relevant stakeholders, where he/she is of the opinion that:

- ambient air quality limits or values are being, or are likely to be exceeded; or
- any other harmful situation exists; and
- the limits or values being exceeded are causing, or may cause, a significant negative impact on the environment or health.

t) **PM10** particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 10µm aerodynamic diameter.

u) **target value** level fixed with the aim of avoiding more long-term harmful effects on human health and the environment as a whole, to be attained where possible over a given period.

v) **zone** area designated by the national authority in which limit values for a specific pollutant are exceeded owing to the concentrations of that pollutant in ambient air due to natural sources.

2.2. MINISTRY OF ENVIRONMENTAL AFFAIRS

National Environmental Management: Air Quality Act

The Department of Environmental Affairs (DEA) have brought into effect the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (AQA) on 11 September 2005 as part of a broad programme of air quality management reform. Sections 21 and 22 of AQA read as follows:

(1) The Minister must, or the MEC may, by notice in the Gazette -

(a) publish a list of activities which result in atmospheric emissions and which the Minister or MEC reasonably believes have or many have significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage, and

(b) when necessary, amend the list by-

(i) adding to the list activities in addition to those contemplated in paragraph (a);

(ii) removing activities from the list; or

(iii) making other changes to particulars in the list.

(2) A list published by the Minister applies nationally and a list published by the MEC applies to the relevant province only.

(3) A notice referred to in subsection (1) -

(a) must establish minimum emission standards in respect of a substance or mixture of substances resulting from a listed activity and identified in the notice, including-

(i) the permissible amount, volume, emission rate or concentration of that substance or mixture of substances that may be emitted, and

(ii) the manner in which measurements of much emissions must be carried out;

(b) may certain transitional and other special arrangements in respect of activities which are carried out at the time of their listing; and

(c) must determine the date on the notice takes effect.

(4)(a) Before publishing a notice in terms of subsection (1) or any amendment to the notice, the Minister or MEC must follow a consultative process in accordance with sections 56 and 57.

(b) Paragraph (a) need not be complied with if the notice is amended in non–substantive way.

No person may without a provisional atmospheric emission license or an atmospheric emission license conduct any activity –

(a) listed on the national list anywhere in the Republic; or

(b) listed on the list applicable in the province anywhere in that province.

These sections of the AQA make the publication of a list of activities, together with emission limits for these activities and the method by which emissions shall be tested mandatory, on at least the Minister.

Listed activity and minimum emission standards

A list of activities associated minimum emission standards are set out in *National Environmental Management: Air Quality Act (ACT 39 of 2004): List of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage - GN 893 of 22 November 2013.*

The standards given below shall apply only to the activities listed with the proviso that "Existing Plant" standards shall apply from the date eight years after the publication date of these regulations to all plant in operation on the final publication date and plant put into operation within three years of the final publication date of these regulations and "New Plant" standards shall apply to all plant put into operation later than three years after final publication date of these regulations.

The minimum emission standards applicable to the Fortune Steels process are summarised in **Table 1** below.

The owner or operator of a facility in which listed activities are operated shall submit an annual emission report to the licensing authority in terms of section 36 of the Act within a year after first date of issue of license to the facility, and annually thereafter not longer than 13 months after submission of the previous report, for each activity operated within the facility which is listed in this regulation, whether such activity was operated for the full period or not. The emission report shall be in an electronic format approved by the National Air Quality Officer.

Table 1a:

Minimum emission standards for secondary steel making

Substance or mixture of substances		Plant status	mg/m^3 under normal conditions of 273 Kelvin and 101.3kPa
Common name	**Chemical symbol**		
Particulate matter	n.a.	New	30
		Existing	100
Sulphur dioxide	SO_2	New	500
		Existing	500
Oxides of nitrogen	NO_x expressed as NO_2	New	500
		Existing	500

Notes:

Category : Category 4: Metallurgical Industry
Subcategory 4.7: Electric arc furnace and steel making.
Description : Electric arc furnace in steel making industry.
Application : All installations.
Special Arrangement : Secondary fume capture installations shall be fitted to all new furnace installations.

Table 1b:

Minimum emission standards for combustion installations

Substance or mixture of substances		Plant status	mg/m^3 under normal conditions of 273 Kelvin and 101.3kPa
Common name	**Chemical symbol**		
Particulate matter	n.a.	New	50
		Existing	100
Sulphur dioxide	SO_2	New	500
		Existing	500
Oxides of nitrogen	NO_x expressed as NO_2	New	500
		Existing	2 000

Notes:

Category : Category 4: Metallurgical Industry, Subcategory 4.2.
Description : Combustion installations not used primarily for steam raising and electricity generation.
Application : All combustion installations (except test or experimental).
Special arrangement : Reference oxygen content appropriate to the fuel type must be used.

Each report shall include all of the following:

a) The name and description of the facility and of the listed activity as on the emission license for the facility.
b) The name and address of the accredited measurement authority that carried out the emission test.
c) The date and time on which the emission test was carried out. The emission test shall be carried out at least once during the reporting period, unless specified otherwise for the specific activity.
d) A declaration to the effect that normal operating conditions were maintained during the emission tests.
e) The total volumetric flow of gas, expressed in normal cubic meters (Nm^3) per unit time and mass flow (kg per unit time) being emitted by the listed activity or activities measured during the emission test, as the average of at least two measurements.
f) The concentration or mass of pollutant for which emissions standards have been set in this schedule emitted by each listed activity within the facility, as the average of at least two measurements.

g) The method or combination of methods used for determining the flow rate and concentration, selected from the reference list of methods. Where a reference method was not used, the reason shall be provided, as well as a description of the method used and documentary proof of equivalence to a reference method.

h) Where continuous emission measurement is prescribed, the report should include results of correlation tests, which should be carried out at least annually, and the availability of the continuous measurement in terms of the number of full hours per annum that valid results were obtained.

i) Remediation measures with an implementation schedule where
   - the average values under (f) above exceed the prescribed standard or
   - in the case where continuous emission measurement is prescribed, results were available for less than 90% of the total hours during the reporting period and/or
   - measurement results exceeded the standard given for that activity for more than 5% of the time that measurements are available.

Ambient Air Quality Limits

The exclusive use of source-based controls (e.g. emission limits) as an air quality management tool has been found to have important short-comings. Emission limits do not take the unique characteristics of the receiving environment into account, such as the dispersion potential, existence of other sources, existing ambient pollutant concentrations, and the sensitivity of the receiving environment. Such limits therefore provide no insurance that ambient air quality objectives will be achieved and that there will be no adverse effects on human health and welfare.

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). An effects-based approach requires the setting of ambient air quality guidelines and standards. Ambient air quality guidelines and standards are laid down by various countries, including South Africa, for the regulation of air concentrations of various criteria pollutants (e.g. sulphur dioxide, particulate matter, nitrogen oxides and lead). Such ambient guideline and standards define satisfactory air quality to ensure human health and welfare, thus providing objectives for air quality management.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the receptor. These guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout the individual's entire lifetime. Air quality guidelines and standards are normally given for specific averaging periods, i.e. the duration over which the standard or guideline is applicable. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average and annual average.

DEA have brought into effect the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (NEMAQA) on 11 September 2005 as part of a broad programme of air quality management reform. The publication in May 2000 of government's Integrated Pollution and Waste Management Policy (IP & WM Policy) marked a turning point for pollution and waste governance in South Africa. The National Air Quality Management Plan (NAQMP), borne from the IP & WM Policy, has as its definition the NEMAQA.

Government's vision with respect to the NAQMP is that the programme will develop, implement and maintain an air quality management regime that contributes to sustainable development and a measurable improvement in the quality of life of all, by harnessing the energy and commitment of all South Africans for the effective prevention, minimisation and control of atmospheric pollution.

DEA is responsible for establishing a national framework for achieving the objectives of NEMAQA, which includes –

a) mechanisms, systems and procedures to attain compliance with ambient air quality standards;
b) mechanisms, systems and procedures to give effect to the Republic's obligations in terms of international agreements;
c) national norms and standards for the control of emissions from point and non-point sources;
d) national norms and standards for air quality monitoring;
e) national norms and standards for air quality management planning;
f) national norms and standards for air quality information management; and
g) any other matter which the Minister considers necessary for achieving the objectives of the Act.

The establishment of national ambient air quality standards is achieved through NEMAQA and the South African Bureau of Standards (SABS) standard setting initiative. The National Ambient Air Quality Standards (NAAQS) have subsequently been published in the Government Gazette of 24 December 2009 and 29 June 2012. The standards are summarised in **Table 2** on the next page.

Table 2:

Ambient air quality standards (@ 25°C and 101.3 kPa)

Substance	Time-weighted average (µg/m^3)				
	10-minutes	1-hour	8-hour	24-hour	Annual
Ozone (O_3)	n.a.	n.a.	120[1]	n.a.	n.a.
Nitrogen dioxide (NO_2)	n.a.	200[2]	n.a.	n.a.	40
Sulphur dioxide (SO_2)	500[3]	350[2]	n.a.	125[4]	50
Lead (Pb)	n.a.	n.a.	n.a.	n.a.	0.5
Particulate matter (PM_{10})	n.a.	n.a.	n.a.	120[4] 75[4]*	50 40*
Particulate matter ($PM_{2.5}$)	n.a.	n.a.	n.a.	65[4] 40[4]** 25[4]***	25 20** 15***
Carbon monoxide (CO)	n.a.	30 000[2]	10 000[1]	n.a.	n.a.
Benzene (C_6H_6)	n.a.	n.a.	n.a.	n.a.	10 5*

Note:

µg/m^3	:	microgram per cubic meter air
DEA	:	Department of Environmental Affairs
1	:	Not to be exceeded more than 11 times per annum.
2	:	Not to be exceeded more than 88 times per annum.
3	:	Not to be exceeded more than 526 times per annum.
4	:	Not to be exceeded more than 4 times per annum.
5	:	Not to be exceeded more than 4 times per annum.
*	:	All standards are to be complied with immediately. Standards indicated with one asterisk are to be complied with as from 1 January 2015. Standards with two asterisks are to be complied with as from 1 January 2016. Standards with three asterisks are to be complied with as from 1 January 2030.

The National Dust Control Regulations was published on 1 November 2013 (Notice 827 of 2013). The purpose of the regulations is to prescribe general measures for the control of dust in all areas and standards for acceptable dust fall in residential and non-residential areas.

The dust fall rate is considered excessive if the 30 day average rate exceeds 600 mg/m^2/day in a residential area and 1 200 mg/m^2/day in a non-residential area. These standards may not be contravened more than twice per annum and not sequential months.

2.3. EKURHULENI METROPOLITAN MUNICIPALITY

Highveld Priority Area (HPA)

The overarching constitutional right to an environment that is not harmful to health or well-being is captured in the objectives of the National Environmental Management: Air Quality Act (No. 39 of 2004) (NEMAQA). Importantly, the promulgation of NEMAQA marked a turning point in the approach to air pollution control and governance in South Africa, introducing the philosophy of Air Quality Management, in line with international policy developments and the environmental right, i.e. Section 24 of the Constitution (Act No. 108 of 1996). The focus shifted from source control to management of pollutant levels in the ambient environment. Numerous tools and instruments are incorporated into the NEMAQA, including the establishment of Priority Areas approach (Sections 18 to 20) of the NEMAQA in so-called "hot-spot" areas where ambient air quality standards are exceeded or may be exceeded. This important air quality management tool has three strategic drivers:

i. It effectively allows for the concentration of limited air quality management capacity (human, technical and financial) for dealing with acknowledged problem areas in order to obtain measurable air quality improvements in the short-, medium- and long-term;

ii. It prescribes a cooperative governance regime by effectively handing-up air quality management authority to the tier of government that can provide leadership and coordination; and

iii. It allows for cutting edge air quality management methodologies that take into account all contributors to the air pollution problem, i.e. “air-shed” air quality management.

The Highveld area in South Africa is associated with poor air quality and elevated concentrations of criteria pollutants occur due to the concentration of industrial and non-industrial sources. The Minister of Environmental Affairs therefore declared the Highveld Priority Area (HPA) on 23 November 2007. As the area declared overlaps provincial boundaries, the Department of Environmental Affairs (DEA) functions as the lead agent in the management of the priority area and is required in terms of Section 19(1) of the NEMAQA to develop an AQMP for the priority area.

The Highveld Priority Area covers 31 106 km^2, including parts of Gauteng and Mpumalanga Provinces, with a single metropolitan municipality, three district municipalities, and nine local municipalities (see **Figure 2** below).

Figure 2: Locality map depicting the Highveld Priority Area (from Air Quality Management Plan for the HPA, DEA 2010)

The baseline assessment for the HPA made a succinct presentation of the major issues to be addressed. Concerns have been highlighted in the areas of ambient air quality, technology and capacity. These issues will be carried forward into the strategy analysis and management planning stages of the AQMP development. The Logical Framework Approach workshop will assist in developing these aspects of the AQMP, where stakeholders will work towards the interventions to be implemented in the HPA.

3. BACKGROUND

3.1. STEEL MELT SHOP

Fortune Steels intends to melt ferrous scrap steel in a coreless induction furnace. The melted steel will then be transferred to a preheated ladle and finally to a continuous casting machine. The casted steel billets will be taken to an on-site rolling mill for further processing.

Raw Material Handling

Steel is a material of which the (mass) content of iron is bigger than that of any other element, with a carbon content generally lower than 2%, and which also usually contains other elements. The carbon content distinguish steel from cast iron. One particularly useful aspect of steel is that it can be hot worked. Low alloy cast steel contains elements such as Mn, Cr, Ni, and Mo in amounts less than 5%.

Super heavy and heavy melting scrap, shredded scrap and blue steel scrap, with an iron yield between 98 and 99%, will be delivered to site by road transport. Following a quality assurance process the scrap steel will be off-loaded into the scrap storage area using a mechanical grab or magnet.

Steel Melting

Two 6MVA coreless induction furnaces will be available to melt ferrous scrap. The induction furnaces operate by utilising a strong magnetic field created by the passing an electric medium frequency alternating current through a coil wrapped around the furnace. The magnetic field in turn creates a voltage across, and subsequently an electric current through, the metal to be melted. The electrical resistance of the metal produces heat, which in turn melts the metal. Since there is no contact between the charge and the energy-carrier, the induction furnace is suited for the melting of scrap steel.

The furnaces contains water-cooled copper coils, the inside of which is internally refractory lined. The outside is insulated and enclosed in a steel shell. The furnace bodies are mounted on frames

equipped with tilting mechanisms. The furnaces are refractory-lined, bucket-shaped, the top of which are operable for charging and de-slagging operations (see **Figure 3**).

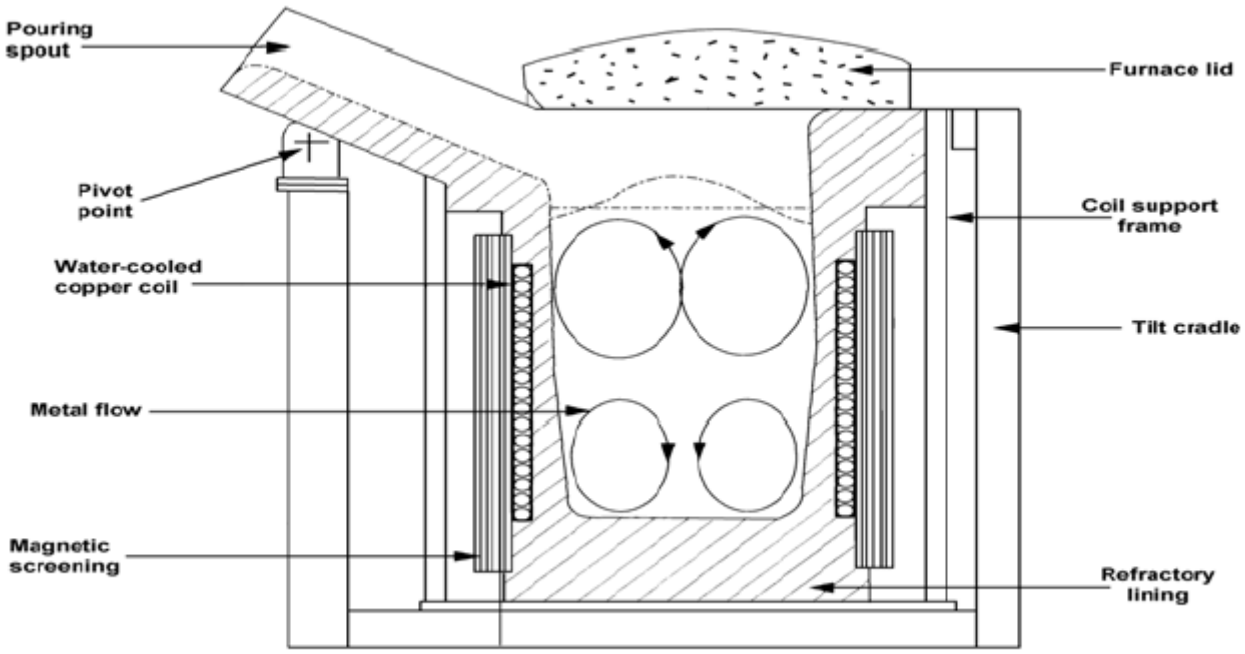

Figure 3: General arrangement of a coreless induction furnace (from Smitheries and Foundries, IPPC European Commission)

The 20 ton furnaces are batch-charged by means of a lifting magnet or a mechanical grab. A two-hour melting cycle is expected.

The scrap steel quality ensures that slag production is limited to below 2%. The slag is manually raked-off the melt surface into a slag box. The slag is temporarily stored inside the furnace building before recycling off-site. The typical composition of induction furnace slag is:

- FeO (10 to 30%)
- SiO_2 (40 to 70%)
- MnO (2 to 10%)
- Al_2O_3 (2 to 15%)

- CaO (0 to 3%)
- MgO (0 to 3%)

Induction furnaces are not suited for holding molten metal. At optimum temperature the metal is transferred to a ladle refining furnace where the chemical properties can be altered through various additives and metal alloys. The refractory lined refining ladle is pre-heated to 1 000°C and is fitted with a slide gate valve. The ladle is used to transfer the metal to the continuous casting machine and is cleaned after every completed cycle.

The melting process will be fitted with an emission control system providing for primary and secondary collection. The primary fume collection system incorporates a custom build swivel hood during the melting process. The charging and tapping processes will be serviced through a secondary system incorporating a roof-mounted hood. Both primary and secondary emission capture systems will feed to a spark arrestor and finally a bag house.

Steel Casting

The continuous, four strand, radius caster is a high productivity device which produces the intermediate product, dimensional steel billets. Through rapid cooling, a fine-grained material with good mechanical properties is obtained. In continuous casting, the molten metal is cast into a water-cooled die, which is open at the bottom (**Figure 4**).

The die gives the desired form to the product. Through intensive cooling, the outside of the metal product solidifies, while it is slowly pulled out of the mould. Through continuous pouring and extraction the product gets longer.

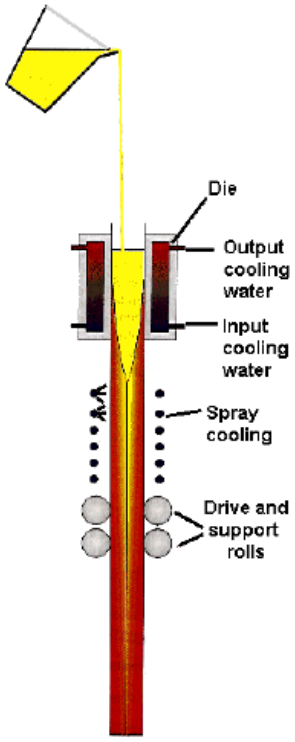

Figure 4: Schematic representation of a strand casting machine used for continuous casting (from Smitheries and Foundries, IPPC European Commission)

After horizontal straightening, a mechanical shear cuts the bloom in 7m lengths. The steel billets are stacked on a cooling bed by means of a conveyor roller table and hydraulic pusher arrangement. The billets are stored for further processing.

3.2. ROLLING MILL

Metal rolling is one of the most important manufacturing processes in the modern world. The large majority of all metal products produced today are subject to metal rolling at one point in their manufacture. Metal rolling is often the first step in creating raw metal forms (see **Figure 5**). The ingot or continuous casting is hot rolled into a bloom or a slab, these are the basic structures for the creation of a wide range of manufactured forms. Blooms typically have a square cross section of greater than 150 x 150mm. Slabs are rectangular and are usually greater than 250mm in width and more than 37.5mm in thickness. Rolling is most often, (particularly in the case of the conversion of an ingot or continuous casting), performed hot.

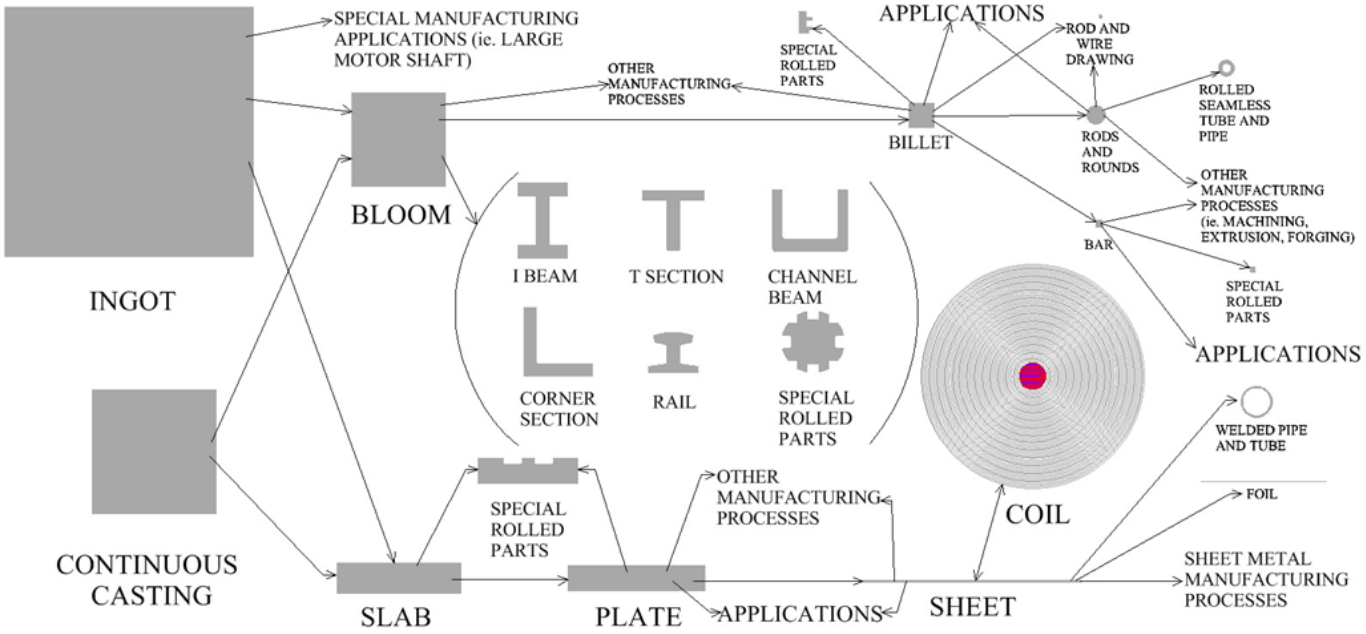

Figure 5: Metal forming process hierarchy of rolling operations in modern manufacturing

At a rolling mill, blooms and slabs are further rolled down to intermediate parts such as plate, sheet, strip, coil, billets, bars and rods. Many of these products will be the starting material for subsequent manufacturing operations such as forging, sheet metal working, wire drawing, extrusion, and machining. Blooms are often rolled directly into I beams, H beams, channel beams, and T sections for structural applications. Rolled bar, of various shapes and special cross sections, is used in the machine building industry, as well as for construction. Rails, for the production of railroad track, are rolled directly from blooms. Plates and sheets are rolled from slabs, and are extremely important in the production of a wide range of manufactured items. Plates are generally considered to be over 6mm in thickness. Plates are used in heavy applications like boilers, bridges, nuclear vessels, large machines, tanks, and ships. Sheet is used for the production of car bodies, buses, train cars, airplane fuselages, refrigerators, washers, dryers, other household appliances, office equipment, containers, and beverage cans, to name a few.

Most metal rolling operations are similar in that the work material is plastically deformed by compressive forces between two constantly spinning rolls. These forces act to reduce the thickness of the metal and affect its grain structure. The reduction in thickness can be measured by the difference in thickness before and after the reduction, this value is called the *draft*. In addition to reducing the thickness of the work, the rolls also act to feed the material as they spin in opposite directions to each

other. Friction is therefore a necessary part of the rolling operation, but too much friction can be detrimental for a variety of reasons. It is essential that in a metal rolling process the level of friction between the rolls and work material is controlled, lubricants can help with this. A basic flat rolling operation, to reduce the thickness of a work piece, is shown in **Figure 6**.

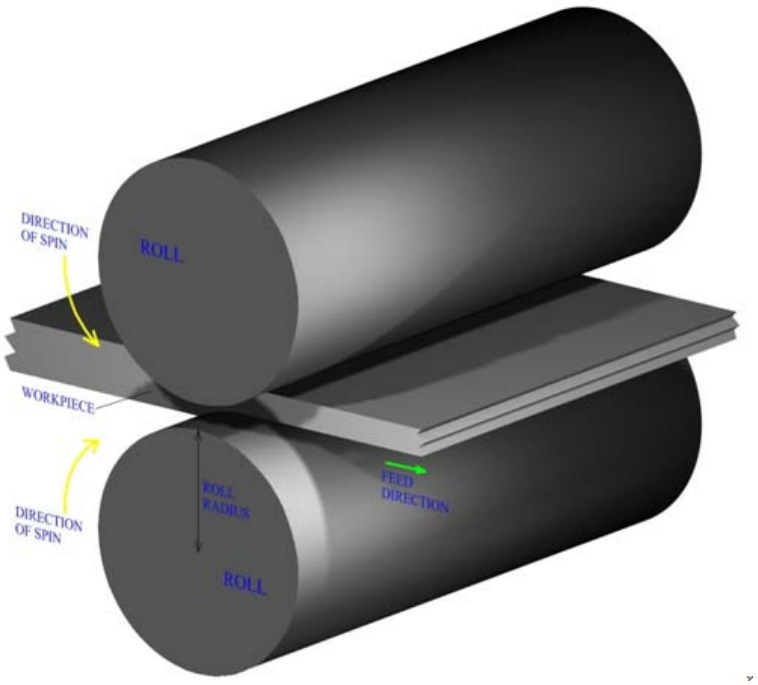

Figure 6: Basic flat rolling operation

Rolling

The Fortune Steels rolling mill features two re-heat furnaces and a number of rolling mills which reheat steel ingots for rolling and shaping standard form steel products.

The intermediate product from the Steel Melt Shop (steel ingots) are fed via a conveyor belt into the reheating furnace, which heat the ingots to approximately 1000°C to enable stretching and shaping. An ejector pushes the heated ingot out of the furnace into Stage 1 of the milling process.

At Stage 1 (Roughing Mill), the heated ingot is passed through the mill three times, being rolled out a little thinner each time. It is cut through hot shearing and then run out on to an extended table conveyor. From Stage 1 the roughened ingot passes to Stage 2, where it is passed through the

Intermediate Mill a further 3 times. During this stage it will form a shape as it is passed through rollers.

From Stage 2 the shaped ingot will be passed via conveyor into Stage 3 (Finishing) which includes being passed via conveyor to the cooling beds, passed through a straightener, cut to length using cold shearing machines, randoms are selected and set aside and first grade products are packaged and stacked for export. Refer to **Figure 7** for a process flow diagram.

During full production the rolling plant can process approximately 63 000 tons steel ingots per annum. End cutting scrap and mill scale accounts for a production loss of 5%.

Secondary input for rolling mill operations include water for cooling and fuel for the reheating furnaces. The reheating furnaces are fuelled by Coal Tar Fuel (CTF) which is stored on site. Currently 2 x 50 000 litre tanks are planned for the eastern side of the site near the furnaces.

Water is used to cool the steel during the rolling process from approximately 1 000°C to 500°C resulting in a substantial amount of water loss through evaporation. The water is circulated throughout the plant for cooling and is constantly recycled.

The by-products are as follows:

- Misrolls: Ingots that are not rolled correctly at Stage 1.
- Randoms: End products that are not up to standard.
- Off-cuts: Cropped and cut steel pieces.

Misrolls, randoms and off-cuts are stacked and temporarily stored on site to be dispatched back to the scrap storage bay for re-melting.

The surface of the ingots oxidizes in the furnace during heating and then comes off in flakes during rolling and cooling of the steel. The mill scale, washed-off during cooling processes, are sold as a waste product.

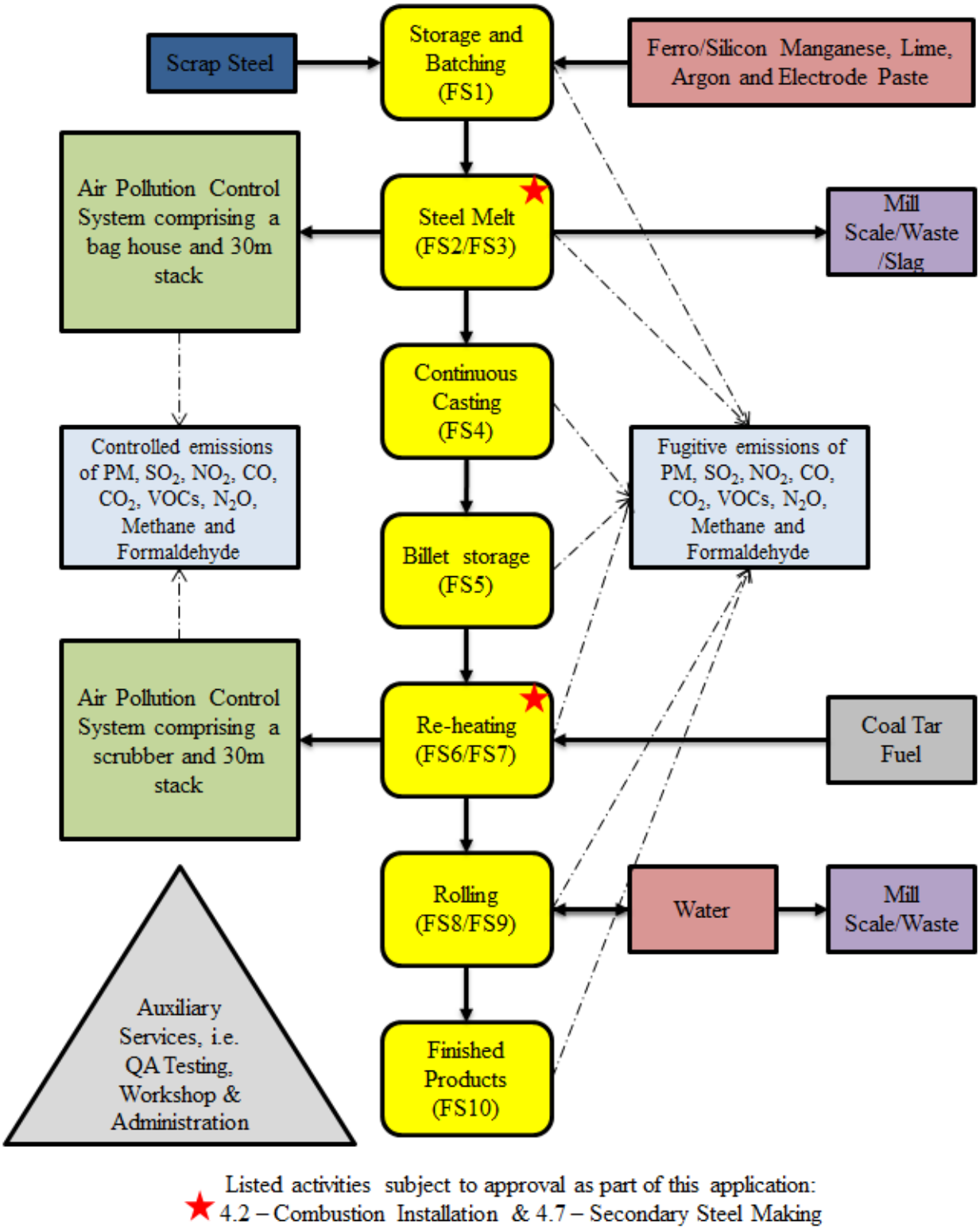

Figure 7: Fortune Steels process flow diagram

Other minor waste items generated during the process are used refractory bricks and steel shavings. Refractory bricks are used for maintenance purposes in the reheat furnaces. The bricks are not a constant consumable and therefore very little used refractory bricks are generated as a waste item per annum. Wasted bricks are disposed of at a registered landfill site. Steel shavings are generated at the workshop where the rollers, which are used to form the desired shape of the end product, are machined. The shavings are collected in steel drums and transported to the recycling plant for re-melting. Approximately one to two steel drums of steel shavings are generated per month.

The outputs produced are standard steel products including "rat" products (coils, sheets, strip, plates etc.) and "long" products (bars, rods, pipes, beams, rails, etc.). These form the inputs into the further downstream conversion where steel products such as coils, plates or merchant bars are converted into immediate products such as roofing, angles, flats, window sections, wire, tubes etc.

3.3. EMISSIONS INVENTORY

Melting and Casting Process

Emissions from the scrap handling operations are fugitive particulates generated from receiving, unloading, storing, and charging of the furnace.

Particulate emission rates of 0.06 to 1kg/tonne metal charge have been reported in literature, but at present, emission rates of 0.04 to 3kg/tonne are normal. The highest particulate emission rates occur during charging and at the beginning of the melting cycle. Particle sizes range from 1 – 100µm, with more than 50% being smaller than 10 – 20µm.

Dust emission levels and PM distribution from a German IF foundry fitted with a hood and bag filter emission control system are as follows:

- 10 400m^3/hour
- 0.4mg/Nm^3
- 78% PM_{10}
- 50% $PM_{2.5}$

As for the chemical composition of the particulate matter, there is no published data regarding the melting of steel, but there is reason to believe that it is close to that of the composition of the dust emitted during the melting of cast iron:

- $FeO + Fe_2O_3$ (30 to 70%)
- SiO_2 (5 to 25%)
- MnO (<5%)
- Al_2O_3 (3 to 10%)
- CaO (<1%)
- ZnO (<5%)
- Metallic oxides (<0.1%)
- Ignition loss (0 – 10%)

Charging oily scrap or borings in a cold furnace will lead to the presence of organic vapours in the exhaust gases, which will not be burned since they are created at the beginning of the melting cycle.

Emissions from refractory re-heating and continuous casting are also likely. The emissions are release uncontrolled and can be as much as 275g/t molten steel.

Rolling Process

The major source of atmospheric emissions from primary and secondary rolling operations is controlled emissions from the reheat process. Fugitive emissions from the process are estimated at less than 1% of the total emission load.

Particulate matter (PM), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) are the primary pollutants of concern. In addition, there are volatile organic compounds (VOCs) associated with the combustion of coal tar fuel.

Housekeeping tasks involving dry sweeping and vehicle entrained emissions are possible additional fugitive sources of emissions in and around the plant.

The reheat furnaces are fitted with a local exhaust ventilation system. Emissions pass through a centrifugal spray scrubber (calcium carbonate solution) before release above roof height from a 30m stack.

Coal tar fuel combustion emissions

Two major categories of fuel oil are burned by combustion sources: distillate oils and residual oils. Distillate oils are more volatile and less viscous than residual oils. They have negligible nitrogen and ash contents and usually contain less than 0.3 percent sulfur (by weight). Distillate oils are used mainly in domestic and small commercial applications, and include kerosene and diesel fuels. Being more viscous and less volatile than distillate oils, the heavier residual oils may need to be heated for ease of handling and to facilitate proper atomization. Because residual oils are produced from the residue remaining after the lighter fractions (gasoline, kerosene, and distillate oils) have been removed from the coal, they contain significant quantities of ash, nitrogen, and sulfur. Residual oils are used mainly in utility, industrial, and large commercial applications.

Particulate emissions may be categorized as either filterable or condensable. Filterable emissions are generally considered to be the particulates that are trapped by the glass fiber filter in the front half of a Reference Method 5 or Method 17 sampling train. Vapors and particles less than 0.3 microns pass through the filter. Condensable particulate matter is material that is emitted in the vapor state which later condenses to form homogeneous and/or heterogeneous aerosol particles. The condensable particulate emitted from combustion of fuel oil is primarily inorganic in nature.

Filterable particulate matter emissions depend predominantly on the grade of fuel fired. Combustion of lighter distillate oils results in significantly lower PM formation than does combustion of heavier residual oils.

PM emissions from residual oil burning are related to the oil sulfur content. This is because low-sulfur oil, either from naturally low-sulfur crude oil or desulfurized by one of several processes, exhibits substantially lower viscosity and reduced asphaltene, ash, and sulfur contents, which results in better atomization and more complete combustion.

Boiler load can also affect filterable particulate emissions in units firing residual oil. At low load (50 percent of maximum rating) conditions, particulate emissions may be lowered by 30 to 40 percent and by as much as 60 percent from small industrial and commercial units. However, no significant particulate emission reductions have been noted at low loads from boilers firing any of the lighter grades. At very low load conditions (approximately 30 percent of maximum rating), proper combustion conditions may be difficult to maintain and particulate emissions may increase significantly.

Sulfur oxides (SOx) emissions are generated during oil combustion from the oxidation of sulfur contained in the fuel. The emissions of SOx from conventional combustion systems are predominantly in the form of SO_2. Uncontrolled SOx emissions are almost entirely dependent on the sulfur content of the fuel and are not affected by unit size, burner design, or grade of fuel being fired. On average, more than 95 percent of the fuel sulfur is converted to SO_2, about 1 to 5 percent is further oxidized to sulfur trioxide (SO_3), and 1 to 3 percent is emitted as sulfate particulate. SO_3 readily reacts with water vapor (both in the atmosphere and in flue gases) to form a sulfuric acid mist.

Oxides of nitrogen (NOx) formed in combustion processes are due either to thermal fixation of atmospheric nitrogen in the combustion air ("thermal NOx"), or to the conversion of chemically bound nitrogen in the fuel ("fuel NOx"). The term NOx refers to the composite of nitric oxide (NO) and nitrogen dioxide (NO_2). Test data have shown that for most external fossil fuel combustion systems, over 95 percent of the emitted NOx is in the form of nitric oxide (NO). Nitrous oxide (N_2O) is not included in NOx but has recently received increased interest because of atmospheric effects.

Experimental measurements of thermal NOx formation have shown that NOx concentration is exponentially dependent on temperature, and proportional to N_2 concentration in the flame, the square root of O_2 concentration in the flame, and the residence time. Thus, the formation of thermal NOx is affected by four factors: (1) peak temperature, (2) fuel nitrogen concentration, (3) oxygen concentration, and (4) time of exposure at peak temperature. The emission trends due to changes in these factors are generally consistent for all types of combustors: an increase in flame temperature, oxygen availability, and/or residence time at high temperatures leads to an increase in NOx production.

Fuel nitrogen conversion is the more important NOx-forming mechanism in residual oil units. It can account for 50 percent of the total NOx emissions from residual oil firing. The percent conversion of fuel nitrogen to NOx varies greatly, however; typically from 20 to 90 percent of nitrogen in oil is converted to NOx. Except in certain large units having unusually high peak flame temperatures, or in units firing a low nitrogen content residual oil, fuel NOx generally accounts for over 50 percent of the total NOx generated.

A number of variables influence how much NOx is formed by these two mechanisms. One important variable is firing configuration. NOx emissions from tangentially (corner) fired units are, on the average, less than those of horizontally opposed units. Also important are the firing practices employed during operation. Low excess air (LEA) firing, flue gas recirculation (FGR), staged combustion (SC), reduced air preheat (RAP), low NOx burners (LNBs), burning oil/water emulsions (OWE), or some combination thereof may result in NOx reductions of 5 to 60 percent. Load reduction (LR) can likewise decrease NOx production. Nitrogen oxide emissions may be reduced from 0.5 to 1 percent for each percentage reduction in load from full load operation. It should be noted that most of these variables, with the exception of excess air, only influence the NOx emissions of large oil-fired units.

The rate of carbon monoxide (CO) emissions from combustion sources depends on the oxidation efficiency of the fuel. By controlling the combustion process carefully, CO emissions can be minimized. Thus if a unit is operated improperly or not well maintained, the resulting concentrations of CO (as well as organic compounds) may increase by several orders of magnitude. The presence of CO in the exhaust gases of combustion systems results principally from incomplete fuel combustion. Several conditions can lead to incomplete combustion, including insufficient oxygen (O_2) availability; poor fuel/air mixing; cold-wall flame quenching; reduced combustion temperature; decreased combustion gas residence time; and load reduction (i.e. reduced combustion intensity). Since various combustion modifications for NOx reduction can produce one or more of the above conditions, the possibility of increased CO emissions is a concern for environmental, energy efficiency, and operational reasons.

Small amounts of organic compounds are emitted from combustion. As with CO emissions, the rate at which organic compounds are emitted depends, to some extent, on the combustion efficiency of the

unit. Therefore, any combustion modification which reduces the combustion efficiency will most likely increase the concentrations of organic compounds in the flue gases.

Total organic compounds (TOCs) include VOCs, semi-volatile organic compounds, and condensable organic compounds. Emissions of VOCs are primarily characterized by the criteria pollutant class of unburned vapor phase hydrocarbons. Unburned hydrocarbon emissions can include essentially all vapor phase organic compounds emitted from a combustion source. These are primarily emissions of aliphatic, oxygenated, and low molecular weight aromatic compounds which exist in the vapor phase at flue gas temperatures. These emissions include all alkanes, alkenes, aldehydes, carboxylic acids, and substituted benzenes (e. g., benzene, toluene, xylene, and ethyl benzene).

The remaining organic emissions are composed largely of compounds emitted from combustion sources in a condensed phase. These compounds can almost exclusively be classed into a group known as polycyclic organic matter (POM), and a subset of compounds called polynuclear aromatic hydrocarbons (PAH or PNA). There are also PAH-nitrogen analogs. Information available in the literature on POM compounds generally pertains to these PAH groups.

Formaldehyde is formed and emitted during combustion of hydrocarbon-based fuels including coal and oil. Formaldehyde is present in the vapor phase of the flue gas. Formaldehyde is subject to oxidation and decomposition at the high temperatures encountered during combustion. Thus, larger units with efficient combustion (resulting from closely regulated air-fuel ratios, uniformly high combustion chamber temperatures, and relatively long gas retention times) have lower formaldehyde emission rates than do smaller, less efficient combustion units.

Trace elements are also emitted from the combustion of oil. The quantity of trace elements entering the combustion device depends solely on the fuel composition. The quantity of trace metals emitted from the source depends on combustion temperature, fuel feed mechanism, and the composition of the fuel. The temperature determines the degree of volatilization of specific compounds contained in the fuel. The fuel feed mechanism affects the separation of emissions. In general, the quantity of any given metal emitted depends on the physical and chemical properties of the element itself; concentration of the metal in the fuel; the combustion conditions; and the type of particulate control device used, and its collection efficiency as a function of particle size.

Some trace metals concentrate in certain waste particle streams from a combustor (bottom ash, collector ash, flue gas particulate), while others do not. Various classification schemes to describe this partitioning have been developed. The classification scheme used by Baig is as follows:

- Class 1: Elements which are approximately equally distributed between fly ash and bottom ash, or show little or no small particle enrichment.
- Class 2: Elements which are enriched in fly ash relative to bottom ash, or show increasing enrichment with decreasing particle size.
- Class 3: Elements which are emitted in the gas phase.

By understanding trace metal partitioning and concentration in fine particulate, it is possible to postulate the effects of combustion controls on incremental trace metal emissions. For example, several NOx controls for units reduce peak flame temperatures (e. g., SC, FGR, RAP, OWE, and LR). If combustion temperatures are reduced, fewer Class 2 metals will initially volatilize, and fewer will be available for subsequent condensation and enrichment on fine PM. Therefore, for combustors with particulate controls, lower volatile metal emissions should result due to improved particulate removal. Flue gas emissions of Class 1 metals (the non-segregating trace metals) should remain relatively unchanged.

Lower local O_2 concentration is also expected to affect segregating metal emissions from boilers with particle controls. Lower O_2 availability decreases the possibility of volatile metal oxidation to less volatile oxides. Under these conditions, Class 2 metals should remain in the vapor phase as they enter the cooler sections of the unit. More redistribution to small particles should occur and emissions should increase. Again, Class 1 metal emissions should remain unchanged.

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions are all produced during fuel oil combustion. Nearly all of the fuel carbon (99 percent) in fuel oil is converted to CO_2 during the combustion process. This conversion is relatively independent of firing configuration. Although the formation of CO acts to reduce CO_2 emissions, the amount of CO produced is insignificant compared to the amount of CO_2 produced. The majority of the fuel carbon not converted to CO_2 is due to incomplete combustion in the fuel stream.

Formation of N_2O during the combustion process is governed by a complex series of reactions and its formation is dependent upon many factors. Formation of N_2O is minimized when combustion temperatures are kept high (above 800°C) and excess air is kept to a minimum (less than 1 percent). Methane emissions vary with the type of fuel and firing configuration, but are highest during periods of incomplete combustion or low-temperature combustion, such as the start-up or shut-down cycle for oil-fired boilers. Typically, conditions that favor formation of N_2O also favor emissions of CH_4.

Vehicle Entrained Emissions

When a vehicle travels paved road surfaces, the force of the wheels causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

The quantity of dust emissions from a given segment of road varies linearly with the volume of traffic. Field investigations also have shown that emissions depend on source parameters that characterize the condition of a particular road and the associated vehicle traffic. Characterization of these source parameters allow for "correction" of emission estimates to specific road and traffic conditions present on public and industrial roadways.

Dust emissions from paved roads have been found to vary directly with the fraction of silt (particles smaller than 75 micrometers in diameter) in the road surface materials.

Other variables are important in addition to the silt content of the road surface material. For example, at industrial sites, where haul trucks and other heavy equipment are common, emissions are highly correlated with vehicle weight.

Emission rates

Due to the absence of locally generated emission factors, use was made of the comprehensive set of emission factors published by the United States Environmental Protection Agency (US-EPA) in its AP-42 document *Compilation of Pollution Emission Factors*, the reference document *Best Available*

Techniques for the Smitheries and Foundries Industry published by the European Integrated Pollution Prevention and Control Bureau as well as the *Emission Estimation Technique Manual for Ferrous Foundries* published by the Australian Government, Department of Environment and Heritage.

Reference was also made to fugitive emission rates obtained from ambient air quality monitoring and stack emission monitoring data conducted by EHRCON on similar and other processes over the past ten years. **Table 3** below summarizes emission rates for Fortune Steels in Nigel.

Table 3a:

Fortune Steels – Summary of emission rates for the Steel Melt Shop

Activity	Emission rate (g/s)				
	PM_{10}	SO_2	NO_2	CO	VOCs
1. Scrap material handling [a]	0.013	n.s	n.s	n.s	n.s
2. Smelting	0.137 [b]	0.046 [c]	0.046 [c]	1.139 [c]	0.068 [c]
3. Pouring [d]	0.060	n.s	n.s	n.s	n.s
4. Casting [d]	0.060	n.s	n.s	n.s	n.s
5. Billet cooling/handling [e]	1.595	n.s	n.s	n.s	n.s
6. Ladle cleaning [f]	1.937	n.s	n.s	n.s	n.s

Notes:

g/s : Gram per second

ns : Not significant

a : Average scrap material intake of 70 000 ton per annum, PM_{10} emission factor of 0.3kg/ton scrap handled. Australian Government, Department of Environment and Heritage, National Pollutant Inventory, Emission Estimation Technique Manual for Ferrous Foundries, Version 1.2, September 2004

b : Average production rate of 63 000 ton per annum, PM_{10} emission factor of 3kg/ton metal smelted 98% pollution control efficiency, European IPPC Bureau BAT for Smitheries and Foundries

c : Average production rate of 63 000 ton per annum, SO_2/NO_2 emission factor of 0.02kg/ton metal smelted CO emission factor of 0.5kg/ton metal smelted, VOC emission factor of 0.03kg/ton metal smelted No emission control. Australian Government, Department of Environment and Heritage, National Pollutant Inventory, Emission Estimation Technique Manual for Ferrous Foundries, Version 1.2, September 2004

d : Average production rate of 63 000 ton per annum, PM_{10} emission factor of 1.4kg/ton metal smelted 98% pollution control efficiency. US EPA, AP-42, Volume I, 5 Edition, Chapter 12.13 & Appendix B.2.

e : Average production rate of 63 000 ton per annum, PM_{10} emission factor of 0.7kg/ton metal smelted No emission control. US EPA, AP-42, Volume I, 5 Edition, Chapter 12.13 & Appendix B.2.

f : Average production rate of 63 000 ton per annum, PM_{10} emission factor of 0.85kg/ton metal smelted US EPA, AP-42, Volume I, 5 Edition, Chapter 12.13 & Appendix B.2.

Table 3b:

Fortune Steels – Summary of emission rates for the Rolling Mill

Pollutant	Emission factor kg/l [a]	Emission rate g/s [b, c & d]
Nitrogen oxides	$6.6E^{-3}$	0.477
Sulphur dioxide	0.011	0.794
Carbon monoxide	$6.0E^{-4}$	0.043
Carbon dioxide	3	216.667
PM_{10}	$1.1E^{-3}$	0.080
Total organic compounds	$1.5E^{-4}$	0.011
Methane	$1.2E^{-4}$	0.009
Nitrous oxide	$6.0E^{-5}$	0.005
Polycyclic organic matter	$1.6E^{-7}$	<0.001
Formaldehyde	$7.3E^{-6}$	<0.001

Notes:

a : 95% pollution control efficiency. Emission factor in kilogram per litre (kg/l) fuel utilised (EPA AP-42, Chapter 1.3)
b : Emission rate unit in gram per second (g/s)
c : Average fuel consumption of 260 litres per hour

Table 3c:

Fortune Steels – Summary of emission rates from vehicle movement

Activity	Emission factor		Emission rate (g/s)	
	TSP	PM10	TSP	PM10
Vehicle movement [a]	2.43 kg/VKT	1.20 kg/VKT	0.281	0.139

Notes:

kg/VKT : Kilogram per vehicle kilometre travelled
g/s : Gram per second
a : US EPA, AP42, Volume I, 5 Edition, Chapter 13.2.1
Calculated for a road surface silt loading of 9.7 g/m^2,
a mean vehicle weight of 15 tons and 10 kilometres travelled on site per day.

3.4. METEOROLOGY

The macro-ventilation characteristics of a region are determined by the nature of the synoptic systems that dominate the circulations of the region, and the nature and frequency of occurrence of alternative systems and weather perturbations over the region. Meso-scale processes affecting the dispersion potential include thermo-topographically induced circulations, the development and dissipation of surface inversions, and the modification of the low-level wind field and stability regime by urban areas.

Atmospheric processes at meso-scale were taken onto account in the characterisation of the atmospheric dispersion potential of the study area. Reference was made to hourly average meteorological data recorded by the South African Weather Service in Nigel, modelled to the process location. Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth.

Summary of Climatic Region H - The Highveld

The South African Weather Service has partitioned the country into 15 climatic regions. This division is based firstly on geographic considerations, more specifically the prominent mountain ranges (great escarpment) which after constitutes the main climatic divides, besides also other features such as rivers and political boundaries; secondly, on the interior plateau, use has been made of the change from BW to BS and from BS to C climates according to the Köppen classification.

The average annual precipitation in the highveld region varies from about 900mm on its eastern border to about 650mm in the west. The rainfall is almost exclusively due to showers and thunderstorms and falls mainly in summer (85% of annual rainfall), from October to March, the maximum fall occurring in January. Heavy falls of 125 to 150mm occasionally fall in a single day. The annual average number of thunderstorms is 75. These storms are often violent with severe lightning and strong gusty south-westerly winds and are sometime accompanied by hail. The region has the highest hail frequency in South Africa; about 4 to 7 occurrences can be expected annually in one spot.

Average daily maximum temperature is roughly 27°C in January and 17°C in July but in extreme cases these may rise to 30°C and 26°C respectively. Average daily minima range from about 13°C in January to 0°C in July, whereas extremes can sink to 1°C and -13° respectively. The period during which frost is likely to form lasts on the average for about 120 days from May to September.

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of mixing and inversion layers.

Surface wind field

Dispersion comprises vertical and horizontal components of motion. The wind field largely determines the horizontal dispersion of pollution in the atmospheric boundary layer. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume stretching. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction and the variability in wind direction, determine the general path pollutants will follow, and the extend of cross-wind spreading.

In the study area, the mean daytime surface winds are predominantly northwesterly as a result of the prevalent anticyclonic circulation, with easterly winds being the next most frequent. In the winter, the frequency of southwesterly winds increases because of the passage of cyclonic westerly waves. Light topographically induced winds from the eastern sector are common at night. The so-called Escarpment Breeze that develops at night under weak pressure gradients is up to 1 000m deep.

Winds are mostly light except during thunderstorms. Very occasionally tornadoes do occur. Sunshine duration in summer is about 60% and in winter about 80% of the possible.

An annual average surface wind speed of 3.3m/s was recorded between January 2008 and December 2013.

Period, diurnal, and seasonal wind roses for the period January 2008 and December 2013 are presented in **Figure 8**. Wind roses comprise 16 spokes, which represents the directions from which

winds blew during the period. The colours used in the wind roses reflect the different categories of wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The value given in the centre of the circle describes the frequency with which calms occurred, i.e. periods during which the wind speed was below 1m/s.

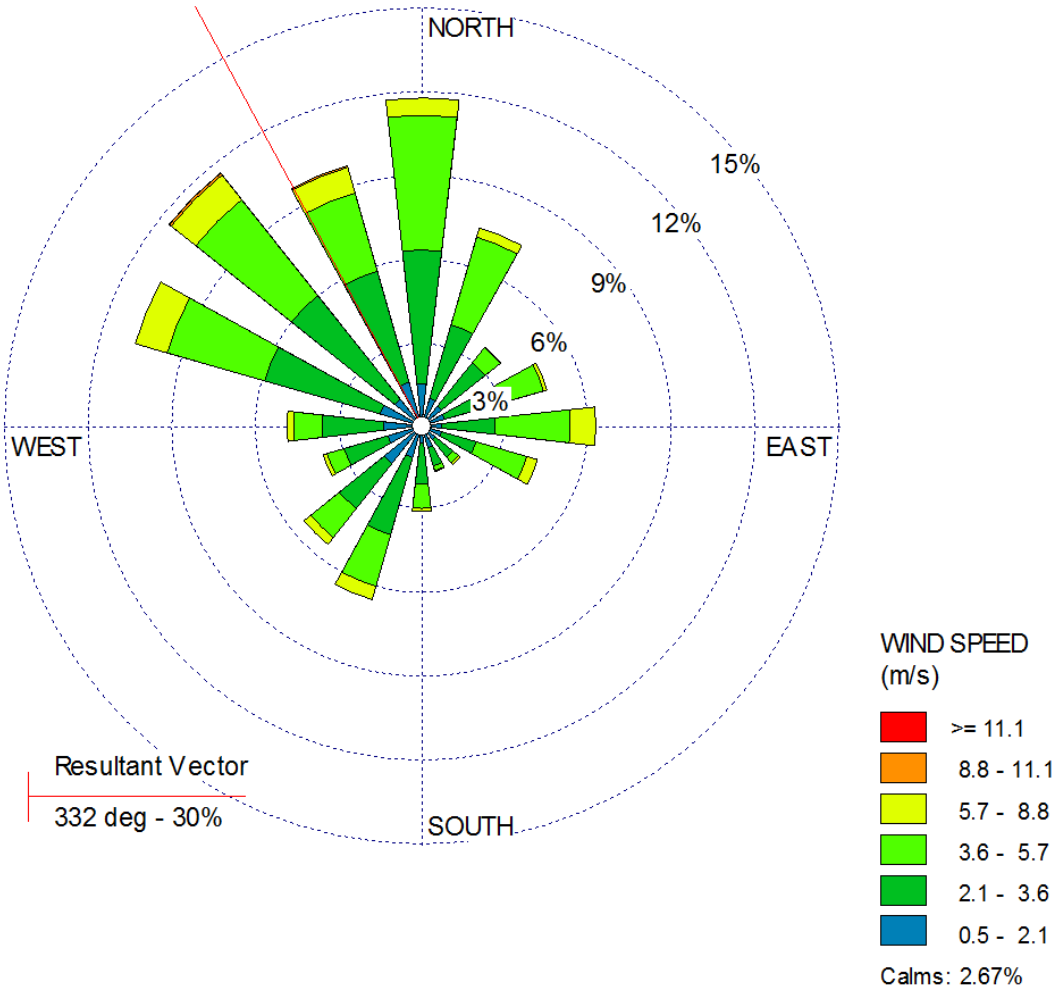

Figure 8a: Period wind rose

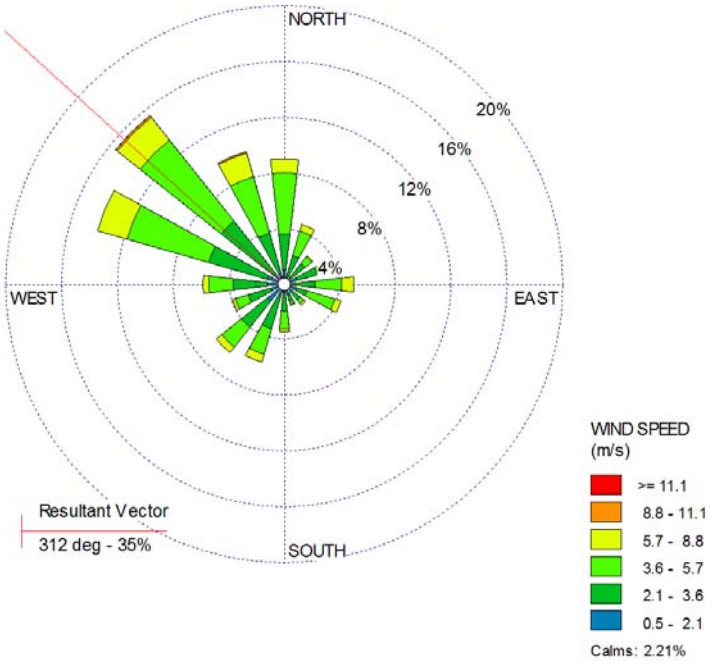

Figure 8b: Day wind rose

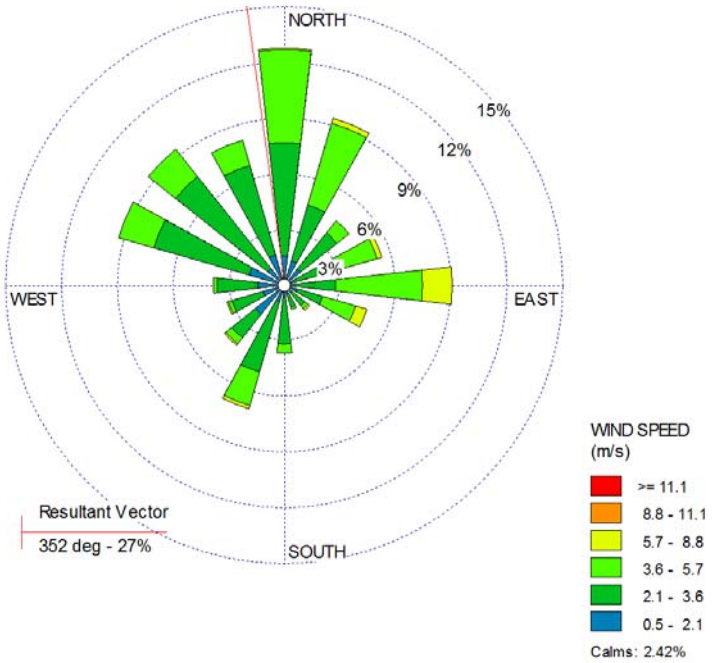

Figure 8c: Evening wind rose (18H00 to 24H00)

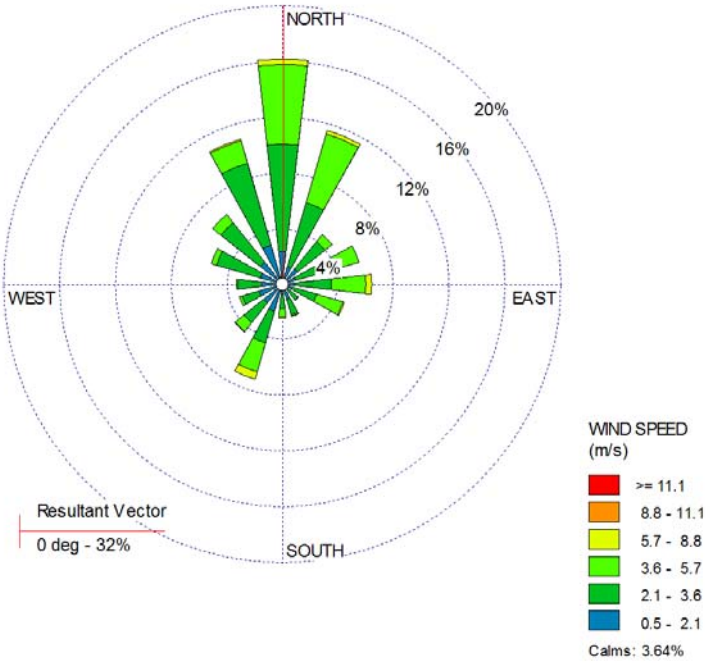

Figure 8d: Night wind rose (00H00 to 06H00)

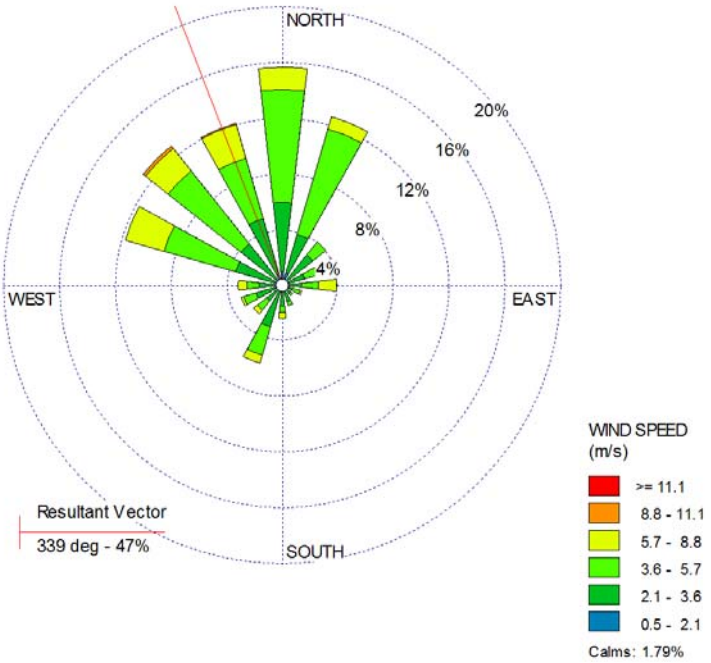

Figure 8e: Spring wind rose

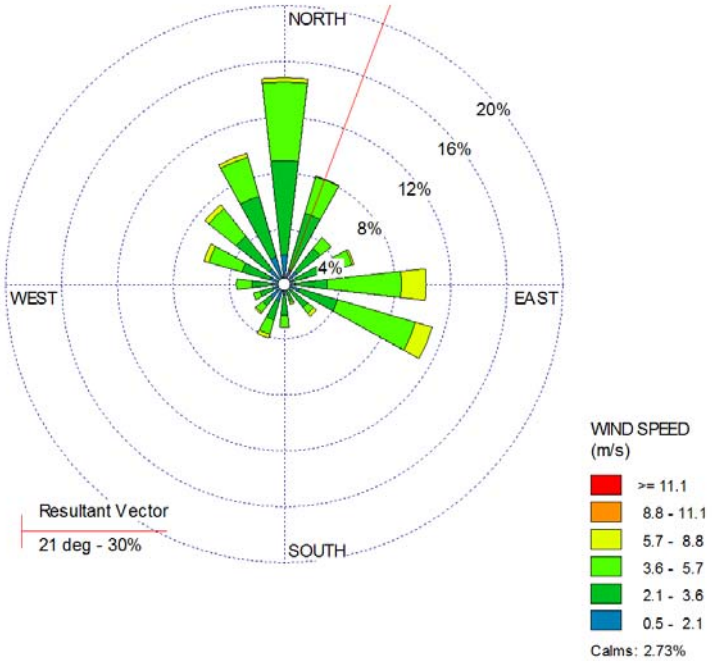

Figure 8f: Summer wind rose

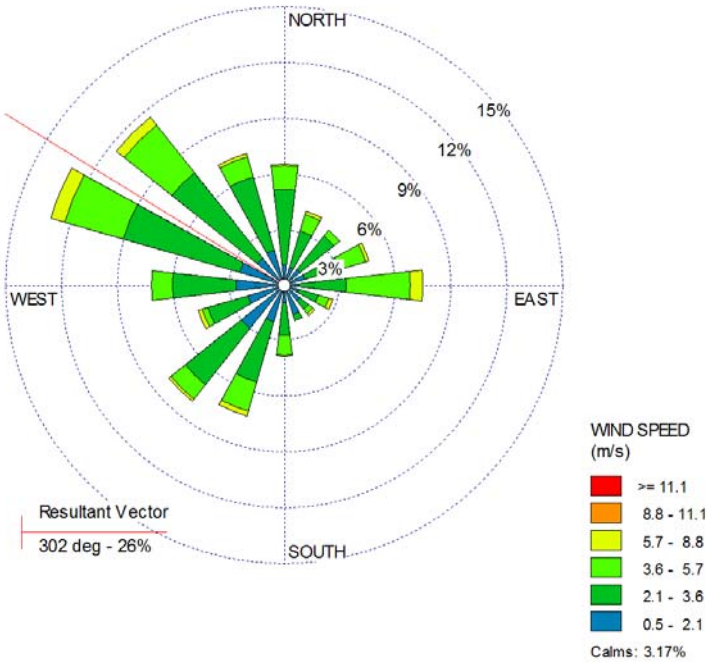

Figure 8g: Autumn wind rose

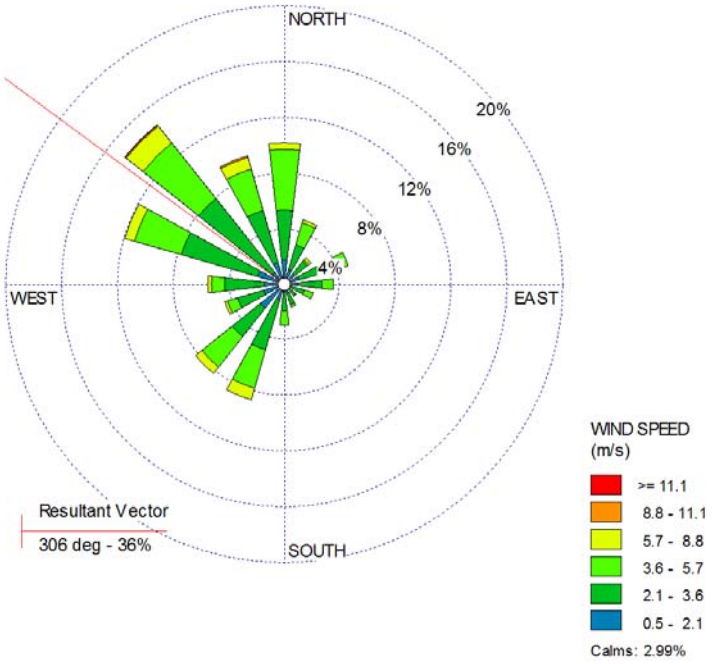

Figure 8h: Winter wind rose

Mixing height and atmospheric stability

The vertical component of dispersion is a function of the extent of thermal turbulence and the depth of the surface mixing layer. Unfortunately, the mixing layer is not easily measured and must often be estimated using prognostic models that derive the thickness from some of the other parameters that are often measured, e.g. solar radiation and temperature. During the day-time, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground based inversions and the erosion of the mixing layer. Day-time mixing heights were calculated with the prognostic equations of Batchvarova and Gryning, while night-time boundary layer heights were calculated from various diagnostic approaches for stable and neutral conditions. The mixing layer in the study area ranges from 0 metres (only a stable or neutral layer exists) during night-times to the base of the lowest-level elevated inversion during unstable, day-time conditions.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in **Table 4**. The hourly standard deviation of wind direction, wind speed and solar radiation is used to determine hourly-average stability classes (STAR method).

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends mainly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. The situation is more pronounced during the winter months due to strong night-time inversions and a slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

Table 4:

Atmospheric stability classes

Class A	very unstable	calm wind, clear skies, hot day-time conditions
Class B	moderately unstable	clear skies, day-time conditions
Class C	unstable	moderate wind, slightly overcast day-time conditions
Class D	neutral	high winds or cloudy days and nights
Class E	stable	moderate wind, slightly overcast night-time conditions
Class F	very stable	low winds, clear skies, cold night-time conditions

For elevated releases, the highest ground level concentrations would occur during unstable, day-time conditions. The wind speed resulting in the highest ground level concentration depends on the buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speed, on the other hand, the plume may reach the ground closer, but due to the increased ventilation, it will be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. The highest concentrations for low level releases would occur during weak wind speeds and stable atmospheric conditions. Air pollution episodes frequently occur just prior to the passage of a frontal system that is characterised by calm wind and stable conditions.

On the Highveld, the high frequency of anticyclonic circulation and associated subsidence in the upper air reaches a maximum in winter. The subsidence is conducive to the formation of elevated temperature inversions throughout the year with a frequency of 60% and winter base height of about 1300 and 2600 m AGL in summer.

Stable and clear conditions are ideal for the formation of surface temperature inversions at night. The winter inversions in the HPA region vary in strength from 5°C to 7°C and in depth from 300 to 500m above ground level (AGL) and occur between 80 and 90% of winter nights. Inversions of more than 10°C occur on more than 25% on winter nights.

In summer, the surface inversions are weaker and seldom exceeded 2°C in strength. The maximum midday mixing depths vary between 1 000m and 2 000m AGL in winter and may exceed 2 500m in summer.

The presence of subsidence induced semi-permanent absolutely-stable layers at approximately 800 hPa (about 350 m AGL) and 500 hPa (about 3500 m AGL) extend over the southern African sub-continent. The vertical transport of aerosols between the surface and the tropopause is controlled by these stable layers. Aerosols typically accumulate below the base of the respective layers and in turn, the layers promote transport of the aerosols at their respective levels. The trajectories pass through different height levels, but become trapped between absolutely-stable layers.

Highveld Meteorology and Air Quality

The predominant anticyclonic circulation over the Highveld, particularly in winter, results in light winds, clear skies and the development of surface temperature inversions at night that persist well into the morning. The mechanisms to disperse pollutants that are released at or near ground level into this stable atmosphere are typically weak. Pollutants tend therefore to accumulate near their source or to travel under the light near-surface drainage winds. Relatively high ambient concentrations may occur especially at night and in the morning when the surface inversions are strongest. This meteorology is particularly relevant to low-level industrial stacks, domestic fuel burning and motor vehicles.

During the day, surface warming induces the break-up of the surface inversion and promotes convection, which enhances the dispersion the nigh-time pollution build-up. Convection, on the other hand, may bring emissions from taller stacks down to ground level, so-called fumigation, that result in episodes of high ambient pollutant concentrations.

Immediately above the surface inversion, the low-level jet (LLJ), a strong nocturnal wind system, provides an effective mechanism to transport pollutants from taller stacks away from their source. The LLJ occurs over the much of the area at night and is stronger and more persistent in winter.

Westerly flow into the area is associated with the introduction of clean, mostly maritime, air. Hence, ambient air quality improves with the passage of wintertime westerly waves over the Highveld and ambient pollutant concentrations decrease. Convective summer showers and thundershowers wash pollutants out of the atmosphere on a relatively local scale, while widespread convective rain activity can reduce ambient pollutant concentrations on a larger scale.

Pollutants released in the Highveld do not only affect the Highveld. Easterly airflow associated with a ridging Indian Ocean Anticyclone results in recirculation over the subcontinent. Pollutants emitted in the Highveld are recirculated at different spatial and temporal scales depending on the strength of the ridging anticyclone. The recirculation may be limited to the Highveld for a few days only or for a number of days of resulting in increases in ambient pollutant concentrations. Recirculation on larger spatial scales may transport pollutants emitted in the Highveld well beyond its boundaries and into neighbouring municipalities and even across international borders.

4. AIR QUALITY IMPACT ASSESSMENT

4.1. EXISTING AIR QUALITY

The outdoor sources of air pollution resulting from human activities comprise three broad categories.

Stationary sources, which can be subdivided into; rural area sources, e.g. agriculture, mining and quarrying and industrial point and area sources, e.g. manufacturing of chemicals, non-metallic mineral products, basic metal industries and power generation.

Community sources, e.g. heating of homes and buildings, municipal waste and sewage sludge incinerators, fireplaces, cooking facilities, laundry services and cleaning plants.

Mobile sources, such as combustion-engine vehicles, e.g. light duty petrol-powered cars, light and heavy-duty diesel-powered vehicles, motorcycles, aircraft and line sources such as fugitive emissions from vehicle traffic.

Air pollutants are traditionally classified into suspended particulate matter (dusts, fumes, mists and smokes), gaseous pollutants (gases and vapours) and odours.

Particulate matter suspended in air includes total suspended particles (TSP), PM_{10} (SPM with a aerodynamic diameter of less than 10µm), $PM_{2.5}$ (SPM with a aerodynamic diameter of less than 2.5µm), fine and ultra fine particles, diesel exhaust, coal fly-ash, mineral dusts (e.g. coal, asbestos, limestone and cement), metal dusts and fumes (e.g. zinc, copper, iron, lead), acid mists (e.g. sulphuric acid), fluoride particles, paint pigments, pesticide mists, carbon black, oil smoke and many others.

Gaseous pollutants include sulphur compounds (e.g. sulphur dioxide and sulphur trioxide), carbon monoxide, nitrogen compounds (e.g. nitric oxide, nitrogen oxide and ammonia), organic compounds (e.g. hydrocarbons, volatile organic compounds, polycyclic aromatic hydrocarbons and halogen derivatives, aldehydes etc.), halogen compounds (e.g. HF and HCl) and odorous substances.

Secondary pollutants may be formed from gaseous pollutants by thermal, chemical or photochemical reactions. For example, by thermal action sulphur dioxide can be oxidised to sulphur trioxide which, dissolved in water, gives rise to the formation of sulphuric acid mist. Photochemical reactions

between nitrogen oxides and reactive hydrocarbons can produce ozone, formaldehyde and peroxyacetyl nitrate; reactions between hydrochloric acid and formaldehyde can form bischloromethyl ether.

While some odours are known to be caused by specific chemical agents such as hydrogen sulphide, carbon disulphide and mercaptans, others are difficult to define chemically.

The main source of information on air pollution in developing countries is the Air Management Information System (AMIS) set up the World Health Organisation (WHO). AMIS is based on voluntary reporting of data by municipalities of the WHO member states. The AMIS core data base collects information on annual (arithmetic) mean and high (95-, 98-) percentiles of daily mean concentrations of SO_2, NO_2, O_3, CO, SPM, lead and other potentially monitored compounds in more than 100 cities. In principle data from three types of monitoring stations are stored: 'industrial' reflecting levels in areas affected by emissions from industry, 'city centre/commercial' reflecting levels mostly affected by traffic and 'residential' which should reflect the lowest level of population exposure.

Highveld Priority Area Air Quality

The state of ambient air quality in the HPA has been the subject of investigation and monitoring for more than 30 years in step with the growing power generation industry, mining and other industrial sectors such as the petrochemical and metallurgical sectors. The state of air quality in the Highveld region is described in the Air Quality Baseline Assessment for the Highveld Priority Area (DEA, 2010).

The total annual emissions of PM_{10} on the HPA is estimated at 279 630 tons, of which approximately half is attributed to dust entrainment on mine haul roads. The emission of PM_{10} from the primary metallurgical industry accounts for 17% of the total emission, with 12% of the total from power generation. By contrast, power generation contributes 73% of the total estimated NO_x emission of 978 781 tons per annum and 82% of the total estimated SO_2 emission of 1 622 233 tons per annum.

Industrial sources in total are by far the largest the contributor of emissions in the HPA, accounting for 89% of PM_{10}, 90% of NO_x and 99% of SO_2.

Major sources in the HPA are grouped into the following categories:

1. Power Generation
2. Coal Mining
3. Primary Metallurgical Operations
4. Secondary Metallurgical Operations
5. Brick Manufacturers
6. Petrochemical Industry
7. Ekurhuleni Industrial Sources (excluding the above)
8. Mpumalanga Industrial Sources (excluding the above)
9. Agricultural operations (seasonal)

Parts of the HPA experience relatively good air quality, but generally ambient air quality in the HPA is poor and eight extensive areas occur where ambient SO_2, PM_{10} and O_3 concentrations exceed air quality standards. These "hotspots" are illustrated in **Figure 9** by the number of modelled exceedences of the 24-hour SO_2 and PM_{10} standards.

The air quality hotspots result mostly from a combination of emissions from the different industrial sectors and residential fuel burning, with motor vehicle emissions, mining and cross-boundary transport of pollutants into the HPA adding to the base loading.

Available monitoring data confirms that the areas of concern are in the vicinity of Ekurhuleni, Kendal, Witbank, Middelburg, Secunda, Ermelo, Standerton, Balfour, and Komati where exceedences of ambient SO_2 and PM_{10} air quality standards occur.

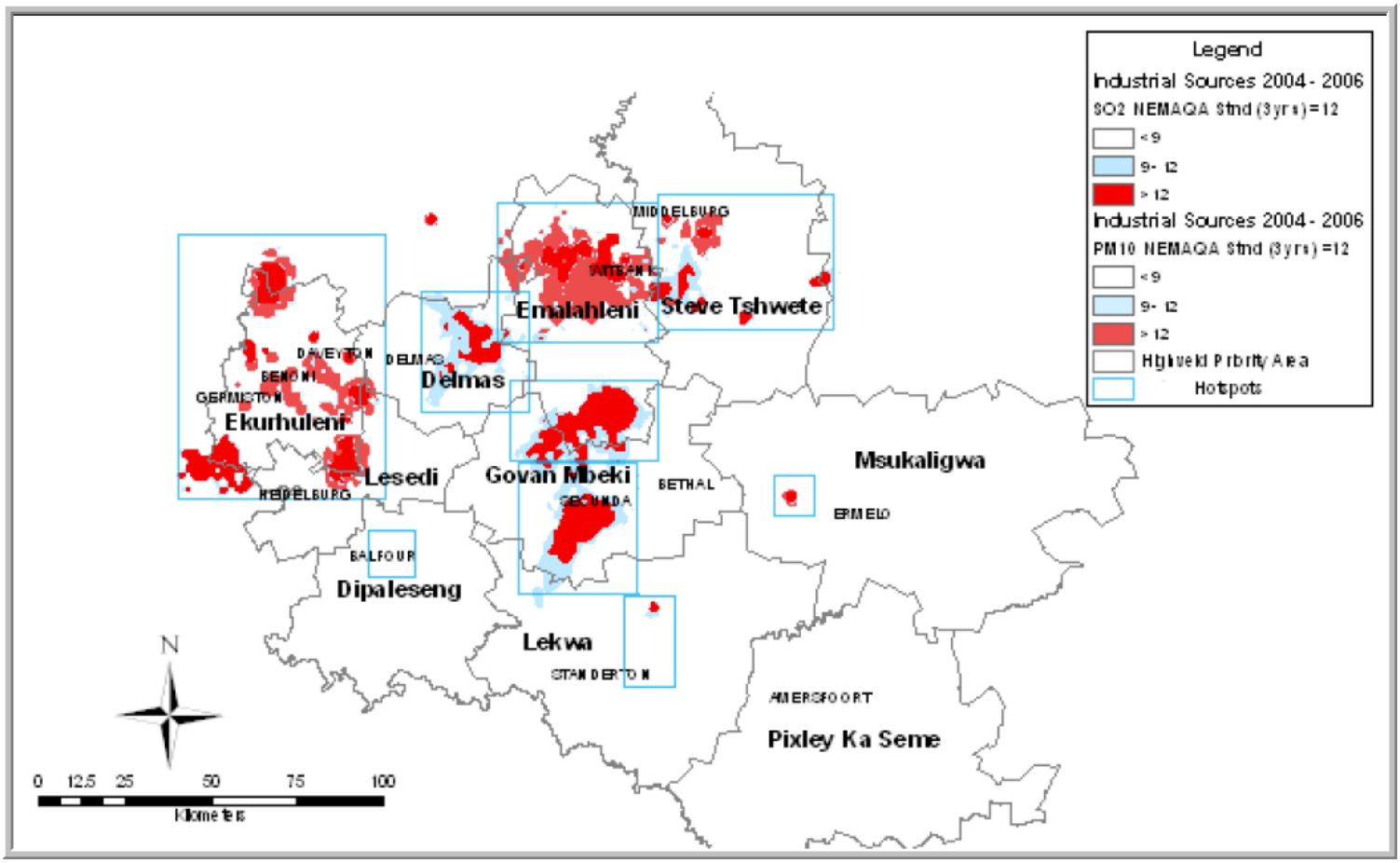

Figure 9: Modelled frequency of exceedence of 24-hour ambient SO_2 and PM_{10} standards and the 1-hour NO_2 standard in the HPA, indicating the air quality Hot Spot areas (from Air Quality Management Plan for the HPA, DEA 2010)

The effects of poor dispersion conditions in the winter are evident throughout the monitoring record for all pollutants, resulting in greater frequency of exceedences of the standards. PM_{10} displays this seasonal trend most strikingly, showing a sharp contrast between wintertime peaks and summer minimum values at monitoring sites. Seasonal trends are clearly observed for O_3 in the monitoring record, as springtime peaks are easily identified. Monitoring data show CO and benzene to be within acceptable limits at the new sites. Trends in pollutant concentrations, based on current data, cannot be conclusively identified, marred in particular by poor data collection.

Exceedences of ambient air quality standards present situations where potential impacts on human health can occur. Ambient monitoring and dispersion modeling have identified eight areas on the HPA where ambient concentrations of PM_{10}, SO_2 or NO_2 exceed the ambient standards. Exposure

may be high where these exceedences coincide with populated areas and the risks to human health may be significant.

The Ekurhuleni Air Quality Hotspot

Ekurhuleni Metropolitan Municipality (EMM) has the highest population density on the HPA, and the greatest concentration of industries and motor vehicles. Air quality is generally poor throughout the EMM with frequent modeled exceedances of the 1-hour and 24-hour SO_2 concentrations and the 24-hour PM_{10} standards. The entire EMM is regarded as an air quality hotspot, with a number of nodes of frequent modeled exceedance of the standards.

There is unfortunately no reliable ambient monitoring data available in Ekurhuleni to support the model predictions. The hotspot is characterised by exceedances of both SO_2 and PM_{10} standards. The major source contribution in each of the nodes is from clay brick manufacturing. The contribution of industries in the area dominates the source apportionment, showing clearly that residential fuel burning, motor vehicles and coal mining are far less significant in considering the total air quality loading for all pollutants (**Figure 10**). Residential fuel burning does make a notable contribution to ambient concentrations. Motor vehicles contribute most significantly of all other sectors besides industries in this hotspot to elevated NOx concentrations.

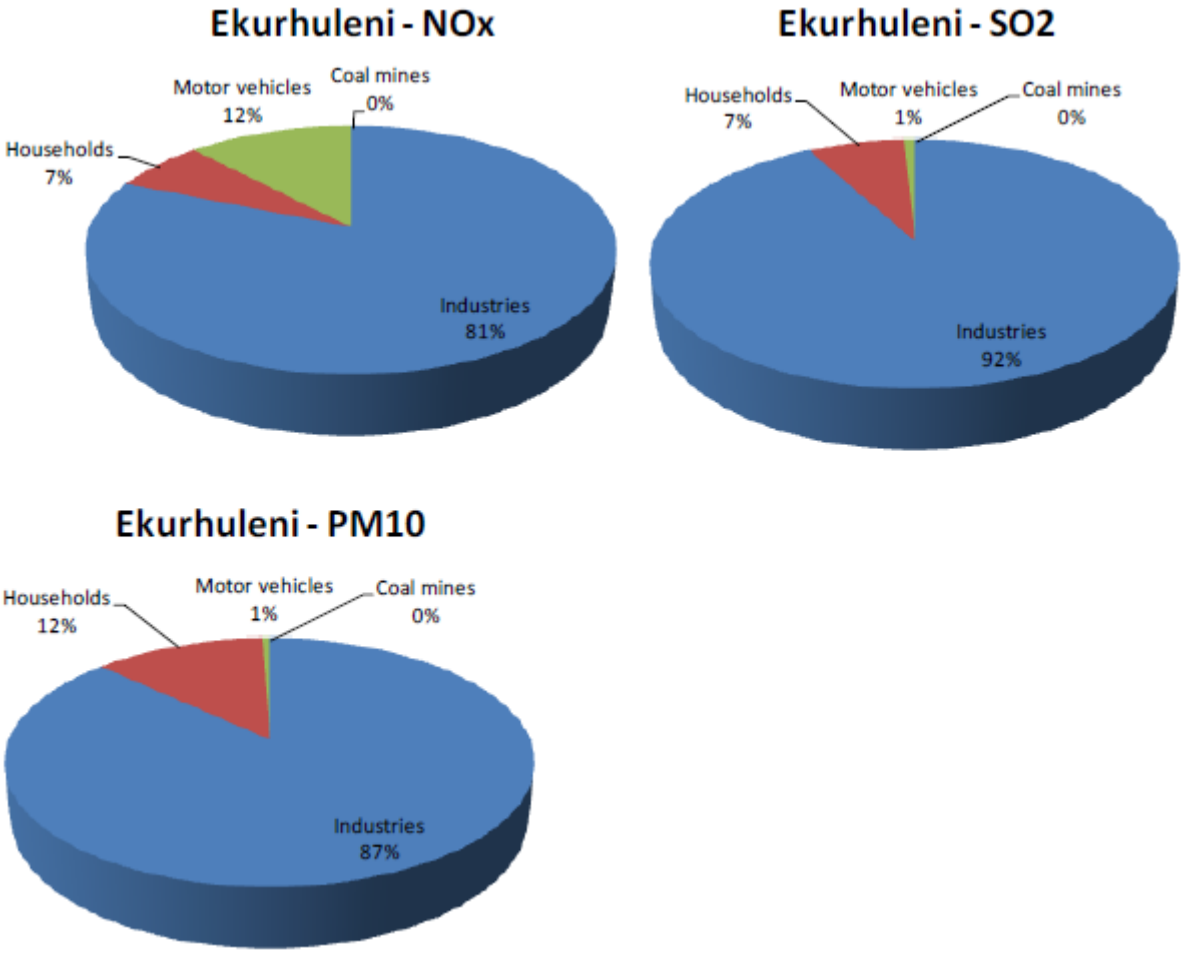

Figure 10: Contribution of different sources to ambient concentrations in the Ekurhuleni Hot Spot (from Air Quality Management Plan for the HPA, DEA 2010)

Particulate Matter

In Western Europe and North America efforts to control emissions of particulate matter have generally resulted in positive trends. In many cities the annual ambient average concentrations of PM_{10} are in the range of 20 to 50µg/m^3.

However, annual average concentrations in some cities in Eastern Europe and in most developing countries can be well above 100µg/m^3.

Particle size is a critical factor in internal dose distribution. The location of initial deposition in the airways depends on particle size, with coarse particles being deposited in the upper respiratory tract

and fine particles being transported to the lower respiratory tract. The smaller particles contain the secondarily formed aerosols (gas to particle conversion), combustion particles and condensed organic vapours and metal fumes.

Irritant effects from inhaled particles may result in increased airway constriction, altered mucociliary transport, and changes in alveolar macrophage activity. These effects apply across a wide range of inhaled particles, acting alone or together with common gaseous air pollutants, such as SO_2, NO_x or Ozone. Other toxic effects are more chemical specific and, depending on the nature of the chemical, may include organs outside the respiratory tract. Bronchi constriction, arising from chemical and/or mechanical stimulation of irritant neural receptors in the bronchi, has been reported as a response to exposure to inert dusts, as well as acid and alkaline aerosols. Individuals with asthma or emphysema and other respiratory diseases may have increased particle deposition due to altered breathing patterns or airway structural changes, which may then contribute in a cascading effect to even more bronchi constriction and particle deposition.

Mortality outcomes calculated for South African urban areas estimate that outdoor air pollution caused 3.7% of total mortality from cardiopulmonary disease in adults aged 30 years and older, 5.1% of mortality attributable to cancers of the trachea, bronchus, and lung in adults, and 1.1% of mortality from acute respiratory infections in children under 5 years of age.

Sulphur dioxide

SO_2 is a colourless pungent, irritating, water-soluble and reactive gas. In most cities of developed countries the annual mean concentrations of SO_2 in residential areas range between 20 and 40µg/m^3.

However, in developing countries the annual mean concentration of SO_2 in ambient air may be as high as 300µg/m^3. High concentrations are especially evident in cities with cold winters, under conditions of poor atmospheric dispersion such as inversions or when emission from a major source are brought to ground by certain atmospheric conditions.

Due to its reactivity, SO_2 has a highly non-uniform dose distribution along the conductive airways of the respiratory tract. For low to moderate tidal volumes and nasal breathing, the penetration into the

lungs is negligible. For larger tidal volumes and oral inhalation, doses of interest may extend into the segmental bronchi. SO_2 can only reach the gas-exchange region of the lungs after adsorption onto particulate matter.

Another special consideration for SO_2 is that there is great variation in susceptibility to bronchoconstrictive responses. Persons having asthma or atopy can be about ten times more responsive than healthy subjects.

Nitrogen oxides

Ambient concentrations of NO_2 in air are highly variable. Natural background concentrations can range from less than 1µg/m^3 to more than 9µg/m^3. In cities, ambient annual mean concentrations can range from 20-90µg/m^3 with hourly maximum concentrations from 75-1 000µg/m^3. In Johannesburg, annual average concentrations in excess of 70µg/m^3 have been recorded regularly since the 1990s.

NO_2 is a relatively water-insoluble gas and appreciable amounts of inhaled NO_2 can penetrate to, and elicit biological responses in small lung airways. As with SO_2 there is much greater susceptibility to bronchoconstrictive responses in individuals with asthma.

Carbon monoxide

Natural ambient concentrations of CO range between 0.01 and 0.23mg/m^3. In urban environments, mean concentrations over eight hours are usually less than 20mg/m^3, and one-hour peak levels are usually less than 60mg/m^3. Highest concentrations are usually measured near major roads, as vehicles are the major source of CO.

CO exerts its toxic effects after binding with haemoglobin in the capillaries of the lungs.

Ozone

Background one-hour average concentrations of O_3 in remote and relatively unpolluted parts of the world are often in the range of 40 to 70µg/m^3. In cities maximum mean hourly concentrations can be

as high as 300 to 400µg/m^3. High O_3 concentrations can persist for 8 to 12 hours per day for several days, when atmospheric conditions favour O_3 formation and poor dispersion conditions exists.

O_3 is a relatively water-insoluble gas. It reacts and produces toxic effects on the small airway surfaces. The dose-delivery is greatest in terminal and respiratory bronchioles. Unlike NO_2 and SO_2, there is very little difference in lung function responsiveness between asthmatics and healthy subjects. There is, however great variability in individual responsiveness that is not yet fully understood.

Lead

Levels of lead found in air, food, water and soil/dust vary widely throughout the world and depend on the degree of industrial development, urbanization and other lifestyle factors. In cities of developing countries traffic-related lead levels range between 0.3 and 1µg/m^3 with extreme annual mean values between 1.5-2µg/m^3.

Lead is inhaled as fine particles and deposited in the lungs. Since lead uptake by blood is dependent on deposition pattern and solubility, total lead content is only a surrogate for the biologically effective dose.

4.2. DISPERSION SIMULATION

Dilution of air contaminants in the atmosphere is an important process in preventing undesirable levels of pollutants in the ambient air. Atmospheric dispersion of air contaminants is the result of ventilation, atmospheric turbulence and molecular diffusion. However, gaseous and particulate air contaminants are primarily dispersed into the ambient air through wind action and atmospheric turbulence, much of it on the micro scale level. Depending on the relevant environmental and adiabatic lapse rates, various plume formation can be predicted. These include, looping, neutral, coning, fanning, lofting, fumigating and trapping.

Moisture content and form in the atmosphere can have a profound effect upon the air quality. The presence and amount of water vapour in the atmosphere affects the amount of solar radiation received and reflected by the earth.

Several dispersion models have been developed and are the mathematical description of the meteorological transport and dispersion of air contaminants. In order to describe the position of the place where the concentration of contaminants will be estimated, relative to both the source and the ground, a standard Cartesian (x, y, z) co-ordinate system is used in which:

- the physical source is located at the origin,
- the x-axis lies along the mean wind direction,
- x is the distance from the source,
- y is the lateral distance from the mean wind direction,
- z is the height above ground level,
- h is the physical height of the source,
- Δh is the additional height by which the plume rises due to its buoyancy and/or momentum,
- $H = h + \Delta h$ is the effective (plume) height of the release, and
- u is the mean wind speed at plume height.

Most models in use today assume Gaussian distribution of emission pollutants, horizontally and vertically downwind of the source. With the assumption that the distributions in the y and z directions are normal with a standard deviation of σ_i, the concentration of a gas or aerosol (<20µm diameter particles) can be calculated at ground level for a distance downwind of the source:

$$C_{x,y} = \frac{Q}{\pi u \sigma_z \sigma_y} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where $C_{x,y}$ = pollutant concentration in g/m^3 with a maximum ground level concentration where $\sigma_z = 0.707H$,

Q = pollutant emission rate in g/s

π = constant pi = 3.14159

u = mean wind speed in m/s

σ_y = standard deviation of horizontal plume concentration at distance x in m,

σ_z = standard deviation of vertical plume concentration at distance x in m,

exp = base of natural logarithm = 2.71828183

H = effective stack height in m,

x = downwind distance along plume mean centreline from point source in m, and

y = crosswind distance from centreline of plume in m

The Gaussian equation contains explicit references to y and z, and also implicit references to x (since σ_y and σ_z are themselves functions of x). Empirical studies resulted in graphs where values for these constants could be obtained for different Pasquill stability categories. However, these graphs were inaccurate by nature and equations for the variation of σ_y and σ_z with stability class have been developed and are shown in the table below.

Table 5:

Equations for the variation of σ_y and σ_z

Pasquill stability class	σ_y	σ_z
A	$0.22x(1+0.0001x)^{-0.5}$	$0.20x$
B	$0.16x(1+0.0001x)^{-0.5}$	$0.12x$
C	$0.11x(1+0.0001x)^{-0.5}$	$0.08x(1+0.0002x)^{-0.5}$
D	$0.08x(1+0.0001x)^{-0.5}$	$0.06x(1+0.0015x)^{-0.5}$
E	$0.06x(1+0.0001x)^{-0.5}$	$0.03x(1+0.0003x)^{-1}$
F	$0.04x(1+0.0001x)^{-0.5}$	$0.016x(1+0.0001x)^{-1}$

The simplest Gaussian solution assumes that the plume is free to expand in all directions without constraint. In the usual situation of an elevated source at some height above the ground, downwind dispersion is always limited by the presence of the ground, while upward dispersion may be limited by an elevated inversion. Assuming that no pollutant is absorbed by the ground, any pollutant that

reaches the ground is available for upward dispersion and the following equation takes into account reflection at the ground:

$$C_{x,y} = \frac{Q}{2\pi u \sigma_z \sigma_y} \exp \frac{-y^2}{2\sigma_y^2} \left[\exp - \frac{1}{2} \left(\frac{z - H}{\sigma_z^2} \right)^2 \right] + \exp \left[- \frac{1}{2} \left(\frac{z + H}{\sigma_z^2} \right)^2 \right]$$

Results

This section contains the results of the predicted maximum and average ground level concentrations generated through the ISC-AERMOD VIEW model.

Concentration and deposition isopleths illustrated in **Figure 11** reflect interpolated values for each receptor grid point for various averaging periods. It has generally been found that the accuracy of dispersion models improve with increased averaging periods. The prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the process and location. For this reason concentrations resulting from routine releases are given for at least three averaging periods, viz. hourly, daily and annual averages.

The results presented in **Figure 11** reflect the spectrum from maximum ground level concentrations, occurring during very unstable conditions with low wind speeds, to low wind speeds during very stable conditions resulting in maximum impact area. Dispersion results are presented under the following subsections:

- Daily average dust deposition rates during construction.
- Maximum 24-hour and annual average PM_{10} concentration

The dispersion of emissions from the process was modelled using the following inputs:

- Source emission rates contained in **Table 3**.
- Bag house stack parameters; height 30m, diameter 1.5m, exit velocity 23.5m/s and exit temperature 80°C.

- Scrubber stack parameters; height 30m, diameter 0.5m, exit velocity 8.5m/s and exit temperature 50°C.
- A uniform Cartesian grid with a resolution of 250m by 250m.
- A construction footprint of 28 650m^2. 50% control efficiency during construction.
- Local meteorological data for the period January 2008 to December 2013.
- Average annual background nuisance dust deposition rate of 100mg/m^2day for cumulative assessment.
- Average annual background PM_{10} concentration of 25µg/m^3 for cumulative assessment.
- Average annual background SO_2 concentration of 15µg/m^3 for cumulative assessment.
- Average annual background NO_2 concentration of 10µg/m^3 for cumulative assessment.

Please note that only modelling outcomes showing little or more impact (>10% of the standard) were reflected in the report.

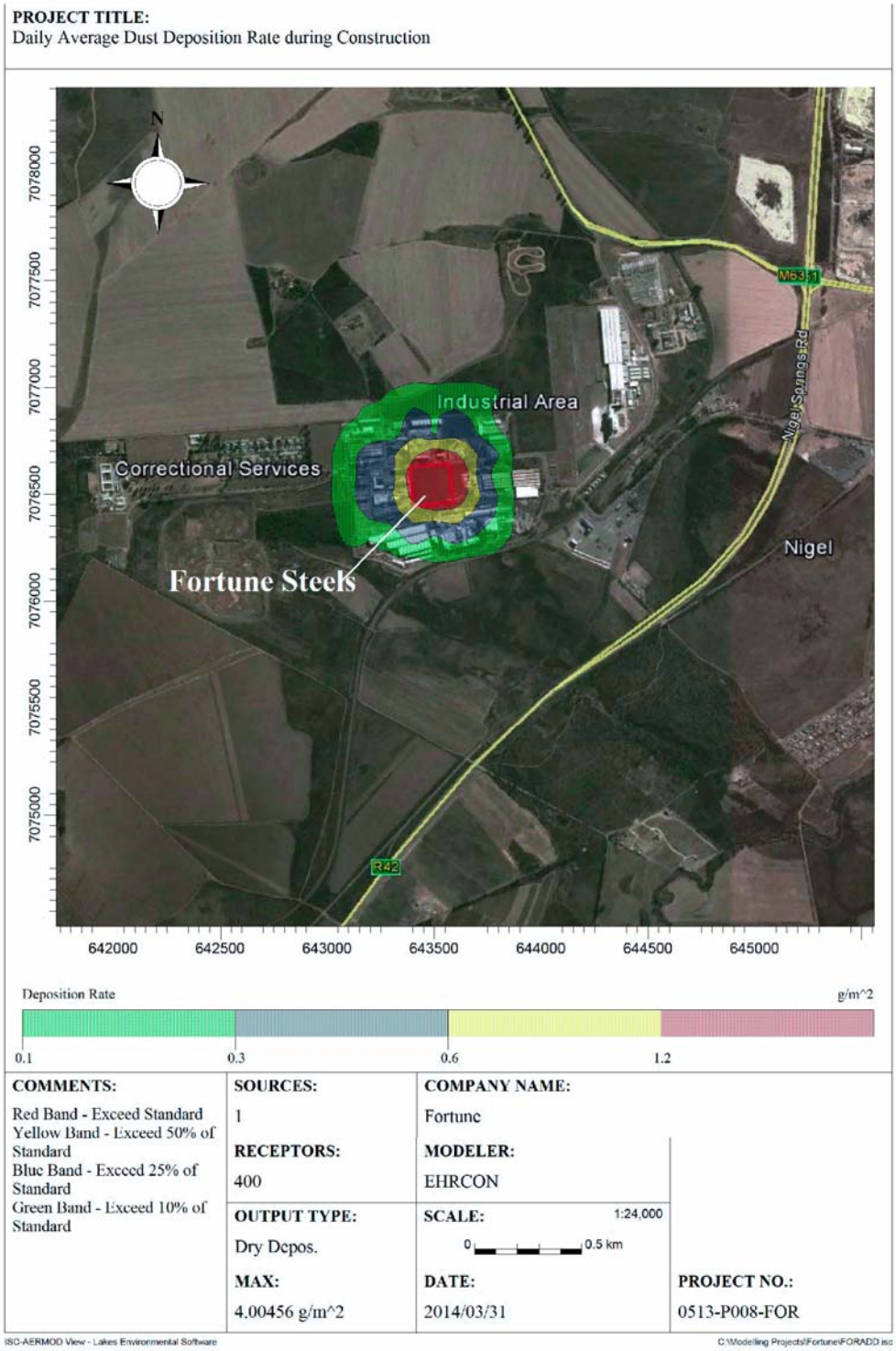

Figure 11a: Daily average dust deposition rate during construction (South African National non-residential standard – 1 200mg/m^2/day)

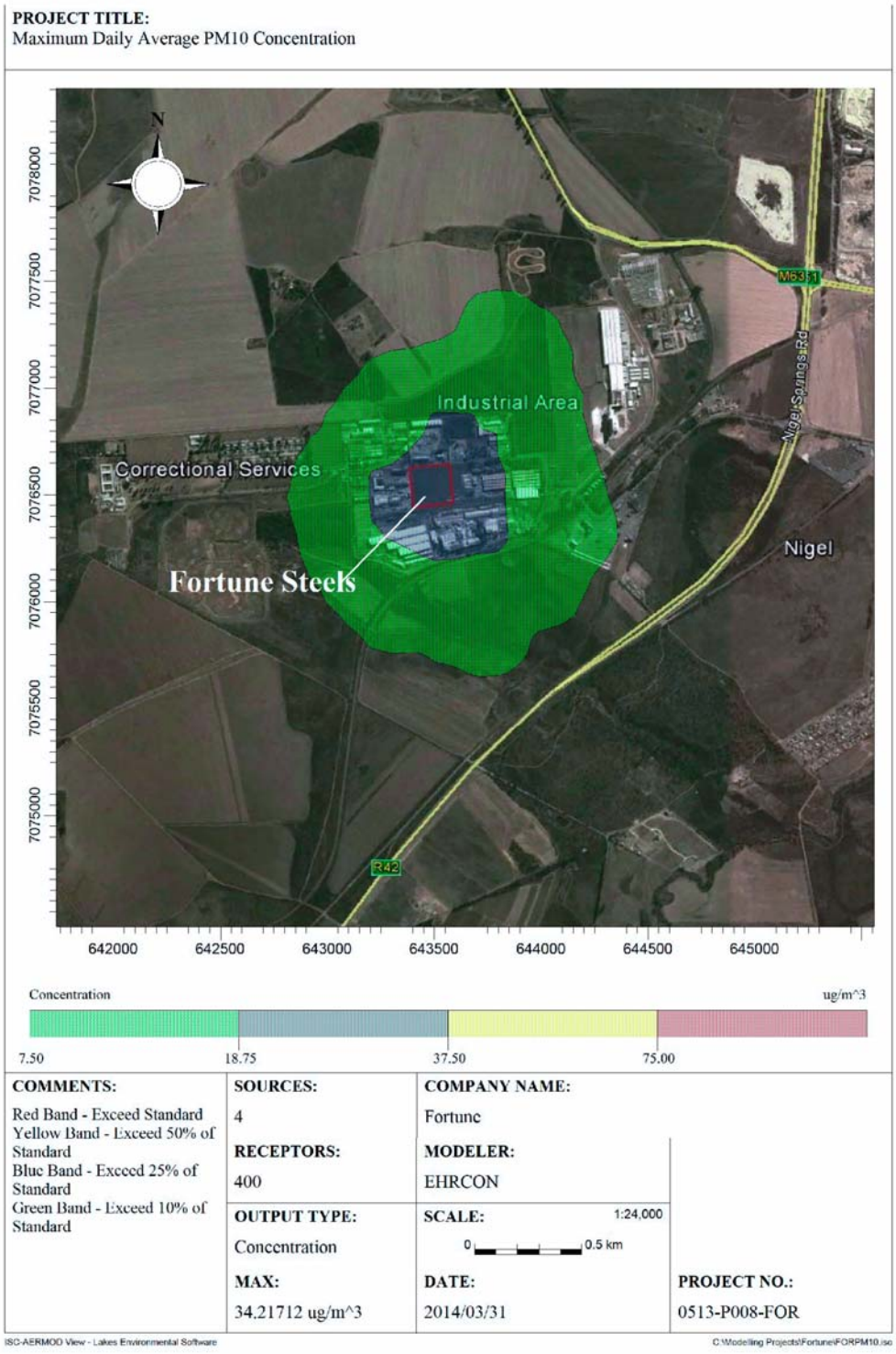

Figure 11b: Daily Average PM_{10} Concentration during normal operations (South African National Standard - 75µg/m^3)

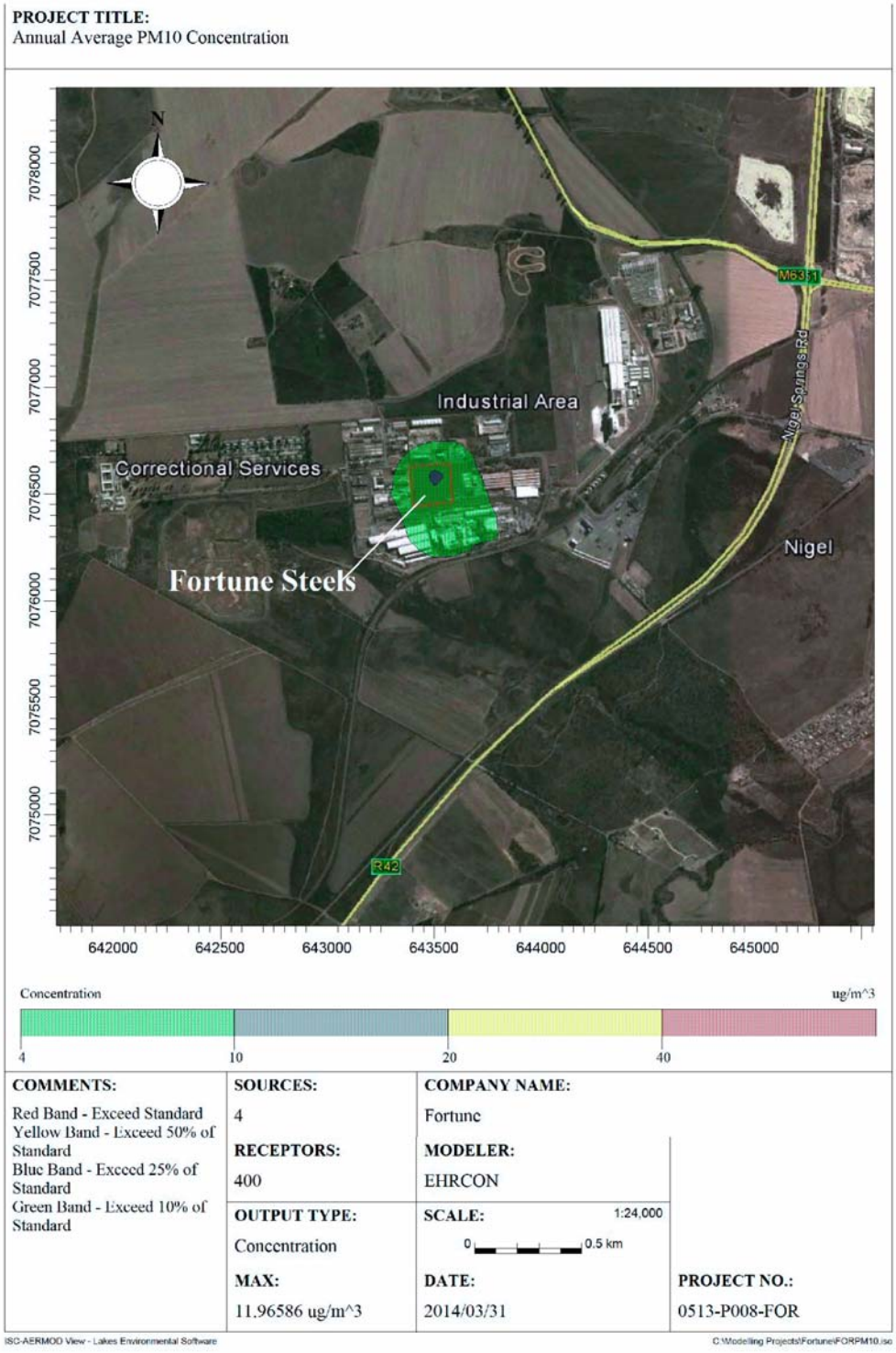

Figure 11c: Annual Average PM_{10} Concentration during normal operations (South African National Standard - 40µg/m^3)

4.3. DISCUSSION

Prior to an analysis of the simulation results it is recommendable to briefly review areas of uncertainty which needs to be taken into account in the interpretation of the results. The range of uncertainty of the Gaussian plume model is given by the US-EPA as being in the range of -50% to +200% when used under the recommended conditions. Uncertainties are, however, not only associated with the mathematical model itself, but also with the generation of the meteorological and source data used as input data. It is well known that wind data errors are the major cause of poor agreement, especially for short-term predictions and long down-wind distances. The selection of a suitable meteorological data set for use in the simulation analysis is fundamental to the accuracy of the results. Errors in source strengths translate directly into errors of similar magnitudes in the model prediction.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model really represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components; the uncertainty due to errors in the model physics, the uncertainty due to data errors and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

The impact evaluation consists of a comparison of modelled results to ambient air quality guidelines and a significance rating of the predicted impacts. Simulations were undertaken to determine dry deposition, PM_{10} and gasses. Averaging periods were selected to facilitate comparisons between predicted concentrations and ambient air quality guidelines.

4.3.1. Dust Deposition

During the construction phase of the project, dust deposition rates in excess of the non-residential standard are predicted at the nearest receivers north and east of the site respectively. These receivers are within 100m of operations. During extreme dry and windy spells, deposition rates as high as 4 000mg/m^2/day may be recorded.

During the operational years of the project exceedence of the non-residential standard will most likely be limited to the site.

Vehicle movement and material handling will remain the most visible sources of nuisance dust throughout the construction and operational live of the project.

4.3.2. PM10

Daily exceedence of the 24-hour standard of 75µg/m^3 as a result of Fortune Steel's operations is estimated to remain below 25% of the standard. The impact is limited to industrial receivers up to a distance of 300m from the process boundary.

It is unlikely that the process independently, would result in annual average PM_{10} concentrations above the national standard of 40µg/m^3 at the nearest receivers.

The latest Air Quality Management Plan for the Ekurhuleni Metropolitan Municipality confirmed the significant contribution of metallurgical processes to ambient PM_{10} concentrations. Other important sources of PM_{10} in area are domestic fuel burning and transport.

This impact study considered the cumulative effects on air quality caused by the aggregate of past and present actions in the area. Baseline criteria pollutant concentrations are supported from recent monitoring data collected in the Highveld Priority Area.

Linear relationships between fine particulate concentrations and human health risks are published by organisations such as the WHO. Relatively low PM_{10} concentrations have been associated with various health effects including; increased respiratory hospital admissions, respiratory system exacerbation and cough, in some cases mortality.

Current PM_{10} concentrations in the study are above the lowest level at which statistically significant health effects have been noted to occur (i.e. 20 to 25µg/m^3). Ambient PM_{10} limits are not based on any safe level but rather constitute an acceptance of risk (i.e. acceptance of an additional one hospital admission for respiratory ailment per million persons exposed).

4.3.3. Gaseous pollutants

Ground level concentrations for all gaseous pollutants are predicted to remain below 10% of the relevant standard, for all reference periods.

4.3.4. Health Impact Assessment

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human activities related to alternatives under study for meeting a project need.

The significance of the aspects/impacts of the Fortune Steels Plant were rated by using a matrix derived from Plomp (2004) and adapted to some extent to fit this process. These matrixes use the consequence and the likelihood of the different aspects and associated impacts to determine the significance of the impacts. The significances of the impacts were determined through a synthesis of the criteria explained below.

Probability – This describes the likelihood of the impact actually occurring.

Improbable	The possibility of the impact occurring is very low, due to the circumstances, design or experience.
Probable	There is a probability that the impact will occur to the extent that provision must be made therefore.
Highly Probable	It is most likely that the impact will occur at some stage of the development.
Definite	The impact will take place regardless of any prevention plans, and there can only be relied on mitigatory actions or contingency plans to contain the effect.

Duration – The lifetime of the impact.

Short term	The impact will either disappear with mitigation or will be mitigated through natural processes in a time span shorter than any of the phases.
Medium term	The impact will last up to the end of the phases, where after it will be negated.

Long term	The impact will last for the entire operational phase of the project but will be mitigated by direct human action or by natural processes thereafter.
Permanent	Impact that will be non-transitory. Mitigation either by man or natural processes will not occur in such a way or in such a time span that the impact can be considered transient.

Scale – The physical and spatial size of the impact.

Local	The impacted area extends only as far as the activity, e.g. footprint
Site	The impact could affect the whole, or a measurable portion of the above mentioned properties.
Regional	The impact could affect the area including the neighboring residential areas.

Magnitude/ Severity – Does the impact destroy the environment, or alter its function?

Low	The impact alters the affected environment in such a way that natural processes are not affected.
Medium	The affected environment is altered, but functions and processes continue in a modified way.
High	Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.

Significance – This is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required.

Negligible	The impact is non-existent or unsubstantial and is of no or little importance to any stakeholder and can be ignored.
Low	The impact is limited in extent, has low to medium intensity; whatever its probability of occurrence is, the impact will not have a material effect on the decision and is likely to require management intervention with increased costs.

Moderate	The impact is of importance to one or more stakeholders, and its intensity will be medium or high; therefore, the impact may materially affect the decision, and management intervention will be required.
High	The impact could render development options controversial or the project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor in mitigation.

The following weights were assigned to each attribute:

Aspect	Description	Weight
Probability	Improbable	1
	Probable	2
	Highly Probable	4
	Definite	5
Duration	Short term	1
	Medium term	3
	Long term	4
	Permanent	5
Scale	Local	1
	Site	2
	Regional	3
Magnitude/Severity	Low	2
	Medium	6
	High	8
Significance	**Sum(Duration, Scale, Magnitude) x Probability**	
	Negligible	<20
	Low	<40
	Moderate	<60
	High	>60

The significance of the major impacts was rated without mitigation measures (WOM) and with mitigation (WM) measures.

Significance	**Without mitigation measures**
Negligible	The impact is not substantial and does not require any mitigation action.
Low	The impact is of little importance, but may require limited mitigation.
Moderate	The impact is of importance and is therefore considered to have a negative impact. Mitigation is required to reduce the negative impacts to acceptable levels.
High	The impact is of major importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.
Significance	**With mitigation measures**
Negligible	The impact will be mitigated to the point where it is regarded as insubstantial.
Low	The impact will be mitigated to the point where it is of limited importance.
Low to Moderate	The impact is of importance, however, through the implementation of the correct mitigation measures such potential impacts can be reduced to acceptable levels.
Moderate	Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.
Moderate to High	The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels.
High	The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance after mitigation could render the entire development option or entire project proposal unacceptable.

Table 6 contains a summary of the potential future impact on human health posed by the process based on predicted conditions.

Table 6a:

Dust deposition impact during construction activities

Nature of Impact		
Nuisance dust emissions during construction		
	Current Situation	**With Process**
Duration	Long term (4)	Short term (1)
Scale	Local (1)	Site (2)
Severity	Low (2)	Medium (6)
Probability	Definite (5)	Highly probable (4)
Significance	Low (35)	Low (36)

Mitigation:

Please refer to other control measures discussed in **Section 4.4**.

Cumulative impacts:

Low background dust deposition rate. Impact from construction mostly limited to the construction site and immediate surroundings.

Residual impacts:

Frequent exceedence of the annual target level up to a distance of 500m from the process boundary. Very infrequent exceedence of the industrial action level.

Table 6b:

PM_{10} impact assessment

Nature of Impact		
PM_{10} impact from normal operations at nearest receivers		
	Current Situation	**With Process**
Duration	Long term (4)	Long term (4)
Scale	Local (1)	Site (2)
Severity	Low (2)	Medium (6)
Probability	Definite (5)	Highly Probable (4)
Significance	Low (35)	Moderate (48)

Mitigation:

The site will be paved and good housekeeping is foreseen.

Predicted traffic flow on site is effective.

Please refer to other control measures discussed in **Section 4.4**.

Cumulative impacts:

Background concentrations above the lower assessment threshold. The process could potentially further increase ambient concentrations at the nearest receivers.

Residual impacts:

Impact from process can be further reduced by applying best available industry techniques. These techniques may include the following; improving burner efficiency, improving oil atomisation and combustion aerodynamics.

Table 6c:

Gaseous pollutant impact assessment

Nature of Impact		
Gaseous pollutant impact from normal operations		
	Current Situation	**With Process**
Duration	Long term (4)	Long term (4)
Scale	Local (1)	Regional (3)
Severity	Low (2)	Low (2)
Probability	Definite (5)	Highly Probable (4)
Significance	Moderate (35)	Moderate (36)

Mitigation:

Please refer to other control measures discussed in **Section 4.4**.

Cumulative impacts:

Short-term background concentrations occasionally above the standard. The process could potentially increase the occurrence of excessive short term ambient concentrations at the nearest receivers. Annual average concentrations expected to remain below the national standard.

Residual impacts:

Impact from process can be further reduced by applying best available industry techniques. These techniques may include the following; improving burner efficiency, improving oil atomisation and combustion aerodynamics.

4.4. RECOMMENDATIONS

Ambient air quality assessment

According to SANS 1929:2009 the concentrations of specific pollutants within an area shall be evaluated against the following thresholds to determine applicable assessment methods:

a) upper assessment threshold, i.e. the 99th percentile pollutant levels represent a pollutant value exceeding 70% of a limit value (taking into account limit values for all periods which have been used to derive averages).
b) lower assessment threshold, i.e. the 99th percentile pollutant levels represent a pollutant value below 50% of all limit values (taking into account limit values for all periods which have been used to derive averages).

Provision should be made for three air pollutant concentration assessment methods, based on the classification pollutant concentrations relative to the upper and lower assessment thresholds. These methods are:

a) mandatory monitoring, which may be supplemented by modelling techniques to provide an adequate level of information on ambient air quality. This method should be implemented where the upper assessment threshold for a specific pollutant is exceeded;
b) a combination of measurement and modelling techniques should be implemented in areas and for pollutants for which concentrations are between the upper and lower assessment thresholds; and
c) the sole use of modelling or objective estimation techniques is permissible for pollutant concentrations below the lower assessment threshold.

The classification to determine applicable assessment methods should be based on air pollutant concentrations recorded during the previous five years where data is available. Results from measurement campaigns of short duration during the period of a year and at locations likely to be typical of the highest pollution levels may be combined with information from emission inventories and modelling to provide the concentration data required. Classification should be reviewed earlier

than every five years in the event of significant changes in activities relevant to ambient air pollutant concentrations.

In view of the predicted ambient pollutant concentrations resulting from emissions from the Fortune Steels operation in Nigel, no further ambient monitoring is recommended. Controlled emissions from process stacks should be confirmed through representative process emission testing at least once per year, in line with the requirements for listed activities (see **Section 2.2**).

The ultimate purpose of monitoring is not merely to collect data, but to provide information necessary to make informed decisions on managing and improving the environment. Monitoring fulfils a central role in this process, providing the necessary sound scientific basis for policy and strategy development, objective setting, compliance measurement against targets and enforcement action.

However, the limitations of monitoring should be recognised. In many circumstances, measurements alone may be insufficient, or impractical for the purpose of fully defining population exposure. No monitoring programme, however well funded and designed, can hope to comprehensively quantify patterns of air pollution in both space and time. At best monitoring provides an incomplete, but useful, picture of current environmental air quality. Monitoring often needs to be used in conjunction with other objective assessment techniques, including modelling, emission measurement and inventories, interpolation and mapping.

Air quality management objectives

The relationship between data collected and the information to be derived from it is essential in compiling an effective air quality management programme. The air quality management programme for Fortune Steels should ideally focus on the following key objectives:

- Determining population exposure and health impact assessment.
- Informing the public about air quality and raising awareness.
- Identifying threats to natural ecosystems.
- Determining compliance with national and international standards.
- Providing objective inputs to management.
- Source apportionment and identification.
- Policy development and prioritisation of management actions.
- Development/validation of management tools such as models and inventories.
- Assessing source impacts.
- Trend qualification, to identify future problems or progress against management actions.
- Application of air quality permits in terms of the new requirements for listed activities as stipulated by AQA.

The setting of clear objectives enables the definition of objectives for data quality. These requirements must be met to ensure that the overall objectives are achieved. This may include the following:

- Measurement accuracy and precision.
- Traceability to metrology standards.
- Temporal completeness (data capturing).
- Spatial representation and coverage.
- Consistency from site to site and over time.
- International comparability/harmonisation.

Monitoring, modelling and emission measurements should be regarded as complementary components in any integrated approach to air quality management.

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