Basic Assessment for the Amendment of the Air Quality Permit for the Iron Ore Handling Facility, Port of Saldanha

Health Specialist Study

Final Report

Prepared for: SRK Consulting

SRK Project Number 399449
SRK Consulting
The Administrative Building
Albion Spring
183 Main Road
Rondebosch
7700
South Africa

Prepared by: Prof Petro Terblanche
Environmental and Public Health Consultant
56 Dely Road
Waterkloof
0181

September 2009

THIS REPORT HAS TO BE READ IN CONJUNCTION WITH THE FOLLOWING REPORT:

“Saldanha Air Quality Permit Amendment Basic Assessment: Air Quality Specialist Baseline Study and Impact Assessment”

SRK Consulting Report No. 399449/42A

VS Reddy, September 2009

Executive Summary

Transnet Limited (Transnet) operates an Iron Ore Handling Facility (IOHF) at the Port of Saldanha, situated 120 km north of Cape Town. Transnet is proposing to increase the current throughput of the IOHF to 60 million tonnes per annum (MTPA) without structural expansions but with improved operational efficiencies to meet anticipated increasing market demand.

The operations at the IOHF currently generate dust, including particulate matter (PM), emissions. This study aims to provide an understanding of the potential health impacts of dust and PM emissions related to a proposed throughput of 60 MTPA on the general public in the areas that are potentially exposed to these emissions.

The health specialist study was designed as a desktop evaluation of existing information on the potential health effects of PM exposures in the general public and particularly a review of information on the lowest exposure levels at which adverse effects in communities have been documented. The study was therefore not a community epidemiological study aimed at establishing a cause effect relationship between PM exposures from the IOHF and respiratory illnesses in possible receptor communities such as Blue Water Bay, Saldanha, Langebaan and Vredenburg. Historic data available on PM levels in the above mentioned receptor areas does not support the execution of a community epidemiological study due to the low PM levels recorded in the monitoring network operated since 2002.

This specialist study also excluded any impact assessment of occupational exposures (within the industrial zone of the IOHF), as exposure levels predicted by dispersion modeling were presented in 24 hour averages over 7 days per week (365 days per year) relevant for community impact assessments. In the case of occupational exposures, levels of PM have to be assessed over 8 hours (1 shift per day) and 40 hour work weeks.

This Health Specialist Study focused on the following objectives as set out in the Terms of Reference (TOR):

- Review relevant literature as well as suitable and available information from previous impact assessment reports on the IOHF at Saldanha.

- Review any health legislation and standards in South Africa relevant to air emissions from the Transnet Iron Ore Handling Facility.

- Discuss the potential health concerns associated with exposure of the general public to inhalable ore particulates (PM_{10}) and dust. Differentiate between health and nuisance concerns[1].

- Describe the public health characteristics of receptor areas for inhalable particulate pollution (PM_{10}) from the handling facility, as delineated by the air quality study.

- Comment on particular population vulnerability factors with regards to emissions from the handling facility.

---

[1] In agreement with SRK, the discussion of nuisance impacts was addressed in the air quality study undertaken for the BA (Reddy and Naidoo, 2009) and is thus not repeated in this health study.

- Utilizing the findings of the air quality study, identify any potential health impacts of the proposed increase in iron ore throughput at the handling facility on the population of the study area, particularly with respect to air emissions. Identify, if possible, significant seasonal differences in exposures and the impact of synergistic factors such as aero-allergens associated with seasonal peaks on the total risk to the community. Differentiate between health and nuisance impacts.

- Assess potential health impacts on the population resulting from the proposed increase in throughput, using the prescribed impact assessment methodology and exposures predicted by dispersion modeling done as part of the Air Quality Specialist Study (Reddy and Naidoo, 2009).

- Recommend practicable mitigation measures to minimize/reduce negative health impacts on the population and to enhance positive impacts. Assess the effectiveness of proposed mitigation measures by re-rating the impact, assuming the mitigation is employed, using the prescribed impact assessment methodology.

- Formulate recommendations for the future monitoring of health impacts in the study area.

The Study was designed and executed to utilize scientific published evidence as well as regulatory agencies' reports on the health impacts of PM on communities exposed to such air pollutants. The hazard significance of PM is determined by:

- The size of the particles (the smaller the particle size, the bigger the concern, as PM with a diameter of <10 mm can be inhaled);
- The chemical composition of the particles; and
- The concentration of inhalable particulate matter (PM_{10}).

Evidence from the literature indicates that exposures to PM_{10} above certain levels can be associated with upper and lower respiratory illnesses such as sinusitis, rhinitis, coughing, bronchitis and changes in pulmonary function (e.g. the volume of air that can be inhaled into the lung might decrease). From a health perspective, both 24 hour peak concentrations and long-term average concentrations are of importance. High peak concentrations, even if long-term averages are low, may cause acute respiratory illnesses, especially in people that are already vulnerable. High long-term average concentrations may contribute to chronic respiratory illnesses.

The existing national and international PM_{10} exposure standards/guidelines and targets were used as indicators of health risks. The South African guideline stipulated in the National Environmental Management: Air Quality Act (NEM:AQA) stipulates a maximum daily concentration of 180 $\mu g/m^3$ and an annual average concentration of 75 $\mu g/m^3$. SANS 1929:2004 guidelines stipulate a maximum daily concentration of 75 $\mu g/m^3$ and an annual average concentration of 40 $\mu g/m^3$.

In this study, the iron oxide (Fe_2O_3) concentrations in the PM was found to be very low (<1%). Evidence from mostly occupational exposure studies indicates that Fe_2O_3 at low doses (<1000 $\mu g/m^3$) are non-toxic. The impact assessment therefore focused on PM_{10} as a uniform substance and indicator of health effects regardless of its elemental properties, due to the evidence of low iron oxide levels monitored in the receptor areas.

Ambient air concentrations of PM_{10} at specific receptor points in a 10 km radius from the IOHF were simulated through the use of a dispersion model (Reddy and Naidoo, 2009) and used to determine exposure levels of the surrounding communities, based on which potential health impacts were assessed.

The study found that, based on well-calibrated modeling results, predicted average maximum daily and annual average concentrations of PM_{10} in all potential receptor areas other than Blue Water Bay are below SANS limit values for both the mitigated and unmitigated scenarios, and thus considered unlikely to cause acute or chronic upper or lower respiratory illnesses in communities exposed to these levels.

For Blue Water Bay, predicted PM_{10} concentrations are higher. While average annual concentration under the unmitigated scenario do not cause concern, the model predicts 89 exceedances of the SANS guideline and 49 exceedances of the NEM:AQA guideline if emissions are not mitigated, which is beyond the three annual exceedances allowed for in the guideline. Under the mitigated scenario, no exceedances of the 75 µg/m^3 guideline are expected, and emissions are hence not expected to be a concern (see Table below).

Predicted PM_{10} concentrations for the period 1 Jan 2008 – 20 Jun 2009 at a throughput of 60 MTPA at the IOHF (µg/m^3)

	Vredenburg		**Blue Water Bay**	
	Unmitigated scenario	**Mitigated scenario***	**Unmitigated scenario**	**Mitigated scenario***
Averaged 24 hr peak PM_{10} concentrations	Winter: 7.6 Summer: 12.4 All Year: 12.4	Winter: 1.2 Summer: 2.2 All Year: 2.2	Winter: 52.5 Summer: 197.6 All Year: 197.6	Winter: 6.8 Summer: 25.5 All Year: 25.5
Averaged 24 hr average PM_{10} concentrations	Winter: 1.0 Summer: 1.8 All Year: 1.8	Winter: 0.2 Summer: 0.4 All Year: 0.3	Winter: 6.8 Summer: 10.3 All Year: 10.3	Winter: 1.0 Summer: 1.5 All Year: 1.4
24 hour peak concentrations above 75 µg/m^3	None	None	Number of exceedances: 89	None
24 hour peak concentrations above 180 µg/m^3	None	None	Number of exceedances: 40	None

** This scenario entails maintaining an ore moisture content of 1.2% and 50% mitigation efficiency, as stipulated in Reddy and Naidoo (2009).*

Winter includes the period from June to November. Summer includes the period from December to May.

From the data available from the modeling, it is evident that without mitigation, a throughput of 60 MTPA of ore at the IOHF in Saldanha could result in a significant number of exceedances of current and proposed 24 hour peak PM_{10} concentration guidelines, and levels considered safe in terms of health, at Blue Water Bay. Mitigation of dust emissions will considerably reduce the estimated intensity of health impacts at Blue Water Bay to acceptable levels. The intensity of health impacts at all other receptors is considered to be low to insignificant for mitigated and unmitigated scenarios.

Predicted health impacts from the for PM_{10} exposures from the IOHF in different receptor areas

Nature of Impact	Receptor area	Mitigation	Extent	Duration	Intensity
Acute upper respiratory illness (24 hour peak exposures)	Blue Water Bay	Without	Local	Long-term	High
		With	Local	Long-term	Low
	Vredenburg	Without	Regional	Long-term	Low
		With	Regional	Long-term	Insignificant
	Langebaan	Without	Regional	Long-term	Low
		With	Regional	Long-term	Insignificant
	Saldanha	Without	Regional	Long-term	Medium
		With	Regional	Long-term	Insignificant
Chronic upper and lower respiratory illnesses (annual exposures)	Blue Water Bay	Without	Local	Long-term	Insignificant
		With	Local	Long-term	Insignificant
	Vredenburg	Without	Regional	Long-term	Insignificant
		With	Regional	Long-term	Insignificant
	Langebaan	Without	Regional	Long-term	Insignificant
		With	Regional	Long-term	Insignificant
	Saldanha	Without	Regional	Long-term	Insignificant
		With	Regional	Long-term	Insignificant

The impact significance has been assessed separately for potential acute respiratory illnesses and for potential chronic effects. The assessment rates the significance of the impact for all receptor areas combined.

Based on the analysis in Table above, the impact of the IOHF on **acute respiratory illnesses**, due to high 24 hour peak concentrations of PM_{10}, is considered to be of high intensity with a local extent. The resulting impact significance is rated as **high (negative) before mitigation**. Applying effective mitigation measures as recommended in the Air Quality Study (Reddy and Naidoo, 2009) is expected to significantly reduce PM_{10} peak concentrations and hence the impact intensity. The resulting impact significance is rated as **low (negative) after mitigation** (see Table below).

Significance of the health impact of the IOHF at 60 MTPA throughput with regards to acute respiratory illnesses in surrounding communities

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Long-term 3	**High** **7**	Probable	**HIGH**	-ve	Medium
Key mitigation measures: • Apply the mitigation measures recommended in the air quality study undertaken for this BA.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Probable	**LOW**	-ve	Medium

The impact of the IOHF on **chronic respiratory illnesses**, due to high long-term concentrations of PM_{10}, is considered to be **insignificant both before and after mitigation** at all receptor areas surrounding the Port.

The modelling undertaken in the Air Quality Study (Reddy and Naidoo, 2009), simulating the concentration and dispersion of PM and dust from the IOHF at a throughput of 60 MTPA, therefore suggests that particularly short-term concentrations in nearby receptors may become unacceptably high if dust is not mitigated at the IOHF. Effectively mitigating the generation of dust, by maintaining an ore moisture content of 1.2% and operating mitigation measures as laid out in the Air Quality Study, is expected to result in acceptable short and long term PM concentrations at nearby receptors that will not pose a risk to human health.

The recommendations put forward in this report are:

- The mitigation measures recommended by the Air Quality Study (Reddy and Naidoo, 2009) must be implemented.

- Transnet should ensure that a suitable Environmental Management System is in place to monitor the mitigation measures. A mitigation efficiency of at least 50% will be required to effectively mitigate potential impacts. If this cannot be achieved, additional mitigation, or more stringent monitoring and implementation of the mitigation will need to be applied.

- Transnet must continue the operation of the PM_{10} monitoring network and ensure that it is reliable and representative for the area. Both the Blue Water Bay and Vredenburg monitoring stations should be retained, as they measure total community exposure. More consistent recording of data (i.e. less gaps in the monitoring) should be achieved. In addition, monitoring should be undertaken at a suitable site (e.g. the boundary of the Port) to measure dust and PM_{10} directly related to Port activites, to monitor and, if necessary, increase, the effectiveness of mitigation measures.

- The PM_{10} concentrations recorded by the monitoring system should be evaluated by a health specialist on a quarterly basis to ensure that they do not present a health risk.

- Transnet should strive towards continuous reduction of dust released from the Port to ensure that operations remain compliant with potentially more stringent future emission standards.

It is not recommended that a community epidemiological study be conducted due to the low concentrations recorded in historic monitoring programmes and predicted for future operations (under adequate mitigation).

It is recommended that the 60 MTPA throughput be allowed under 50% mitigation efficiency as there is no evidence of exposure levels within the sensitive receptor area (Blue Water Bay) which will cause acute or chronic health impacts. A well operated and representative monitoring programme will characterize total exposures from all sources in the area and should trigger intervention if the environmental burden from all sources become a risk to human health.

TABLE OF CONTENTS

List of Tables

List of Figures

Glossary of terms

Alveoli: A small, thin-walled, capillary-rich sac in the lungs where the exchange of oxygen and carbon dioxide occurs.

Aerosols: A gaseous suspension of fine solid or liquid particles.

Bioavailable: The state of a toxicant such that there is increased physicochemical access to the toxicant by an organism. The less the bioavailability of a toxicant, the less its toxic effect on an organism

Bronchitis: An inflammation of the mucous membranes of the bronchial tubes, causing a persistent cough that produces considerable quantities of sputum (phlegm).

Deleterious: Having a harmful or injurious effect.

Deposition: The act of depositing, especially the laying down of matter by a natural process.

Disaggregated: To divide into constituent parts.

Discrete receptors: Exposed individuals, groups or objects that consist of unconnected distinct

Dust fallout: The deposition of a fine, powdery substance that settles on the ground as an adverse, unwanted secondary effect.

Emissions: A substance released or discharged into the environment, generally refers to the release of gases and particulates into the air.

Epidemiology: The branch of medicine that deals with the study of the causes, distribution, and control of disease in populations

Fugitive: An air emission that tends to be inconstant, transient and uncontrolled.

Histology: The study of the microscopic structure, chemical composition and function of the tissue or tissue systems of plants and animals.

Inhalable: Particulate Matter with an aerodynamic diameter of 10 μm and which can be inhaled by humans. Inhalable particles enter the lung less deeply than respirable particles.

Inventory: A detailed, itemized list, report, or record.

Inversion: An atmospheric condition in which the air temperature rises with increasing altitude, holding surface air down and preventing dispersion of pollutants.

Limit values: The maximum permissible level of pollution that can be emitted by a source.

Non-homogenous: Not similar in kind or nature.

Micrometer: (µm) is a unit of length equal to one millionth of a meter. It can be written in scientific notation as 1×10^{-6} m, meaning 1 / 1,000,000 m.

Micron: a metric unit of length equal to one millionth of a meter.

Mitigate: To moderate (a quality or condition) in force or intensity; in order to alleviate a problem.

PM_{10}: Particulate Matter with an aerodynamic diameter of 10 µm and less. Also known as inhalable particulate matter.

$PM_{2.5}$: Particulate Matter with an aerodynamic diameter of 2.5 µm or less. Also known as respirable particulate matter.

Primary standards: Set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.

Quantification: To determine or express the quantity of something.

Receptors: An exposed individual or group that respond to sensory stimuli.

Reclaiming: To retrieve material to be used for future functions.

Rehabilitation: To restore to good condition, operation, or capacity.

Respirable: Particulate Matter with an aerodynamic diameter of 2.5 µm or less is generally referred to as being respirable. These particles can be inhaled deeper into the lung than inhalable particles, they can reach the alveoli.

Rhinitis: Rhinitis is inflammation of the cells lining the nose resulting from the inhalation of an allergen. The symptoms include nasal obstruction, runny nose and sneezing.

Scheduled processes: Any works or processes specified in the Second Schedule of the Atmosphere Pollution Prevention Act 45 of 1965 (APPA).

Secondary standards: Set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

Sinusitis: Sinusitis is an infection of the sinuses, the small, air-filled cavities inside the cheekbones and forehead.

Stacking: Creating a large, usually conical pile of material arranged for outdoor storage.

Stockpiles: To accumulate and maintain a supply of material for future use.

Target values: The desired or acceptable level of pollution that can be emitted by a source.

Terminal: A facility at the end of a transportation line or at a major junction on the line

Time weighted average: The average level of a contaminant or condition to which workers may be exposed without adverse effect over a period such as in an 8-hour day or 40-hour week.

Tippler: A place where loaded rail wagons are emptied by tipping.

Transfer point: The point where iron ore is transferred from one place of equipment (e.g. conveyor) to another (e.g. conveyor, ship loader).

TSP: Total Suspended Particles – defined as all particulates with an aerodynamic diameter less than 100 µm.

Study area: Refers to the entire study area encompassing all the alternative alignments as indicated on the study area map and covers an area with a 10 km radius.

List of abbreviations

ACGIH American Conference of Governmental Industrial Hygienists

ASSA Actuarial Society of South Africa

CSIR Council for Scientific and Industrial Research

DWEA Department of Water and Environmental Affairs

DME Department of Minerals and Energy

DoL Department of Labour

EPA Environmental Protection Agency

EU European Union

EC European Community

IARC International Agency for Research on Cancer

IDLH Immediately Dangerous to Life or Health

IOHF Iron Ore Handling Facility

ISCST Industrial Source Complex Short-Term

LOAEL Lowest Observed Adverse Effect Level

$\mu g/m^3$ microgram per cubic metre

MTPA Million Tonnes per Annum

NAAQOs National Ambient Air Quality Objectives

NEMAQA National Environmental Management: Air Quality Act (No. 39 of 2004)

NOAEL No Observed Adverse Effect Level

OEL Occupational Exposure Limit

OES Occupational Exposure Standard

OSHA Occupational Safety and Health Administration

PM Particulate Matter

PM_{10} Particulate Matter (less than 10 micrometers in diameter)

$PM_{2.5}$ Particulate Matter (less than 2.5 micrometers in diameter)

RSP Respirable Suspended Particles

SANS South African National Standards

SA-AQS South African Air Quality Standards

SAWS South African Weather Services

SRK SRK Consulting

TSP Total Suspended Particulates

ųm micrometer

US-EPA United States Environmental Protection Agency (same as EPA)

WHO World Health Organization

1. Introduction

Transnet Limited (Transnet) possesses a number of core assets for the export of raw materials of important economic value to South Africa. One of these is the Iron Ore Handling Facility (IOHF) in the Port of Saldanha, located on the western seaboard of South Africa, approximately 120 km northwest of Cape Town (Figure 1-1). The ore supplies are transported 860 km from the iron ore mines in Sishen and Assmang in the Northern Cape. The IOHF is situated in the Port of Saldanha.

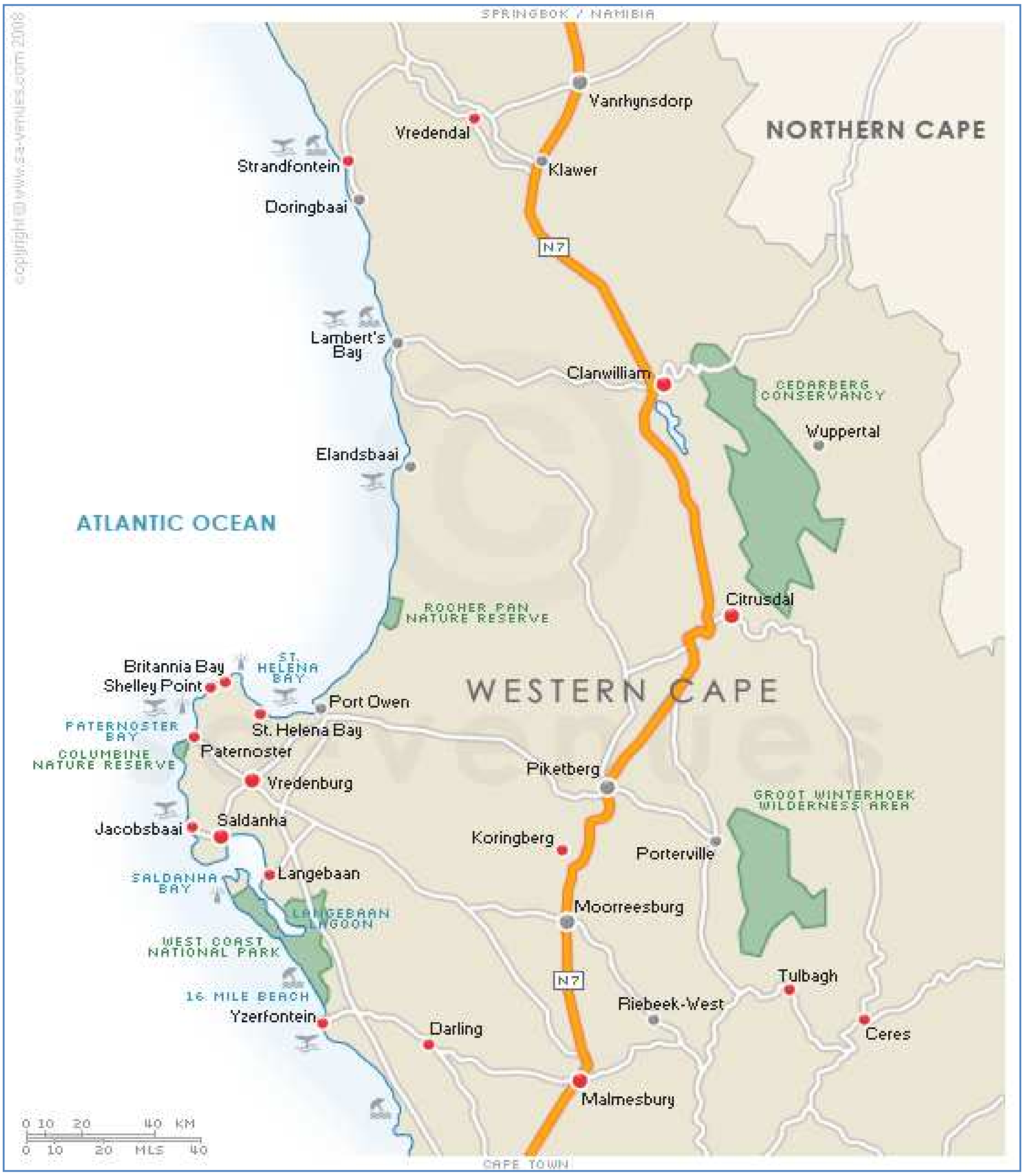

Figure 1-1: Location of Saldanha Bay

Transnet has embarked on a phased expansion program for the IOHF to meet market demands. Since 2001 several impact studies have been completed. In February 2009 SRK Consulting (SRK) was appointed by Transnet to undertake a Basic Assessment (BA) to inform the amendment of the existing air quality permit for the IOHF at the Port of Saldanha, related to a proposed increase in throughput of iron ore from 47 to 60 million tonnes per annum (MTPA).

This report aims to provide a desktop assessment and exposure simulation approach to understand the potential health impacts of a proposed 60 MTPA throughput operation on the general public residing in or visiting the receptor areas exposed to suspended particulate matter potentially generated by the IOHF.

2. Background and Brief

2.1 Project Description

The Port of Saldanha lies approximately 120 km north of Cape Town in Saldanha Bay on the West Coast of South Africa (see Figure 1-1 and 2-1). The main towns in the vicinity of the Transnet iron ore handling facility are Saldanha including Blue Water Bay, Langebaan and Vredenburg, with surrounding formal and informal residential areas. They fall within the Saldanha Bay Local Municipality, which had an estimated population of 81 121 in 2006 (Census data).

The Langebaan Lagoon, a wetland of international importance and a registered RAMSAR site, is located 9 km south-east of the stockpile areas at the Port of Saldanha and connected to Saldanha Bay.

Iron ore is currently transported to the handling facility at the Port of Saldanha by train from the mines in the Northern Cape. The iron ore is offloaded by wagon tipplers, from where it is transported to stockpiles by conveyor[2].

Iron ore is loaded onto and removed from stockpiles by three stacker/reclaimers that perform both functions. Different ore grades are stockpiled separately and blended to the specific export requirements after reclamation. The reclaimed iron ore is transported by conveyor via a sampling building to two shiploaders, which load the ore onto bulk carriers that are moored at the iron ore jetty at the Port.

Dust is emitted during the handling of the iron ore at the facility, and nuisance and health issues have been identified as primary concerns of the adjacent communities. Transnet has embarked on a dust mitigation programme that includes, amongst others, the covering of most conveyors and installation of sprinklers at important dust generating areas within the operation, water cannons at the stockpiles and dust monitoring systems.

---

[2] A limited amount of iron ore is directly loaded onto ships without being stockpiled first.

INSERT LATER

Figure 2-1: The location of the Iron Ore Handling Facility (IOHF) in relation to the surrounding receptor areas.

Transnet has identified operational inefficiencies at the iron ore handling facility. Optimization of the operations is estimated to allow the facility to achieve an iron ore throughput of up to 60 MTPA. Since the facility currently holds a preliminary air quality permit authorizing the handling of up to 47 MTPA, an amendment to the permit must be applied for.

The higher volume of iron ore the facility will be able to handle once the operational inefficiencies are addressed, will result in the tipplers handling more trains than currently required and more ships calling at the Port to receive the iron ore. However, the infrastructure at the handling facility, such as the number of stockyards and amount and type of handling equipment, will not change, as the increased throughput will be achieved by greater operational efficiency, which is expected to result in reduced work stoppage, equipment down time and iron ore spillage.

2.2 Study Objectives

The principal objective of the BA is to provide authorities with sufficient information to reach an informed decision on the application. To this end, the BA Report incorporates "a description and assessment of the significance of any environmental impacts, including cumulative impacts, that may occur as a result of the undertaking of the activity or identified alternatives or as a result of any construction, erection or decommissioning associated with the undertaking of the activity". The specialist health impact assessment report presented here therefore:

- Records and describes the baseline environment associated with the specialist field, in this case health effects from exposures to particulate matter (PM) within the receptor areas of the IOHF in the Port of Saldanha;

- Assess and consider the potential impacts on the environment associated with the proposed development (including the No-Go alternative) in terms of health impacts as mentioned above;

- Gives an indication whether the proposed activity is environmentally acceptable or unacceptable in terms of the respective impacts assessed.

2.3 Health Specialist Study Terms of Reference (ToR)

The purpose of the study is to detail the impact of the proposed development and the resultant change in health conditions.

The ToR for the Health Specialist Study are to:

- Review relevant literature as well as suitable and available information from previous impact assessment reports on the IOHF at Saldanha.

- Review any health legislation and standards in South Africa relevant to fugitive particulate matter emissions from the Transnet iron ore handling facility.

- Discuss the potential health concerns associated with exposure of the general public to inhalable iron ore particulates (PM10) and dust. Differentiate between health and nuisance concerns[3].

- Describe the public health characteristics of receptor areas for inhalable particulate pollution (PM_{10}) from the handling facility, as delineated by the air quality study.

- Comment on particular population vulnerability factors with regards to emissions from the handling facility.

- Utilizing the findings of the air quality study, identify any potential health impacts of the proposed increase in iron ore throughput at the handling facility on the population of the study area, particularly with respect to air emissions. Identify, if possible, significant seasonal differences in exposures and the impact of synergistic factors such as aero-allergens (the area is well known for its spring flowers and may well have high pollen concentrations during this time) associated with seasonal peaks on the total risk to the community. Differentiate between health and nuisance impacts.

- Assess health impacts on the population resulting from the proposed increase in throughput, using prescribed impact assessment methodology.

- Recommend practicable mitigation measures to minimize/reduce negative health impacts on the population and to enhance positive impacts. Assess the effectiveness of proposed mitigation measures by re-rating the impact, assuming the mitigation is employed, using the prescribed impact assessment methodology.

- Formulate recommendations for the future monitoring of health impacts in the study area.

3. Study Approach

The approach to the Health Specialist Study was guided by its objectives as outlined in Sections 2.2 and 2.3.

The health specialist study was designed as a desktop evaluation of existing information on the potential health effects of PM on the general public, and particularly a review of the lowest exposure levels at which adverse effects in communities have been documented.

The study was not a community epidemiological study aimed at establishing a cause effect relationship between PM exposures as a result of the IOHF and any respiratory illnesses in the receptor communities such as Blue Water Bay, Saldanha, Langebaan and Vredenburg. Historic data available on PM levels in the above mentioned receptor areas does not support the execution of a community epidemiological study, due to the low PM levels recorded in the monitoring network operated since 2002.

---

[3] In agreement with SRK, the discussion of nuisance impacts was addressed in the air quality study undertaken for the BA and is thus not repeated in this health study.

This specialist study excluded any impact assessment of occupational exposures (within the industrial zone of the IOHF), as exposure levels predicted by dispersion modeling were presented in 24 hour averages over 7 days per week (365 days per year) relevant for community impact assessments. In the case of occupational exposures, levels of PM have to be assessed over 8 hours (1 shift per day) and 40 hour work weeks. It is assumed that Transnet is monitoring and managing occupational health impacts at the IOHF.

The health study did not address any issues of nuisance caused by dust fall-out from the IOHF, as this was the addressed in the Air Quality Study done in conjunction with the health Specialist Study (Reddy and Naidoo, 2009).

The study utilized available evidence in the literature as well as actual monitored and simulated exposure data obtained through air dispersion modeling. The study did not generate any primary data but applied health effect assessment methodologies and principles to derive its conclusions.

3.1 Evidence Based Information

A review of peer reviewed published information from the scientific literature and International Regulatory bodies provided the knowledge base of this Study. In addition literature reviews contained in the draft specialist studies of Dr Mary Gulumian (Draft health specialist study for the proposed Phase 2 expansion of the IOHF, dated 25 June 2007[4]) and Dr WCA van Niekerk (Infotox Report no. 016-2000) were used.

This literature review provided the context for the actual health impact assessment. The critical data utilized in this report was obtained from the ambient air quality monitoring network data operated by ECOSERV (Pty) Ltd (ECOSERV) and the dispersion modeling results of Vis Reddy of SRK, focusing specifically on the 60 MTPA throughput target. The latter report also provided the location of receptor populations with respect to respirable particulates and nuisance dust fallout.

An observational visit to the site on 30 June 2009 provided additional insights into the characterization of the receptor areas only. A site operational assessment was not done.

3.2 Assumptions and Limitations

The critical input data for the Health Specialist Study, namely predicted ambient air pollution concentrations and deposition levels, was generated by Vis Reddy through dispersion modeling.. The modeling study used the US EPA Industrial Source Complex Short-Term dispersion model (ISCST Version 3) and AERMOD (Version 5.6). Details on the dispersion modeling methodology and its limitations can be found in the Air Quality Report undertaken for this BA (Reddy and Naidoo, 2009).

The Health Study approached the dispersion data with an understanding that the models may under- or over predict concentrations. Due to the comprehensive input data (meteorogical, source and non-complexity of the terrain) available, the predicted concentrations are expected to be accurate reflections of potential future exposures in

---

[4] Neither internal nor external review of this study has been completed.

the receptor areas relevant to this study. This was confirmed by the successful calibration of the model with monitoring results at specific receptor points.

With respect to monitoring data provided by ECOSERV, the data represents all sources of particulate matter (not only that of the ore handling facility) and is an indication of environmental burden in total. The data only represents the current situation (i.e not the expected levels at increased throughput).

The use of dispersion modeling data, which predicts exposures at increased throughput (60 MTPA) and reflects only the contribution of the IOHF to actual exposure data from multiple sources (as measured by the monitoring network), is adequate in this study focusing on potential health effects of inhalation exposure to particulate matter in the receptor areas of the IOHF.

4. Methodology

The methodology used to identify and assess the potential health impacts of the 60 MTPA throughput operations was:

- Obtain monitoring and modeling data from experts on 24 hour average (annual and seasonal) concentrations of respirable particulates with a diameter of <10 µm (PM_{10}) for different community relevant receptor points.

- Obtain predicted dispersion data based on various mitigation efficiency scenarios (with respect to human exposure).

- Compare above data with local and international Air Quality Standards and guidelines, as the latter are used as the measure of acceptable risk.

- Use evidence from the literature combined with exposure data to draw conclusions on potential impacts and mitigation measures for particulate matter exposure from dust generated by the IOHF.

5. Specialist Evaluation and Assessment

The health impact assessment in this study is based on two aspects:

- An analysis of the scientific literature and International Regulatory Agencies’ reports. The literature summary highlights reports on health effects associated with PM in general and does not imply that these effects will or could be a result of exposures caused by the IOHF. The relevance of the literature to the exposures predicted for the IOHF is discussed in Section 5.2; and

- An analysis of the actual pollution potential of the IOHF at the proposed increased throughput, as presented in the air quality study.

5.1 Analysis of the Literature Review

5.1.1 Health Issues Related to Suspended Particulate Matter

The essence of the combined and wide spread evidence from the literature on particulate matter as air pollutants detrimental to human health is briefly summarized below. The evidence deals with particulates in general as well as with iron oxide particulates, which are primarily released by the IOHF at Saldanha, in particular.

The impact of particulates on human health is largely dependent on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory systems also depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (< 8 µm in diameter) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent branches of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1993).

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM_{10} (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of $PM_{2.5}$ (i.e. particulates with an aerodynamic diameter of less than 2.5 µm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, an effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM_{10} and $PM_{2.5}$ are of concern due to their health impact potentials (the smaller the particle the deeper the penetration into the pulmonary system and the bigger the potential effect). As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung. The PM_{10} limits and standards are discussed in Section 5.1.3 of this report.

Several community based studies using PM_{10} as an exposure indicator have indicated strong associations between PM and respiratory and cardiovascular effects at concentrations commonly experienced in typical urban environments (Dockery et al. 1993; Künzli et al. 2000). Exacerbating effects are not only chemical composition but also population susceptibility, duration of exposures and synergistic effects with other pollutants or cigarette smoking.

Several studies in South Africa have highlighted the health risks associated with PM and particularly in households exposed to indoor cooking and heating practices using coal or wood in addition to dust from unpaved roads. (Terblanche, et al. 1993). To date, no exposure/respiratory response curve for the South African population in relation to PM_{10} has been established. South Africa relies heavily on international studies for guidance despite concerns about different exposures, vulnerability factors and poverty (Wichmann and Voyi 2005).

A summary of key literature available on the health effects observed at different exposure levels to PM_{10} is presented below. This summary was derived from the most extensive review of the health effects of PM conducted by the USEPA for the purpose of the development of the Air Quality Criteria for PM (USEPA, 2004). In doing so, over 300 credible publications were reviewed. The USEPA has, based on this review, created two health endpoints for PM exposure: morbidity and mortality.

The morbidity associated end points are defined as upper or lower respiratory illnesses and symptoms such as sinusitis, rhinitis, coughing, bronchitis and lowering in pulmonary function (e.g. the volume of air that can be inhaled into the lung might decrease).

With respect to mortality, several studies from the USEPA review reported a positive association between cardiovascular and respiratory mortality (USEPA, 2004) for high short term 24 hour peak exposures. The USEPA has estimated that the risk of mortality increases by 1 to 8% per 50 $\mu g/m^3$ PM_{10} exposure above background level over a 24 hour period. This implies that for every 50 $\mu g/m^3$ 24 hour average increase in PM_{10} above those levels, approximately 1 to 8 people in a 100 have an increased risk of death. When focusing on the multi cities studies, the EPA risk estimates ranged from 1 to 3.5% increase in mortality per 50 $\mu g/m^3$ PM_{10} (USEPA, 2004) above the guideline levels. The mortality concerns are however based on incidences of peak exposures above considered safe guidelines of the WHO and offer public protection bodies (WHO, 2005).

Dr WCA van Niekerk summarizes in his report (Van Niekerk, 2000) that in many epidemiological studies conducted around the world, positive associations have been observed between ambient levels of PM and various health effects, including mortality, respiratory and cardiovascular hospitalizations, impaired lung function, adverse respiratory symptoms, restricted activity days and the frequency of reported chronic respiratory disease (Health Canada, 1998 and 1999). Daily or short-term variations of PM_{10} and $PM_{2.5}$ levels were significantly associated with increases in mortality of all causes. The increase in $PM_{2.5}$–related risk of mortality was about one-and-a-half times higher per 10 $\mu g/m^3$ increase in air concentrations than for PM_{10}. This was determined in six cities in the USA for 10 $\mu g/m^3$ daily increases above an average concentration that ranged between 11 and 30 µg $PM_{2.5}$ /m^3. The increases in daily mortality per 10 $\mu g/m^3$ daily increase of $PM_{2.5}$ were 1.5%. These cities included communities such as Boston South end with very high traffic densities (Dockery, et.al. 1993).

Particulate matter has also been shown to have significant associations with increased hospitalization, mostly relating to respiratory conditions. Associations with cardiovascular disease were also shown, but the magnitude was generally lower than for respiratory disease. All of 16 epidemiological studies on hospital admissions showed an increase in hospitalization rate between 0.45 and 4.7%

per 10 µg/m^3 daily increase in PM_{10} exposure against a background level of 25 to 53 µg PM_{10}/m^3, which is not unusual for urban areas (Health Canada, 1998).

Relatively few studies examined the effects of long-term or chronic exposure (as opposed to 24-hour peak exposure discussed above) to particulates on mortality and morbidity. Ambient air quality guidelines for annual average particulate levels are therefore not very useful in quantifying health risks, as the health effects have a strong association with daily average particulate concentrations, whereas long-term averages of PM levels could hide high short-term exposures.

The Federal/Provincial Working Group on Air Quality Objectives and Guidelines (WGAQOG) in Canada conducted one of the most comprehensive studies on the health effects of particulates (Health Canada,1998). Data were considered for animal toxicity studies, controlled human exposure studies and human epidemiological studies. The WGAQOG recommended “Reference Levels” above which effects on human health can be demonstrated. The Reference Level was derived statistically from several studies and it should be interpreted as a level above which there is statistical confidence in the dose-response relationship, to enable some quantification of adverse outcome of effects. It is not a threshold level, but rather lies within the range of statistical associations with increasing mortality and hospitalization rates. That is, any increase in ambient particulate level is associated with a statistical increase in daily mortality and hospitalization. The Reference Levels for 24-hour averages are 25 µg/m^3 for PM_{10} and 15 µg/m^3 for $PM_{2.5}$. These Canadian Reference Levels provide a reasonable benchmark against which to assess daily average ambient air concentrations of PM and expected increases in health outcomes.

Iron oxide

Studies on animals and of human exposure have shown that the inhalation of iron ore can have some effect particularly on the upper airways. However, exposures would have to be at concentration levels far above environmental levels which would be associated with the proposed throughput at the Port of Saldanha, and no effects should be observed in the exposure range experienced in the receptor areas surrounding the Port.

The International Agency for Research on Cancer (IARC, 2000) has not classified iron oxides as carcinogens (substances that cause cancer) (Lewis 1995: database), and epidemiological data are not available to support any suggestion of carcinogenicity. Based on animal experiments iron oxide dust might serve as a co-carcinogenic substance, i.e. enhancing the development of cancer at a simultaneous exposure to a carcinogenic substance (Elinder, 1979: 435). However, this has not been shown conclusively.

This health assessment therefore does not consider effects of iron oxide present in the PM emitted from the IOHF separately from the effects of general PM levels, as there is no supporting evidence that, in the case of the IOHF at Saldanha, exposures to iron oxides or iron in particular has specific relevance[5].

5.1.2 Overview of Vulnerability Factors

There is an increased realization that the magnitude of the impact of environmental pollution on human populations is also determined by the degree to which a population is sensitive to and unable to cope with adverse impacts of the air pollution it is exposed to. Blaikie et al. (1994) defined vulnerability as '*the characteristics of a community in terms of their capacity to anticipate, cope with, resist and/or recover from the impact of natural or man-made hazards*'. According to Levy et al. (2002), the understanding of vulnerability at community or population level helps to identify and protect sensitive sub-population groups from the effects of air pollution. John et al. (2006) explains that, since the level of vulnerability determines the magnitude of impacts, there has been a realization that risks cannot only be considered within the boundaries of a traditional framework for risk assessment. Vulnerability analysis therefore extends the traditional risk assessment to provide data on susceptibility issues of communities to risks, as a result facilitating improved risk management.

In South Africa, CSIR is currently involved in vulnerability research, with the ultimate aim of developing vulnerability factors specific to the South African population. John et al. (2006) has identified the following examples of issues that are especially important in the South African context, resulting in people being less resilient to and therefore less able to cope with adverse effects of environmental exposures – including air pollution:

- Life/development stage
- Respiratory diseases;
- HIV/AIDS;
- Nutritional status;
- Housing, and
- Access to electricity.

John et al. (2006) concluded that the integration of vulnerability assessments and the traditional risk assessment process in South Africa faces several challenges. Vulnerability factors specific to the South African situation are therefore not yet available or ready for integration into the health risk assessment process.

In addition to increased awareness on population vulnerability, epidemiological studies provide evidence that several subpopulations are more susceptible to the effects of PM air pollution. Such sub-populations may experience effects at lower levels of PM than the general population, and the severity of effects may be greater. Morawska et al. (2004), Kappos et al. (2004) and the USEPA (2004)

---

[5] There are no ambient air guidelines for exposure to iron oxides, but a health-risk based air concentration for metal iron has been derived from the oral reference dose for screening assessments at hazardous waste sites (Smith, 1996). This is a rough approximation, assuming similar bioavailability across exposure routes. Iron oxide should not be assessed on the same basis as water-soluble iron compounds, for which the ingestion reference dose was determined. Within the uncertainties and rough estimates, the guideline has been considered and put into context. At 1100 µg Fe/m^3 (Smith, 1996), the corresponding guideline concentration for Fe_2O_3 in air is 1 573 µg/m^3. This level is considerably higher than guidelines for controlling exposure to particulates not classified for specific toxicity.

reviewed the subpopulations that appear to be at greatest risk due to exposure to ambient PM and emphasized the following:

- Individuals with respiratory disease (e.g. asthma, chronic obstructive pulmonary disease (COPD), acute bronchitis) and cardiovascular disease (e.g. ischemic heart disease) are at greater risk of premature mortality and hospitalization;
- Individuals with infectious respiratory disease (e.g. pneumonia) are at greater risk of premature mortality and morbidity (e.g. hospitalization and aggravation of respiratory symptoms). Also, exposure to PM may increase individual susceptibility to respiratory infections;
- Diabetic individuals apparently presented a susceptible subpopulation;
- Elderly individuals are also at greater risk of premature mortality and hospitalization for cardiopulmonary causes;
- Children are at greater risk of increased respiratory symptoms and decreased lung function;
- Individuals with allergic disorders are likely to be more susceptible to PM effects than are non-allergic persons; and
- Animal studies indicate that genetic susceptibility might be possible.

Potential Vulnerability Factors in Communities Surrounding the IOHF

The draft Social Impact Assessment report produced for the Phase 2 Expansion (Aucamp, 2007) provided some insights into the profile of the Saldanha community. Aucamp (2007) observed that only 86% of children under one year received the first measles immunization (national target is 90%), and that tuberculosis (TB) prevalence was at 1 062 for every 100 000 people, with a cure rate of 76% (national target is 85%).

The workload on health staff is extremely high in Saldanha Bay, with a nurse/patient ratio of 57 per day, compared to the district average of 40 and a national target of 34. The number of available health care facilities is low, considering that Saldanha Bay Municipality has a relatively large population to serve. Swartland, with the second-largest population in 2006, has 17 health care facilities compared to 12 for the Saldanha Bay Municipality.

The ASSA 2003 population projection model forecasts HIV prevalence to increase from 2,6% in 2001 to 5,5% by 2010 in the Saldanha Bay Municipality. AIDS-related deaths were projected to increase from 69 in 2001 to 150 in 2005 and 282 in 2010. As a proportion of total deaths, AIDS-related deaths were expected to increase from 12.1 % in 2001 to 30,2% in 2010.

These findings indicate that the vulnerability of the Saldanha population to the effects of PM_{10} may be higher than that of the communities in Canada and the USA, which were assessed in the PM_{10} risk assessment projects. However, the highest potential exposures in the receptor area identified by dispersion modeling will be Blue Water Bay, which is likely to have a far less vulnerable community profile than the general Saldanha area, as the socio-economic status of this area, including access to electricity, housing and health care, appears much higher than in the surrounding areas in general.

5.1.3 Standards and Legislation

Air quality guidelines have been assigned for various particle size fractions. South African limits for PM$_{10}$ outlined in the National Environmental Management: Air Quality Act (No.39 of 2004) (NEM:AQA) are 180 µg/m^3 for daily maximum and 60 µg/m^3 for annual average. The daily maximum cannot be exceeded more than three times per year.

In 2004, Standards South Africa published South African limit guidelines for PM$_{10}$ in SANS 1929:2004 as 75 µg/m^3 for the maximum 24-hour exposure and 40 µg/m^3 for the annual average exposure. The maximum 24-hour and annual average PM$_{10}$ target values are 50 µg/m^3 and 30 µg/m^3 respectively. The limit value refers to the level that the ambient PM$_{10}$ concentration should not exceed, and this value is enforceable. The target value is the recommended level that ambient PM$_{10}$ concentrations should not exceed.

The DWEA is currently in the process of finalizing new legal standards in terms of NEM:AQA. The proposed new PM$_{10}$ standards are similar to the PM$_{10}$ limit values published in SANS 1929:2004.

A summary of local and widely recognized international air quality standards for PM$_{10}$ are outlined in Table 5-1-3. The SANS limit value is in a similar range to guidelines or standards proposed by the European Community, World Bank and United Kingdom, but is considerably more stringent than the current DWEA and US-EPA values (see Table 5-1-3).

Table 5-1-3: Air quality guidelines and standards for PM$_{10}$

Country / Organization	Daily maximum concentration (µg/m^3)	Annual average concentration (µg/m^3)
South Africa - current limits in terms of the Air Quality Act (No. 39 of 2004)	180(1)	60 (2)
United States Environmental Protection Agency (US-EPA)	150(3)	50(2) (4)
European Community (EC) standards	50(5)	30(6) 20(7)
UK National Air Quality Objectives	50(8)	40(9)
World Bank (WB)	70(10)	50(10)
South Africa - limits adopted in SANS 1929:2004	75(11) Limit value 50(12)Target value	40(11)Limit value 30(12) Target value
European Union (EU)	130(13) 250(14)	80
Canada	24	--

Notes:
(1) Not to be exceeded more than three times per year.
(2) Represents the arithmetic mean.
(3) Not to be exceeded more than once per year
(4) Requires that the *three-year* annual average concentration be less than this limit.

(5) Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year (by 1 January 2010, no violations of more than 7 times per year will be permitted).
(6) Compliance by 1 January 2005.
(7) Compliance by 1 January 2010.
(8) 24-hour means not to be exceeded more than 35 times a year. Compliance by 31 December 2004.
(9) Annual mean, with compliance required by 31 December 2004.
(10) Pollutant concentration limit at property boundary (World Bank 1998).
(11) Proposed South African limit values, reference: *SANS 1929 - Ambient air quality - Limits for common pollutants.*
(12) Proposed South African target values, reference: *SANS 1929 - Ambient air quality - Limits for common pollutants.*
(13) Median of daily means for winter period (1 October – 31 March)
(14) Calculated from the 95th percentile of daily means for the year.

The WHO has proposed interim targets for PM_{10} given that levels in developing countries often exceed the WHO guideline. The WHO guidelines as well as the targets for PM_{10} annual averages and daily means are given in Table 5-1-4 and 5-1-5 respectively (WHO, 2005).

Table 5-1-4: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)

Annual Mean Level	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Basis for the selected level
WHO interim target-1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at WHO Air Quality Guideline (AQG) levels.
WHO interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1.
WHO interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO Air Quality Guideline (AQG)	**20**	**10**	**These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$ in the American Cancer Society (ACS) study (Pope et al.,2002 as cited in WHO 2005). The use of the $PM_{2.5}$ guideline is preferred by the medical community.**

Table 5-1-5: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Annual Mean Level	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	Basis for the selected level
WHO interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG).
WHO interim target-2 (IT-2)*	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG).
WHO interim target-3 (IT-3)**	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG).
WHO Air Quality Guideline (AQG)	**50**	**25**	**Based on relation between 24 hour and annual levels.**

* 99th percentile (3 days/year)

** For management purposes, based on annual average guideline values: precise number to be determined on basis of local frequency distribution of daily means

As there are no apparent lower threshold effects identified for particulate matter, and due to increasing evidence that the health effects documented are diverse in scope, severity, duration and clinical significance, some organizations such as SANS are proposing more conservative exposure limits than the current guidelines in South Africa.

5.2 Analysis of the Actual Pollution Potential of the Iron Ore Handling Facility

This section of the study combines the findings of the literature review with an analysis of the air quality monitoring and modeling results to determine the potential health effects of the IOHF at Saldanha.

The relevant literature shows that human exposure to PM presents a health concern. The risks associated with PM exposures are determined by:

(a) The aerodynamic size of the PM (the smaller the size of the particle the bigger its ability to penetrate the deep lung areas and contribute to morbidity and mortality);

(b) The chemical properties of the PM (e.g. lead particles which dissolves in the lungs are much more hazardous than carbon particles which are insoluble); and

(c) The total exposures to PM (concentration x time/duration of exposure).

(a) Particle Size

A particle size analysis of the ore handled at IOHF was performed by ECOSERV in 2005 to determine the size distribution of ore particles smaller than 1 mm (see Table 5-2-1) (Burger & Krause, 2000).

Table 5-2-1: Particle size analysis

Particle diameter (µm)	Mass %
1000	42.66%
600	38.63%
300	14.85%
250	0.18%
150	0.59%
100	0.41%
75	0.25%
53	0.26%
45	0.13%
20	0.46%
10	0.32%
5	0.31%
1	0.68%
0.1	0.27%
Sum	**100.00%**

The analysis shows that a small percentage of the ore is of inhalable (0.63% of particles) and respirable (0.95% of particles) size, showing that inhalable and respirable PM is part of the dust emissions from the IOHF.

(b) Chemical Composition

PM can have health effects due to the small size of particles that enter the lung and also if the PM contains toxic substances. Van Niekerk (2000) performed an elemental analysis on the ore handled at the IOHF (Table 5-2-2), and found that many elements in the iron ore are not of toxicological concern and that potentially toxic elements such as lead (Pb) are present in insignificant concentrations and may not be in a bio-available form. This health study thus did not include a review of all possible risks associated with the elemental content of the ore as no exposure data or biological dose is available.

Table 5-2-2: Elemental composition of Sishen course sinter ore (ISCOR, 2000)

Substance	Specification (%)	Typical (%)
Fe	65.00 (min)	65.86
SIO_2	4.20 (max)	3.02
Al_2O_3	2.00	1.34
P	0.058 (max)	0.053
S	0.032 (max)	0.010
TiO_2		<0.051
CaO		<0.102

Substance	Specification (%)	Typical (%)
MgO		<0.04
FeO		<0.30
Mn		<0.03
K_2O	0.24 (max)	0.17
Na_2O		0.02
As		0.003
Cr		0.00129
NI		0.0027
Zn		0.002
Pb		0.0015
Cu		<0.001
Mo		<0.002
V		0.0034
Moisture	1.50 (max)	1.36

Based on the above discussion, this health assessment acknowledges that PM_{10} emitted at the IOHF is a complex mixture, but will treat it as a single polluting substance.

(c) Exposure Assessment

Receptor Areas

The sensitive receptor areas were defined as areas with inhabitants (permanent or temporary) comprising members of the general public which includes the very young, the very old and those with pre-existing disease which makes them vulnerable to the effects of PM inhalation (see section 5.1.2) and which falls within the exposure range of PM generated as a result of the IOHF operations at the Port of Saldanha.

The closest receptor area to the IOHF is Blue Water Bay (±2,5 km north-north-west), which constitutes a residential area and is therefore classified as a sensitive receptor area. The closest town is Saldanha (4,5 km north-west of the Port). Saldanha is the largest natural harbor along the South African coastline and is home to South Africa's largest commercial fishing fleets, the South African Military Academy and SAS Saldanha, a naval training base. The Langebaan resort town lies 12 km south-east of the Port, at the mouth of the Langebaan Lagoon, and is a popular tourist destination. The town of Vredenburg lies approximately 11 km north of the Port.

The community health impact assessment of this study focused on exposure levels measured and modeled in Blue Water Bay (Saldanha), Vredenburg and Langebaan.

The IOHF, source of the emissions considered in this study, is located within a stipulated industrial area (and is surrounded by other industries, some of which also use iron ore). This area represents an area of occupational exposure and needs to be assessed and managed in accordance with the Occupational Health and Safety Act of South Africa. This study excludes an occupational health risk assessment.

Current Exposure Levels

In this study, exposure data were derived from two sources: The ECOSERV monitoring network and the SRK modeling exercise.

The monitoring information represents actual concentrations of PM_{10} over a 24 hour period for **all** sources contributing to PM_{10} (total environmental burden) at the particular monitoring point. This study did not include a source assessment of other sources of PM contributing to the ambient PM concentrations. The monitoring data used in this study cover the period from 2002 to 2008 at two sensitive receptor areas representing human residential areas: Blue Water Bay and Vredenburg.

i. Ambient PM_{10} Monitoring

An ambient PM_{10} monitoring network was set up by Transnet in the area surrounding the IOHF and has been in operation since late 2002. Continuous PM_{10} monitoring stations were set-up in Blue Water Bay and Vredenburg.

The available monthly average PM_{10} concentrations recorded in *Vredenburg* between 2003 and 2009, and combined monthly and seasonal averages over this period, are shown in Table 5.2.3.

Table 5-2-3: Average monthly PM_{10} concentration for Vredenburg, 2003 – 09 (µg/m^3)

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Monthly Averages 2002-2009**	**Seasonal Averages 2002-2009**
Dec	20.22		24.51		21.51	19.40		21.41	Summer 31.73
Jan		19.51		22.08		17.47	19.00	19.52	
Feb		18.74		26.51	140.30		31.50	54.26	
Mar		4.77		9.28	139.77		30.21	46.01	Autumn 45.51
Apr		20.43		20.00	124.54		23.44	47.10	
May		23.20		27.88	110.34		12.28	43.42	
Jun		13.93	15.54		55.07			28.18	Winter 19.41
Jul		20.62	18.22			11.18		16.67	
Aug		14.43	13.40			12.33		13.39	
Sep		17.35	17.45		17.02	15.74		16.89	Spring 19.36
Oct	17.91		21.35		24.81	20.71		21.19	
Nov	21.08		19.42		20.76	18.67		19.98	
Annual Average	**19.73**	**17.00**	**18.56**	**21.15**	**72.68**	**16.50**	**23.28**		

The data indicates that PM_{10} levels recorded at the monitoring station are typically lower in the second half of the year (winter and spring) than in the first half of the year (summer and autumn).

None of the monthly averages exceeded the 180 µg/m^3 current South African limit. The highest monthly average recorded during the monitoring period was 140.3 µg/m^3 in February 2007, with similarly high values in the subsequent three months. This means that, although 24 hourly peak values were not provided, the proposed guideline of 75 µg/m^3 for 24 hour peak values must have been exceeded at times during these months.

The highest average daily PM_{10} concentration at Vredenburg for the period from July 2008 – May 2009 (for which daily data is available) was 73.17 µg/m^3, recorded on 05 February 2009. Neither the SA standard of 180 µg/m^3 24 hour average stipulated in NEM:AOA or the proposed guideline of 75 µg/m^3 were exceeded during the period for which daily data was available.

The monitoring data shows the total environmental burden (i.e. PM_{10} from all contributing sources, including the Saldanha IOHF), and it is not possible to determine the contribution of the IOHF to these levels.

The available monthly average PM_{10} concentrations recorded in *Blue Water Bay* between 2002 and 2009, and combined monthly and seasonal averages over this period, are shown in Table 5.2.4.

Table 5-2-4: Average monthly PM_{10} concentration for Blue Water Bay, 2002-09 (µg/m^3)

	2002	2003	2004	2005	2006	2007	2008	2009	Monthly Averages 2002-2009	Seasonal Averages 2002-2009
Dec		24.37		24.74		18.25	25.17		23.13	Summer 25.17
Jan			21.25		25.03		18.83	22.47	21.90	
Feb			64.06		21.06	20.64		16.13	30.47	
Mar			24.50		25.83	21.26		25.83	24.35	Autumn 27.93
Apr			30.75		28.02	26.36		20.12	26.31	
May			32.15		23.52	60.66		16.13	33.12.	
Jun			11.96	18.15		42.59			24.24	Winter 22.29
Jul			28.42	24.32			12.76		21.93	
Aug			21.23	17.73			23.15		20.70	
Sep			23.54	18.99		21.03	18.52		20.52	Spring 21.99
Oct	22.27	23.09	27.59	25.09		22.90	19.95		23.48	
Nov		24.73		24.74		21.80	16.57		21.96	
Annual Average	**22.27**	**24.06**	**28.58**	**21.97**	**24.69**	**28.39**	**19.28**	**20.14**		

As for Vredenburg, PM_{10} levels recorded at this monitoring station are typically lower in the second half of the year (winter and spring) than in the first half of the year (summer and autumn).

None of the monthly averages exceeded the 180 µg/m^3 current South African limit. The highest monthly average recorded during the monitoring period was 64.06 µg/m^3 in February 2004.

The highest average daily PM_{10} level at Blue Water Bay for the period from September 2008 to May 2009 (for which daily data is available) was 59.5 µg/m^3 recorded on 23 February 2009. Neither the SA standard of 180 µg/m^3 24 hour average stipulated in NEM:AOA or the proposed guideline of 75 µg/m^3 were exceeded during the period for which daily data was available.

ii. Dust Fall-Out Monitoring

Environmental dust monitoring was also undertaken by Transnet in the area surrounding the IOHF since 2002. However, dust fall-out data cannot be used as a proxy for levels of exposure to inhalable and respirable PM and is only an indication of the nuisance effect of the dust emitted from the IOHF. The nuisance impact of the IOHF was addressed by the Air Quality Study (Reddy and Naidoo, 2009), and is thus not discussed further in this report.

iii. Modeling Results

The modeling of PM_{10} concentrations in areas surrounding the Port, at a throughput of 60 MTPA of iron ore at the Port, covered an 18 month period from January 2008 – June 2009 and included two main scenarios: no dust mitigation at the IOHF[6] and applying mitigation measures with 50% efficiency while maintaining the ore moisture content at 1.2%. Specific averaged seasonal and 24 hour peak concentrations were modeled for Blue Water Bay and Vredenburg, which are discussed below. The model also produced maps showing the predicted averaged 24 hour peak concentrations of PM_{10} in all areas surrounding the Port. These are provided further below.

Vredenburg

All averaged and 24 hour peak PM_{10} concentrations that are predicted in Vredenburg as a result of Port operations were significantly below 75 µg/m^3, both for the unmitigated and the mitigated scenario (see Table 5-2-5). No exceedances of the 75 µg/m^3 or even 180 µg/m^3 guideline are thus expected. Predicted concentrations are significantly lower in winter than in summer.

Blue Water Bay

The PM_{10} concentrations that are predicted by the model in Blue Water Bay as a result of Port operations are considerably higher than those in Vredenburg. Under the unmitigated scenario, average predicted daily concentrations are relatively low (6.8 µg/m^3 in winter and 10.3 µg/m^3 in summer) and lie well within the guidelines.

However, the average 24 hour peak concentration in summer is predicted to reach 197.6 µg/m^3, thus exceeding both the 75 µg/m^3 and the 180 µg/m^3 guidelines at times. Analysis of the 24 hour peak concentrations predicted for each day of the 535-day modeling period, which comprises two summer / autumn periods with typically higher concentrations and one winter / spring period with typically lower concentrations, indicates that although the vast majority of predicted concentrations are very low, a number of unacceptably high concentrations, exceeding the South African guidelines, can be expected:

- 83% of modeled 24 hour peak concentrations were below the guideline of 75 µg/m^3 (in total, 29% of the values lay below 1 µg/m^3);
- 9% of modeled 24 hour peak concentrations were between 75 µg/m^3 and 180 µg/m^3; and
- 8% of modeled 24 hour peak concentrations were above 180 µg/m^3.

---

[6] The underlying assumptions for this scenario are very conservative and unlikely to ever occur, as laid out in the Air Quality Report (Reddy and Naidoo, 2009).

The highest modeled 24 hour peak concentration is 590 µg/m^3, which is significantly above guidelines or limits considered safe for health purposes.

Under the mitigated scenario, all predicted averaged and 24 hour peak PM_{10} concentrations in Blue Water Bay as a result of Port operations were significantly below 75 µg/m^3 (see Table 5-2-5). No exceedances of the 75 µg/m^3 or even 180 µg/m^3 guideline are thus expected in this scenario. Predicted concentrations are considerably lower in winter than in summer.

The predicted concentrations for Vredenburg and Blue Water Bay, discussed above, are summarized in Table 5-2-5 below.

Table 5-2-5: PM_{10} concentrations modeled for the period 1 Jan 2008 – 20 Jun 2009 at a throughput of 60 MTPA at the IOHF (µg/m^3)

	Vredenburg		**Blue Water Bay**	
	Unmitigated scenario	**Mitigated scenario***	**Unmitigated scenario**	**Mitigated scenario***
Averaged 24 hr peak PM_{10} concentrations	Winter: 7.6 Summer: 12.4 All Year: 12.4	Winter: 1.2 Summer: 2.2 All Year: 2.2	Winter: 52.5 Summer: 197.6 All Year: 197.6	Winter: 6.8 Summer: 25.5 All Year: 25.5
Averaged 24 hr average PM_{10} concentrations	Winter: 1.0 Summer: 1.8 All Year: 1.8	Winter: 0.2 Summer: 0.4 All Year: 0.3	Winter: 6.8 Summer: 10.3 All Year: 10.3	Winter: 1.0 Summer: 1.5 All Year: 1.4
24 hour peak concentrations above 75 µg/m^3	None	None	Number of exceedances: 89	None
24 hour peak concentrations above 180 µg/m^3	None	None	Number of exceedances: 40	None

** This scenario entails maintaining an ore moisture content of 1.2% and 50% mitigation efficiency , as stipulated in Reddy and Naidoo (2009).*
Winter includes the period from June to November. Summer includes the period from December to May.

Average concentrations at the Port Jetty and the NPA Building, both within the industrial zone of the Port and hence excluded from this assessment of health impacts on the surrounding communities, can reach much higher levels than predicted for Blue Water Bay and Vredenburg. Averaged 24 hour peak concentrations at the Port Jetty are predicted to reach 1 526 µg/m^3 in summer and 980 µg/m^3 in winter in the unmitigated scenario, and 212 µg/m^3 in summer and 128 µg/m^3 in winter in the mitigated scenario, while daily averages are much lower. Averaged 24 hour peak concentrations at the NPA building are predicted to reach 365 µg/m^3 in summer and 209 µg/m^3 in winter in the unmitigated scenario and 57 µg/m^3 in summer and 48 µg/m^3 in winter in the mitigated scenario, while daily averages are again much lower. These values need to be considered in the assessment of occupational risk, which falls outside the scope of this study.

The maps showing the predicted footprint of averaged 24 hour PM_{10} peak concentrations in the areas surrounding the Port are shown below.

For the unmitigated scenario (see Figure 5-2-3-2), predicted average 24 hour peak concentrations of 180 µg/m^3 and above, exceeding guidelines stipulated in the NEM:AQA, reach parts of Blue Water Bay, while all of Blue Water Bay is predicted to experience average 24 hour peak concentrations above the SANS guideline of 75 µg/m^3 at times.

Average 24 hour peak concentrations in all other receptor areas are predicted to be below 75 µg/m^3. While average 24 hour peak concentrations in parts of Saldanha are expected to be above 50 µg/m^3, they are between 10 µg/m^3 and 50 µg/m^3 in Vredenburg and Langebaan.

For the mitigated scenario (see Figure 5-2-3-3), average 24 hour peak concentrations are predicted to be between 10 µg/m^3 and 50 µg/m^3 in Blue Water and below 10 µg/m^3 in the other surrounding residential areas.

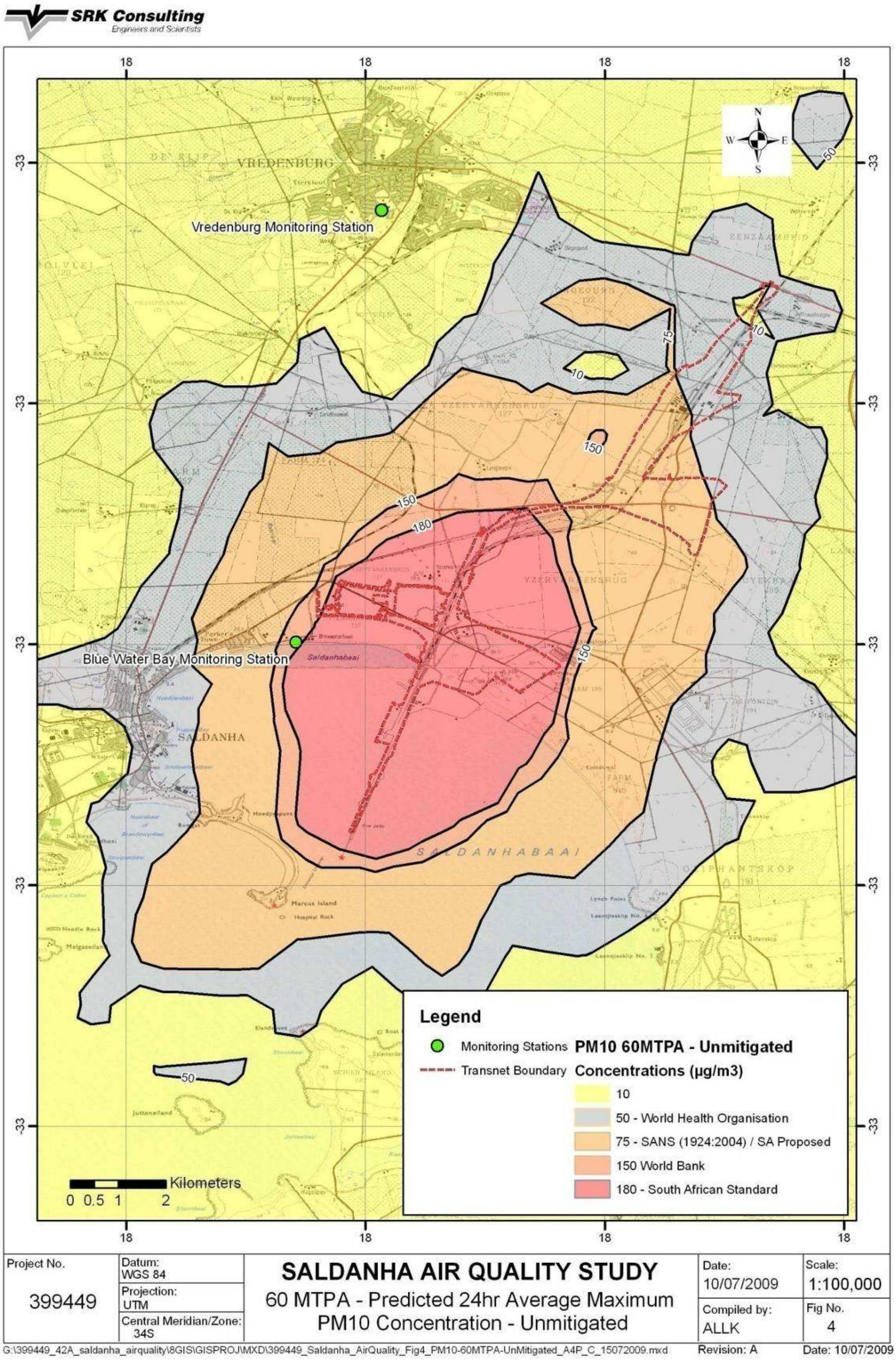

Figure 5-2-3-2: Predicted receptor exposure to PM_{10} in unmitigated scenario

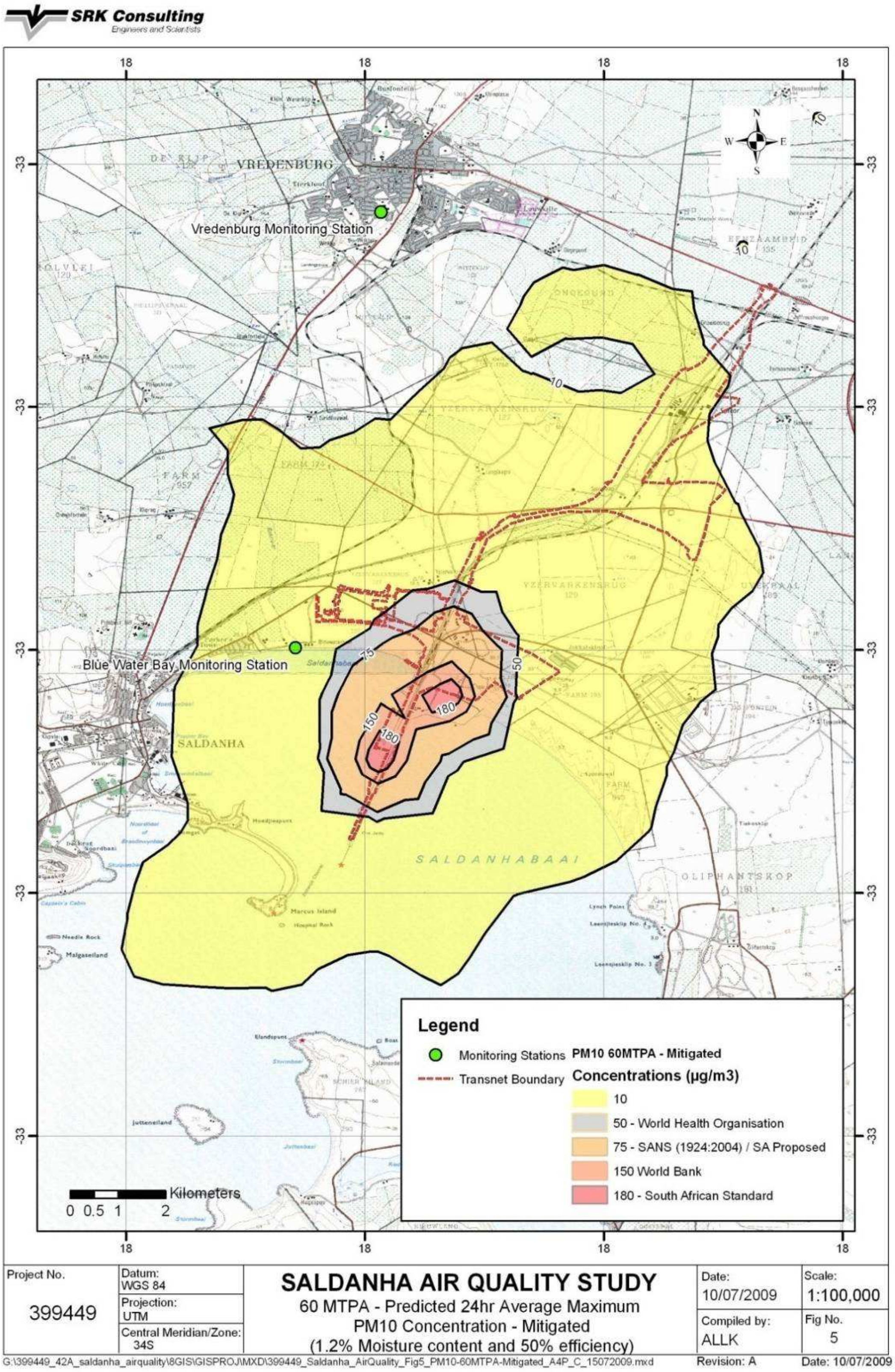

Figure 5-2-3-3: Predicted receptor exposure to PM_{10} when 50% efficient mitigation practices are maintained

5.3 Health Impact Assessment

From a health perspective, both 24 hour peak concentrations and long-term average concentrations are of importance. High peak concentrations, even if long-term averages are low, may cause acute respiratory illnesses, especially in people that are already vulnerable. High long-term average concentrations may cause chronic respiratory illnesses.

From the data available from the modeling, it is evident that without mitigation, a throughput of 60 MTPA of ore at the IOHF in Saldanha could result in a significant number of exceedances of current and proposed 24 hour peak PM_{10} concentration guidelines, and levels considered safe in terms of health, at **Blue Water Bay**. The highest predicted 24 hour peak concentration of 590 $\mu g/m^3$ is more than three times the currently allowed daily maximum concentration of 180 $\mu g/m^3$ in terms of NEM:AQA and nearly eight times the stipulated daily limit of 75 $\mu g/m^3$ in terms of SANS, which is considered to be more relevant for health purposes. The intensity of the health impact of the unmitigated operation of the IOHF at 60 MTPA on the Blue Water Bay community, with respect to acute respiratory illnesses, is thus considered to be high (see Table 5-2-6).

With regards to annual average concentrations, the predicted concentrations at Blue Water Bay in unmitigated circumstances are considered to be acceptable for health purposes, and modeled concentrations fall within the South African limits stipulated in NEM:AQA (60 $\mu g/m^3$) and SANS (40 $\mu g/m^3$). The predicted levels also fall below the very conservative WHO guidelines for annual concentrations of 20 $\mu g/m^3$, which was based on the lowest level with a demonstrated health effect (see Table 5-1-4). The intensity of the health impact of the unmitigated operation of the IOHF at 60 MTPA on the Blue Water Bay community, with respect to chronic respiratory illnesses, is thus considered to insignificant (see Table 5-2-6).

If effective mitigation is applied, both 24 hour peak and particularly annual average concentrations of PM_{10} at Blue Water Bay are predicted to be low, although somewhat higher than at other receptors. The intensity of the health impact of the mitigated operation of the IOHF at 60 MTPA on the Blue Water Bay community is thus considered to be low with respect to acute respiratory illnesses and insignificant with respect to chronic respiratory illnesses (see Table 5-2-6).

In **Saldanha**, the model indicates that average 24 hour peak concentrations can reach close to 75 $\mu g/m^3$ under unmitigated circumstances, which indicates that actual 24 hour peak concentrations could lie above this limit, though not to the extent at which this happens in Blue Water Bay. The intensity of the health impact of the unmitigated operation of the IOHF at 60 MTPA on the Saldanha community, with respect to acute respiratory illnesses, is thus considered to be medium. As annual averages are likely to be lower than those at Blue Water Bay, the intensity of the health impact of the unmitigated operation of the IOHF at 60 MTPA on the Saldanha community, with respect to chronic respiratory illnesses, is considered to be insignificant (see Table 5-2-6),

Under mitigated circumstances, both the 24 hour peak and annual average concentrations of PM_{10} at Saldanha are expected to be very low, with insignificant impacts on the health of the population there (see Table 5-2-6).

In **Vredenburg** and **Langebaan**, predicted 24 hour peak and annual average concentrations of PM_{10} under unmitigated circumstances are expected to be low, with low impact intensity on acute health conditions and insignificant impact intensity on chronic health conditions. For mitigated circumstances, very low concentrations are predicted, with resulting health impact intensities considered to be insignificant (see Table 5-2-6).

The above discussion is summarized in Table 5-2-6. Blue Water Bay is considered to fall within the local extent of the footprint for impact rating purposes, while all other receptors fall within a regional area. The duration of the impact is considered to be long-term, as it will remain for as long as the IOHF operates.

Table 5-2-6: Predicted health impacts from the for PM_{10} exposures from the IOHF in different receptor areas

Nature of Impact	Receptor area	Mitigation	Extent	Duration	Intensity
Acute upper respiratory illness (24 hour peak exposures)	Blue Water Bay	Without	Local	Long-term	High
		With	Local	Long-term	Low
	Vredenburg	Without	Regional	Long-term	Low
		With	Regional	Long-term	Insignificant
	Langebaan	Without	Regional	Long-term	Low
		With	Regional	Long-term	Insignificant
	Saldanha	Without	Regional	Long-term	Medium
		With	Regional	Long-term	Insignificant
Chronic upper and lower respiratory illnesses (annual exposures)	Blue Water Bay	Without	Local	Long-term	Insignificant
		With	Local	Long-term	Insignificant
	Vredenburg	Without	Regional	Long-term	Insignificant
		With	Regional	Long-term	Insignificant
	Langebaan	Without	Regional	Long-term	Insignificant
		With	Regional	Long-term	Insignificant
	Saldanha	Without	Regional	Long-term	Insignificant
		With	Regional	Long-term	Insignificant

The impact significance has been assessed separately for potential acute respiratory illnesses and for potential chronic effects. The assessment below rates the significance of the impact for all receptor areas combined.

Based on the analysis in Table 5-2-6, the impact of the IOHF on **acute respiratory illnesses**, due to high 24 hour peak concentrations of PM_{10}, is considered to be of high intensity with a local extent. The resulting impact significance is rated as **high (negative) before mitigation**. Applying effective mitigation measures as recommended in the Air Quality Study (Reddy and Naidoo, 2009) is expected to significantly reduce PM_{10} peak concentrations and hence the impact intensity. The resulting impact significance is rated as **low (negative) after mitigation** (see Table 5-2-7).

Table 5-2-7: Significance of the health impact of the IOHF at 60 MTPA throughput with regards to acute respiratory illnesses in surrounding communities

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Long-term 3	**High 7**	Probable	**HIGH**	-ve	Medium
Key mitigation measures: • Apply the mitigation measures recommended in the air quality study undertaken for this BA.								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Probable	**LOW**	-ve	Medium

Based on the analysis in Table 5-2-6, the impact of the IOHF on **chronic respiratory illnesses**, due to high long-term concentrations of PM_{10}, is considered to be **insignificant both before and after mitigation** at all receptor areas surrounding the Port.

6. Conclusions

Evidence from the literature shows that health risks are associated with certain levels of exposure to PM, where both high short term exposures as well as high long-term exposures are of concern. As a result, standards and guidelines have been set for daily and annual PM exposure limits to protect the health of the general public. Those standards are continuously being revised as new evidence become available.

The modeling undertaken in the Air Quality Study (Reddy and Naidoo, 2009), simulating the concentration and dispersion of PM and dust from the IOHF at a throughput of 60 MTPA, suggests that particularly short-term concentrations in nearby receptors may become unacceptably high if dust is not mitigated at the IOHF. Effectively mitigating the generation of dust, by maintaining an ore moisture content of 1.2% and operating mitigation measures at 50% efficiency, is expected to result in acceptable short and long term PM concentrations at nearby receptors that will not pose a risk to human health.

7. Recommendations

The following recommendations are made if the increased throughput of 60 MTPA is approved:

- The mitigation measures recommended by the Air Quality Study (Reddy and Naidoo, 2009) must be implemented.
- Transnet should ensure that a suitable Environmental Management System is in place to monitor the mitigation measures. A mitigation efficiency of at least 50% will be required to effectively mitigate potential impacts. If this cannot be achieved, additional mitigation, or more stringent monitoring and implementation of the mitigation will need to be applied.
- Transnet must continue the operation of the PM_{10} monitoring network and ensure that it is reliable and representative for the area. Both the Blue Water Bay and

Vredenburg monitoring stations should be retained, as they measure total community exposure. More consistent recording of data (i.e. less gaps in the monitoring) should be achieved. In addition, monitoring should be undertaken at a suitable site (e.g. the boundary of the Port) to measure dust and PM_{10} directly related to Port activites, to monitor and, if necessary, increase, the effectiveness of mitigation measures.

- The PM_{10} concentrations recorded by the monitoring system should be evaluated by a health specialist on a quarterly basis to ensure that they do not present a health risk.
- Transnet should strive towards continuous reduction of dust released from the Port to ensure that operations remain compliant with potentially more stringent future emission standards.

It is not recommended that a community epidemiological study be conducted due to the low concentrations recorded in historic monitoring programmes and predicted for future operations (under adequate mitigation).

It is recommended that the 60 MTPA throughput be allowed under 50% mitigation efficiency as there is no evidence of exposure levels within the sensitive receptor area (Blue Water Bay) which will cause acute or chronic health impacts. A well operated and representative monitoring programme will characterize total exposures from all sources in the area and should trigger intervention if the environmental burden from all sources become a risk to human health.

8. References

Aucamp, I. (2007) Environmental Impact Assessment: Phase 2 Expansion of the Saldanha Iron Ore Export Terminal. Draft Social Impact Assessment.

Blaikie P, Cannon T, Davis I and Wisner B. 1994. At risk: natural hazards, people's vulnerability and disasters, Routledge. London.

Burger, L.W., Krause, N. (2006). Baseline Air Quality Assessment for the Bulk Ore Terminal – Saldanha Bay (Western Cape). Report No. APP/06/02 Rev 0.0.

CEPA/FPAC Working Group (1998). National Ambient Air Quality Objectives for Particulate Matter. Part 1: Science Assessment Document, A Report by the Canadian Environmental Protection Agency (CEPA) Federal-Provincial Advisory Committee (FPAC) on Air Quality Objectives and Guidelines.

DEAT. 2005 Government Gazette, National Environmental Management Air Quality Act, 2004. No. 28899.

Dockery, D.W., Pope, C.A., Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E. Ferris, B.G., Speizer, F.E., (1993). An Association between Air Pollution and Mortality in Six U.S. Cities The New England Journal of Medicine, 329, 1753-1759.

ECOSERV, 2005. Ambient dust reporting SAPO Monitoring Network. November 2003 to October 2004, Report no. ASO162.

Elinder, C.G. and Piscator, M. (1979). Iron. (In: Fribert, L., et al. Handbook on the Toxicology of Metals. Amsterdam : Elsevier/North-Holland Biomedical Press, p.435-539).

Gulumian, M. (2007). Draft Health Consultation Report on Dust at the Iron Ore Export Handling Facility in Saldanha. Wits Health Consortium Report. 25 June 2007.

Health Canada. (1998). National Ambient, Air Quality Objectives for Particulate Matter. Report by the CEPA/FPAC Working Group on Air Quality Objectives and Guidelines.

Health Canada. (1999). Priority Substances List. Assessment Report – Respirable Particulate Matter less than or equal to 10 Microns. Draft Report, 1999.

IARC. (2000). Monographs Series, Volumes 1-74. Overall Evaluations of Carcinogenicity to Humans. International Association for Research on Cancer.

John, J., Matooane M., Oosthuizen, R., Binedell M. (2006). Vulnerability to air pollution exposure: who is more at risk? Report No: CSIR/NRE/PW/IR/2006/0040/A. Pretoria: CSIR.

Kappos, A.D., Bruckmann, P., Eikmann, T., Englert, N., Heinrich, U., Hōppe, P., Koch, E., Krause, G.H.M., Kreyling, W.G., Rauchfuss, K., Rombout, P.,Schuiz-Kemp, V., Thiel, W.R., Wichmann, H.E. 2004. Health effects of particles in ambient air. Int. J. Hyg. Environ. Health, 207:399-407.

Keen, K.L. (1996). Teratogenic Effects of Essential Trace Metals : Deficiencies and Excesses. (In: Change, et al. Toxicology of Metals. Boca Raton: CRC Lewis Publishers, p. 977-1001).

Kornelius, G. Muderne, L. and le Roux, N. 2006. Atmospheric Impact of the Holcim Roodepoort Extensions. Report APP/06/MW-01-Rev.04.

Künzli, N., Kaiser, R., Medina, S., Studnicka, M., Chanel, O., Filliger, P., Herry, M., Horak, J. F., Puybonnieux-Texier, V., Quénel, P., Schneider, J., Seethaler, R., Vergnaud, J., Sommer, H., (2000). Public-health impact of outdoor and traffic-related air pollution: A European assessment. The Lancet, 356, 795-801.

Levy, J.I., Greco, S.L., Spengler, J.D. (2002). The importance of population susceptibility for air pollution risk assessment: a case study of power plants near Washington, DC. Environmental Health Perspectives, 10:1253-1260.

Lewis, R. Editor. (1995). SAX's Dangerous Properties of Industrial Materials. Ninth Edition. New York: Van Nostrand Reinhold, CD ROM Edition.

Morawska, l., Moore, M.R. and Ristovski, Z.D. (2004). Health Impacts of Ultrafine Particles. Canberra: Australian Department of the Environment and Heritage.

Reddy, V.S., Naidoo, D. (2009). Saldanha Air Quality Permit Basic Assessment: Air Quality Specialist Baseline Study and Impact Assessment. SRK Project No: 399449/42A. (Draft Final Report).

SANS 1929. 2005. South African national Standard, Ambient air Quality – Limits for common pollutants.

Smith, R.L. (1996). Risk-based concentrations: prioritizing environmental problems using limited data. Toxicology, 106, 243.

Terblanche, A.P.S., Nel, C.M.E., Opperman, L., Nyikos, H. (1993). Exposure to air pollution from transitional household fuels in a South African population. Journal of Exposure Analysis and Environmental Epidemiology 3 (SI), 15-22.

USEPA. (2004).Epidemiology of human health effects associated with ambient particulate matter. In: Air Quality Criteria for Particulate Matter. Vol. II of II. Research Triangle Park, NC: USEPA Document no. EPA/600/P-99/002bF. October 2004.

USEPA. (2006). Particulate Matter. http://www.epa.gov/oar/particlepollution/. Accessed 26.01.07

Van Niekerk, W.C.A. (2000). Preliminary Dust Management Investigation and Environmental Impact Assessment. Screening Environmental Health Risk Assessment. Infotox cc. Document No. 016-2000.

WHO. (2005). WHO Air Quality Guidelines Global Update. Meeting Report. Geneva: World Health Organization.

Wichmann, J. and Voyi, K.V. (2005). Air pollution epidemiology studies in South Africa: Need for freshening up. Reviews in Environmental Health 20, 265-301.