Project done on behalf of
Ninham Shand Consulting Services

AIR QUALITY ASSESSMENT FOR THE OPEN CYCLE GAS TURBINE (OCGT) POWER PLANT'S ADDITIONAL UNITS IN MOSSEL BAY

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EXECUTIVE SUMMARY

INTRODUCTION

Airshed Planning Professionals performed the air quality assessment for the Environmental Impact Assessment (EIA) for an Open Cycle Gas Turbine (OCGT) power plant adjacent to the PetroSA facility near Mossel Bay in 2005. Eskom proposes to install three additional turbine units at the OCGT power plant presently under construction. The total number of units would therefore be six. Additional units are being proposed as a result of a higher growth rate in annual electricity demand nationally than that predicted when the approved OCGT plant was considered. Both the power station and the refinery are located in a rural area with low population density.

The main aim of this investigation was to determine the impact from the additional units as well as the previously approved units (and now under construction) on the surrounding environment and human health. To accomplish this, a good understanding of the general and local climate of the area need to be established and subsequently all emission rates need to be quantified and atmospheric dispersion modelling executed.

The specific terms of reference are as follows:

- Collate and compile existing data for the ambient air pollution conditions emanating from the region (i.e. establishing the baseline conditions) and prepare dispersion simulations of baseline emissions;
- Prepare an emissions inventory of proposed additional sources at the power station, and prepare dispersion simulations of emissions for the following 4 scenarios:
    - o Plant operating 2 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
    - o Plant operating 2 hours per day with NOx = 600 mg/Nm³ (i.e. no NOx reduction measures);
    - o Plant operating 6 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
    - o Plant operating 6 hours per day with NOx = 600 mg/Nm³ (i.e. no NOx reduction measures).
- Prepare an emissions inventory of the fugitive gaseous emissions emanating from the fuel transfer, handling and storage;
- Dispersion simulation results of incremental impacts from the power station only (i.e. additional three units), as well as cumulative impacts from both the power station (all six units) and the refinery;
- Impact analysis of during normal operation, start-up, shut-down and upset conditions;
- Illustrate plume dispersion for worst-case and medium to strong wind scenarios; and
- Analyse predicted concentration levels (i.e. compliance checking with current and proposed legislation).

METHODOLOGY

Baseline Conditions

Quantifying the baseline conditions requires an analysis of both ambient air quality data observations and predictive methods. A general description of the climate for the greater region can be found from historical records (e.g. South African Weather Service reports). However, it is necessary to obtain local meteorological data to determine the conditions specifically applicable to the project.

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. An analysis of the ventilation potential of prevailing synoptic systems, and of the nature and frequency of occurrence of weather perturbations, provides for an effective characterization of the macro-scale dispersion potential. Diurnal variations in dispersion potentials associated with meso-scale ventilation processes are most successfully evaluated on the basis of hourly average observations and estimations.

Use was made of data from the PetroSA weather station. Hourly average meteorological data, including wind speed, wind direction and temperature was used, and mixing heights were estimated for each hour, based on prognostic equations, while night-time boundary layers were calculated from various diagnostic approaches. Wind speed and solar radiation were used to calculate hourly stability classes.

For the completion of a baseline investigation, the data included both air quality and meteorological data. Air quality data included dispersion simulations showing predicted ground level concentrations from the OCGT power plant currently under construction as well as the PetroSA refinery. A comprehensive source inventory for PetroSA was completed by Harmse and Rowe of Ilitha (2004).

Impact Assessment

An air pollution inventory was compiled for both stack and fugitive emissions from the additional open cycle gas turbines (OCGT) at the power station. The emission rates were based on information supplied by Eskom.

Dispersion modelling of all emissions using hourly average meteorological data for the area was completed. The US EPA approved Industrial Source Complex (ISC) Model version 3 was used. Hourly, daily and annual average concentrations were calculated for comparison to and compliance with national air quality guidelines. The impact assessment was based on guidelines developed/adopted by institutions such as World Health Organisation (WHO), World Bank, United States Environmental Protection Agency (US EPA) and South Africa. The proposed South African limit values have been included for compliance with proposed legislation.

IMPACT ASSESSMENT

Table 1: Maximum predicted concentrations from the Eskom power station (6 units) and from both the Eskom power station (operating 2 hours per day) and the PetroSA Refinery (Scenarios 1 and 2).

Pollutant	Impact Period	Guideline/ Standard (µg/m³)(3)	Maximum off-site impact from the Power station (7)		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc (µg/m³)	% of standard	conc (µg/m³)	% of standard	conc (µg/m³)	% of standard
PM10(1)	Highest Daily	75(4)	0.3	<1	1.2	1.6	1.2	1.6
	Annual	40(4)	0.012	<1	0.18	<1	0.18	<1
SO_2(1)	Highest Hourly	350(5)	3.4	<1	0.05	<1	3.4	<1
	Highest Daily	125(4)	0.14	<1	0.009	<1	0.14	<1
	Annual	50(4)	0.006	<1	0.001	<1	0.006	<1
CO(1)	Hourly	30 000(4)	5.2	<1	75	<1	75	<1
NO_2(1) (165 mg/Nm³)	Highest Hourly	200(4)	28	14	170	85	170	85
	Highest Daily	150(6)	1.0	<1	30	20	30	20
	Annual	40(4)	0.05	<1	4.5	11	4.5	11
NO_2(2) (600 mg/Nm³)	Highest Hourly	200(4)	100	50	170	85	170	85
	Highest Daily	150(6)	4	2.7	30	20	30	20
	Annual	40(4)	0.19	<1	4.5	11	4.5	11

Notes: (1) Scenario 1.

(2) Scenario 2.

(3) Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.

(4) South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.

(5) EC.

(6) World Bank.

(7) The impact from the three additional units alone is the same as the impact from the three units currently under construction. The impact for all six units is double the impact for the three units currently under construction.

Table 2: Maximum predicted concentrations from the Eskom power station (6 units) and from both the Eskom power station (operating 6 hours per day) and the PetroSA Refinery (Scenarios 3 and 4).

Pollutant	Impact Period	Guideline/ Standard (µg/m³)[3]	Maximum off-site impact from the Power station[7]		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc (µg/m³)	% of standard	conc (µg/m³)	% of standard	conc (µg/m³)	% of standard
PM10[1]	Highest Daily	75[4]	0.5	<1	1.2	1.6	1.2	1.6
	Annual	40[4]	0.03	<1	0.18	<1	0.18	<1
SO_2[1]	Highest Hourly	350[5]	3.6	1	0.05	<1	3.6	1
	Highest Daily	125[4]	0.24	<1	0.009	<1	0.24	<1
	Annual	50[4]	0.014	<1	0.001	<1	0.014	<1
CO[1]	Hourly	30 000[4]	5.6	<1	75	<1	75	<1
NO_2[1] (165 mg/Nm³)	Highest Hourly	200[4]	28	14	170	85	170	85
	Highest Daily	150[6]	2	1.3	30	20	30	20
	Annual	40[4]	0.1	<1	4.5	11	4.5	11
NO_2[2] (600 mg/Nm³)	Highest Hourly	200[4]	100	50	170	85	170	85
	Highest Daily	150[6]	7.2	4.8	30	20	30	20
	Annual	40[4]	0.4	1	4.5	11	4.5	11

Notes: [1] Scenario 3.
[2] Scenario 4.
[3] Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.
[4] South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.
[5] EC.
[6] World Bank.
[7] The impact from the three additional units alone is the same as the impact from the three units currently under construction. The impact for all six units is double the impact for the three units currently under construction.

IMPACT ASSESSMENT – ROUTINE EMISSIONS

Inhalable particulates (PM10)

PM10 predicted cumulative concentrations would be very similar to the existing baseline conditions, since the PetroSA refinery is the main contributor to the cumulative impact. The cumulative concentrations are, however, well below the SANS limits for both daily and annual averaging periods.

The Eskom power station would be contributing 7% to the predicted cumulative annual average ground level concentrations for 2 hours operation per day, and 17% for 6 hours operation per day. The predicted concentrations for all six units would be double the concentration predicted for the initial three units. The predicted highest daily concentration from the all six units would be 0.3 µg/m^3, and for annual 0.012 µg/m^3 (operating two hours per day), and 0.5 µg/m^3 and 0.03 µg/m^3 respectively (operating six hours per day).

Sulphur dioxide (SO_2)

It was predicted that the EC hourly guideline (350 µg/m^3) and the SA daily and annual standards (125 µg/m^3 and 50 µg/m^3) would not be exceeded for the power station in isolation. The highest hourly predicted ground level concentration for the power station (operating six hours per day) would be 1% of the EC limit (350 µg/m^3). The predicted ground level concentrations for the highest daily and annual averaging periods would be less than 1% of the SA standards. As for PM10, the predicted concentrations for all six units would be twice the concentration predicted for the initial three units. The predicted concentrations for the 6 hour scenario would be 1.7 (daily) and 2.3 (annual) times higher than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (3.4 and 3.6 µg/m^3 respectively).

Nitrogen dioxide (NO_2) (165 mg/Nm^3)

The predicted NOx cumulative concentrations would be the very similar to the baseline conditions, since emissions from PetroSA refinery remains to be the main contributor to local airshed. The predicted ground level concentrations at the power station for the highest daily and annual averaging periods would be less than 1% of the SANS limits, while the predicted concentration for the highest hourly averaging period (28 µg/m^3) would be 14% of the 200 µg/m^3 limit. The Eskom power station would be contributing 2% to the predicted cumulative annual average ground level concentrations (for the 6 hour scenario). The predicted concentrations for the 6 hour scenario would be 2 times higher (daily and annual) than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (28 µg/m^3).

Nitrogen dioxide (NO_2) (600 mg/Nm³)

With an increase in NOx emissions from the power station (600 mg/Nm³) the predicted ground level concentrations at the power station for the highest hourly averaging period (100 µg/m³) would be 50% of the 200 µg/m³ limit. The Eskom power station would contribute 4% for the predicted cumulative annual average ground level concentrations (for the 6 hour scenario). The predicted concentrations for the 6 hour scenario would be 1.8 (daily) and 2.1 (annual) times higher than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (100 µg/m³).

Carbon monoxide (CO)

The highest predicted hourly CO concentration (all six units) would be 5.6 µg/m^3 and 75 µg/m^3 for the power station only, and cumulative, respectively. This is less than 1% of the SANS limit.

Fugitive Volatile Organic Compounds

The highest predicted diesel concentration from fugitive emissions (fuel transfer and handling, including pumps, valves, flanges and tanks) would be 700 µg/m³. This is 9 % of the Ontario half-hour standard of 7 800 µg/m³ for mineral spirits. The highest predicted daily concentration would be 100 µg/m³, which is approximately 4 % of the Ontario daily standard of 2 600 µg/m³.

Greenhouse gases

The proposed power station will produce 77 ton CO_2/TJ fuel used (IPPC, 2004), i.e. 123 ton CO_2 per hour per unit, resulting in an annual emission of 539 228 tpa assuming 6 units are operational 2 hours per day and 1 617 684 tpa assuming 6 hours per day.

The annual South Africa emission rate of CO_2 is approximately 365 million metric tons expressed as carbon dioxide (CO_2) equivalent (CO_2E). CO_2 emissions from the proposed power station will be between 0.15 – 0.44 % of South Africa's total CO_2 emissions, depending on operational hours.

IMPACT ASSESSMENT – START-UP AND SHUT-DOWN EMISSIONS

Start-up and shut-down conditions last less than 30 and 10 minutes, respectively. Apart from carbon monoxide, the emissions of sulphur dioxide and oxides of nitrogen during start-up and shut-down would be similar or lower than during normal operation. Based on on-line monitoring data, carbon monoxide was 5 times the normal emissions and twice during shut-down. However, the predicted impacts from CO would still be well below the standard.

No data could be supplied to confirm the impact of particulate matter.

IMPACT ASSESSMENT – UPSET CONDITIONS

Upset conditions were given as: the power station operating for 24 hours per day and a NOx emission of 600 mg/Nm³ (i.e. assuming no low-NOx burner). Under these conditions the standard would be exceeded. (This is however based on the conservative assumption that all NOx would be NO_2.)

If the power station would be operating for 24 hours per day with a NOx emission of 165/Nm³ (i.e. low-NOx burner), the standard would not be exceeded.

CONCLUSIONS

In general, with an additional three units operating, i.e. six units in total, the predicted concentrations from the power station alone, would be double the predicted concentrations from the three units currently under construction.

Scenario 1

- It is predicted that the OCGT would contribute 1 % to the cumulative predicted annual average NO_2 ground level concentrations due to the power station and the PetroSA refinery.
- The nitrogen dioxide concentrations would not exceed the guidelines or standards for the hourly, daily or annual averaging periods and would be 14%, <1% and <1% of the guidelines and standards, respectively for the power station, and 85%, 20% and 11% for the cumulative scenario. Given that these emissions were all assumed to be NO_2, when it may only be as little as 10% of the total NOx emissions, it can be concluded that NO_2 would be further below the respective guidelines and standards.
- The OCGT would be the main source of sulphur dioxide impacts; however the predicted concentrations are well below the standards (less than 1%).
- The inhalable particulates and carbon monoxide concentrations from the OCGT also would not exceed the respective standards (less than 1%). The PetroSA refinery would be the main source of impact for these pollutants, but even cumulative predicted concentrations are well below the standards and SANS limits.

Scenario 2

- It is predicted that the OCGT would contribute 4 % to the cumulative predicted annual average NO_2 ground level concentrations due to the power station and the PetroSA refinery.

- The nitrogen dioxide concentrations would not exceed the guidelines or standards for the hourly, daily or annual averaging periods and would be 50%, 2.7% and <1% of the guidelines and standards, respectively for the power station, and 85%, 20% and 11% for the cumulative scenario.
- The predicted ground level concentrations would be 3.6 times higher for the NOx at 600 mg/Nm³ scenario compared to the NOx at 165 mg/Nm³ scenario.

Scenario 3

- For an increase in operating hours from 2 hours per day to six hours per day, predicted highest hourly ground level concentrations would remain similar, whereas highest daily and annual average concentrations would be approximately 2 times higher respectively.

Scenario 4

- It is predicted that the OCGT would contribute 9 % to the cumulative predicted annual average NO_2 ground level concentrations due to the power station and the PetroSA refinery.
- The nitrogen dioxide concentrations would not exceed the guidelines and standards for the hourly, daily or annual averaging periods and would be 50%, 5% and 1% of the guidelines and standards, respectively for the power station, and 85%, 20% and 11% for the cumulative scenario.

Even for the worst case scenario (operating 6 hours per day and NOx at 600 mg/Nm³) the Eskom power station would only contribute 9 % to the cumulative predicted annual average concentrations, and would not exceed any of the standards or guidelines. Additionally, given that the emissions were all assumed to be NO_2, when it may only be as little as 10% of the total NOx emissions, a conservative approach has been adopted and levels may be even lower than predicted. Therefore NOx concentrations could be up to 600 mg/Nm³ and the plant could operate for 6 hours per day without exceeding any guidelines or standards.

RECOMMENDATIONS

It is recommended that once the power station is operational the emissions concentrations for NO_2 be verified.

Since oxides of nitrogen is the only significant pollutant, it is recommended to investigate the possibility of expand the existing PetroSA monitoring programme by including NOx monitors in the vicinity of the power station and in the areas of maximum predictions.

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AIR QUALITY ASSESSMENT FOR THE OPEN CYCLE GAS TURBINE (OCGT) POWER PLANT'S ADDITIONAL UNITS IN MOSSEL BAY

1. INTRODUCTION

Airshed Planning Professionals performed the air quality assessment for the Environmental Impact Assessment (EIA) for an Open Cycle Gas Turbine (OCGT) power plant adjacent to the PetroSA facility near Mossel Bay in 2005. Eskom proposes to install three additional turbine units at the OCGT power plant presently under construction. Additional units are being proposed as a result of a higher growth rate in annual electricity demand nationally than that predicted when the approved OCGT plant was considered. Both the power station and the refinery are located in a rural area with low population density.

The proposed additional units would be located immediately to the west of the present OCGT power plant (Figure 1-1).

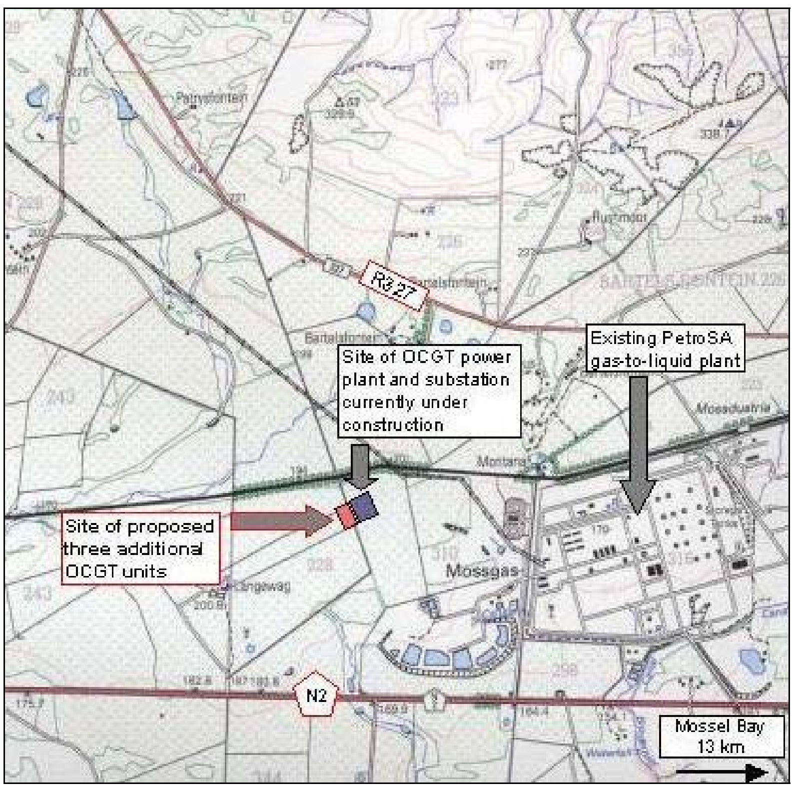

Figure 1-1: Location of the OCGT power plant's proposed additional units.

Airshed Planning Professionals (Pty) Ltd was contracted by Ninham Shand Consulting Services to conduct an air quality impact assessment study for the additional units at the OCGT Eskom Power Station.

The main aim of this investigation is to determine the impact from the additional units as well as the previously approved units (and now under construction) on the surrounding environment and human health. To accomplish this, a good understanding of the general and local climate of the area need to be established and subsequently all emission rates need to be quantified and atmospheric dispersion modelling executed.

1.1 Terms of Reference

The air quality investigation comprises two main components, viz. a baseline study and an impact assessment. The baseline study includes a review of the site-specific atmospheric dispersion potentials, and existing ambient air quality in the region, in addition to the identification of potentially sensitive receptors. Use was made of readily available information in addition to meteorological and air quality data recorded in the vicinity of the site in the characterisation of the baseline condition. In assessing the potential impacts associated with the proposed project, an emissions inventory needed to be compiled, atmospheric dispersion simulations undertaken and predicted concentrations evaluated.

The specific terms of reference are as follows:

- Collate and compile existing data for the ambient air pollution conditions emanating from the region (i.e. establishing the baseline conditions) and prepare dispersion simulations of baseline emissions;
- Prepare an emissions inventory of proposed additional sources at the power station, and prepare dispersion simulations of emissions for the following 4 scenarios:
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    - o Plant operating 2 hours per day with NOx = 600 mg/Nm³ (i.e. no NOx reduction measures);
    - o Plant operating 6 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
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- Analyse predicted concentration levels (i.e. compliance checking with current and proposed legislation).

1.2 Methodological Overview

1.2.1 Baseline Conditions

Quantifying the baseline conditions requires an analysis of both ambient air quality data observations and predictive methods. A general description of the climate for the greater region can be found from historical records (e.g. Weather Bureau Reports). However, it is necessary to obtain local meteorological data to determine the conditions specifically applicable to the project.

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. An analysis of the ventilation potential of prevailing synoptic systems, and of the nature and frequency of occurrence of weather perturbations, provides for an effective characterization of the macro-scale dispersion potential. Diurnal variations in dispersion potentials associated with meso-scale ventilation processes are most successfully evaluated on the basis of hourly average observations and estimations.

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1.2.2 Impact Assessment

An emissions inventory was compiled and included emissions from the additional open cycle gas turbines (OCGT) at the power station. These emission rates were based on information supplied by Eskom.

Dispersion modelling of all emissions using hourly average meteorological data for the area was completed. The US EPA approved Industrial Source Complex (ISC) Model version 3 was used. Hourly, daily and annual average concentrations were calculated for comparison to and compliance with national air quality guidelines. The impact assessment was based on guidelines developed/adopted by institutions such as World Health Organisation (WHO), World Bank, United States Environmental Protection Agency (US EPA) and South Africa. The proposed South African limit values have been included for compliance with proposed legislation.

1.3 Outline of Report

The relevant air quality guidelines and standards are described in Section 2. Section looks at techniques to reduce nitrogen oxide emissions formed during combustion of fuels. The baseline environment including the atmospheric dispersion potential of the site, the emission inventory and the dispersion modelling results is included in Section 4. Section 5 covers the impact assessment, and the conclusions can be found in Section 6.

2. AMBIENT AIR QUALITY EVALUATION CRITERIA

Air quality limits and thresholds are fundamental to effective air quality management, providing the link between the potential source of atmospheric emissions and the user of that air at the downwind receptor site. Ambient air quality limits indicate generally safe exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality limits are typically set for common air pollutants which cause widespread exposures. Suspended fine particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, lead and ozone are classified by most countries as 'criteria pollutants' with air quality limits being set for these pollutants (Section 2.1). Ambient air quality limits are not published for all possible air pollutants to which the public may be exposed. Such limits are typically only set for commonly occurring air pollutants that result in relatively widespread public exposures.

2.1 Air Quality Limits for Criteria Pollutants

National air quality standards are given in Schedule 2 of the National Environmental Management: Air Quality Act, Act 39 of 2004. These standards which largely reflect the national air quality guideline values established in the 1990s are considered to be dated and in need of revision.

The Department of Environmental Affairs and Tourism (DEAT) is in the process of reviewing and revising the national air quality standards published in the Air Quality Act with the purpose of ensuring that these limits are protective of human health and welfare. The review process was initiated by the gazetting of a new interim guideline for sulphur dioxide in December 2001, with these revised sulphur dioxide limits having been included in the Air Quality Act. Subsequently the Department engaged the South African Bureau of Standards (SABS) to facilitate the further development of health-based ambient air quality standards. Two documents were compiled during this process, viz. (i) SANS 69 - South African National Standard - Framework for setting & implementing national ambient air quality standards, and (ii) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. The latter document includes air quality limits for particulate matter less than 10 µm in aerodynamic diameter (PM10), dustfall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene. The SANS documents were finalized and published during the last quarter of 2004. The proposed new standards, based on the SANS 1929 limits were published in the government gazette on the 9th June 2006 for public comment. In this publication the Minister indicated that margins of tolerance, compliance timeframes, and permissible frequencies of exceedences will be included in the regulations.

2.1.1 Suspended Particulate Matter

The impact of particles on human health is largely depended 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 system 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 (PM10) 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 bifurcations 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, 1994).

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of PM2.5 (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, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. 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.

PM10 limits and standards issued nationally and abroad are documented in Table 2-1. In addition to the PM10 standards published in schedule 2 of the Air Quality Act, the Act also includes standards for total suspended particulates (TSP), viz. a 24-hour average maximum concentration of 300 µg/m³ not to be exceeded more than three times in one year and an annual average of 100 µg/m³.

During the 1990s the World Health Organisation (WHO) stated that no safe thresholds could be determined for particulate exposures and responded by publishing linear dose-response relationships for PM10 and PM2.5 concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document contain guidelines that define concentrations which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. These guidelines would provide air quality managers and policy makers with an explicit objective when they were tasked with setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO air quality guidelines (AQGs), the Working Group also proposed interim targets (IT) levels, in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2-2 and 2-3.

Table 2-1: Air quality standard for inhalable particulates (PM10)

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)[1]	180(a)	60
RSA SANS limits (SANS:1929,2004)	75(b) 50(c)	40(d) 30(e)
Australian standards	50(f)	-
European Community (EC)	50(g)	30(h) 20(i)
World Bank	70(j)	50(j)
United Kingdom	50(k)	40(l)
United States EPA	150(m)	50(n)
World Health Organisation	(o)	(o)

Notes:
(a) Not to be exceeded more than three times in one year.
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Target value. Permissible frequencies of exceedance and date by which limit value should be complied with not yet set.
(d) Limit value. Margin of tolerance and date by which limit value should be complied with not yet set.
(e) Target value. Date by which limit value should be complied with not yet set.
(f) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 5 days per year. Compliance by 2008.
(g) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). 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.)
(h) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005
(i) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010
(j) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(k) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Not to be exceeded more than 35 times per year. Compliance by 31 December 2004
(l) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Compliance by 31 December 2004
(m) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(n) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). To attain this standard, the 3-year average of the weighted annual mean PM10 concentration at each monitor within an area must not exceed 50 µg/m³.
(o) WHO (2000) issued linear dose-response relationships for PM10 concentrations and various health endpoints with no specific guideline provided. WHO (2005) made available during early 2006 proposes several interim target levels (see subsequent tables).

[1] On 9 June 2006 the Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (90 day comment period given). The proposed PM10 standards are given as 75 µg/m³ for highest daily (compared to the current standard of 180 µg/m³) and 40 µg/m³ for annual averages (compared to 60 µg/m³ at present) (Government Gazette No. 28899, 9 June 2006).

Table 2-2: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)

Annual Mean Level	PM10 (μg/m³)	PM2.5 (μg/m³)	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 AQG
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 PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred.

Table 2-3: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Daily Mean Level	PM10 (μg/m³)	PM2.5 (μg/m³)	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

2.1.2 Sulphur Dioxide

SO_2 is an irritating gas that is absorbed in the nose and aqueous surfaces of the upper respiratory tract, and is associated with reduced lung function and increased risk of mortality and morbidity. Adverse health effects of SO_2 include coughing, phlegm, chest discomfort and bronchitis. Ambient air quality guidelines and standards issued for various countries and organisations for sulphur dioxide are given in Table 2-4.

Table 2-4: Ambient air quality guidelines and standards for sulphur dioxide for various countries and organisations

Authority	Maximum 10-minute Average (µg/m³)	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	500(a)	-	125(a)	50
RSA SANS limits (SANS:1929,2004)	500(b)	-	125(b)	50
Australian standards	-	524(c)	209 (c)	52
European Community (EC)	-	350(d)	125(e)	20(f)
World Bank	-	-	125(g)	50(g)
United Kingdom	266(h)	350(i)	125(j)	20(k)
United States EPA	-	-	365(l)	80
World Health Organisation (2000)	500(m)		125(m)	50(m) 10-30(n)
World Health Organisation (2005)	500(o)		20(o)	(o)

Notes:
(a) No permissible frequencies of exceedance specified
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.
(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).
(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).
(f) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.
(g) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(h) UK Air Quality Objective for 15-minute averaging period (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 35 times per year. Compliance by 31 December 2005.
(i) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 24 times per year. Compliance by 31 December 2004.
(j) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 3 times per year. Compliance by 31 December 2004.
(k) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2000.
(l) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(m) WHO Guidelines for the protection of human health (WHO, 2000).
(n) Represents the critical level of ecotoxic effects (issued by WHO for Europe); a range is given to account for different sensitivities of vegetation types (WHO, 2000).
(o) WHO Air Quality Guidelines, Global Update, 2005 – Report on a Working Group Meeting, Bonn, Germany, 18-20 October 2005. Documents new WHO guidelines primarily for the protection of human health. The 10-minute guideline of 500 µg/m³ published in 2000 remains unchanged but the daily guideline is significantly reduced from 125 µg/m³ to 20 µg/m³ (in line with the precautionary principle). An annual guideline is given at not being needed, since "compliance with the 24-hour level will assure lower levels for the annual average".

It is important to note that the WHO air quality guidelines (AQGs) published in 2000 for sulphur dioxide have recently been revised (WHO, 2005). Although the 10-minute AQG of 500 µg/m³ has remained unchanged, the previously published daily guideline has been significantly reduced from 125 µg/m³ to 20 µg/m³. The previous daily guideline was based on epidemiological studies. WHO (2005) makes reference to more recent evidence which suggests the occurrence of health risks at lower concentrations. Although WHO (2005) acknowledges the considerable uncertainty as to whether sulphur dioxide is the pollutant responsible for the observed adverse effects (may be due to ultra-fine particles or other correlated substances), it took the decision to publish a stringent daily guideline in line with the precautionary principle. The WHO (2005) stipulates an annual guideline is not needed for the protection of human health, since compliance with the 24-hour level will assure sufficiently lower levels for the annual average. Given that the 24-hour WHO AQG of 20 μg/m³ is anticipated to be difficult for some countries to achieve in the short term, the WHO (2005) recommends a stepped approach using interim goals as shown in Table 2-5.

Table 2-5: WHO air quality guidelines and interim guidelines for sulphur dioxide (WHO, 2005)

	24-hour Average Sulphur Dioxide (μg/m³)	**10-minute Average Sulphur Dioxide (μg/m³)**
WHO interim target-1 (IT-1) (2000 AQF level)	125	
WHO interim target-2 (IT-2)	50(a)	
WHO Air Quality Guideline (AQG)	**20**	**500**

(a) Intermediate goal based on controlling either (i) motor vehicle (ii) industrial emissions and/or (iii) power production; this would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvements that would justify further improvements (such as aiming for the guideline).

Historically, institutions such as the South African Weather Services stored meteorological data with a minimum of one hour resolution. Subsequently, regulatory models, such as the US Environmental Protection Agency's Industrial Source Complex Short Term Version 3 (ISCST3), have been developed to accept hourly average meteorological parameters as the shortest time interval. ISCST3 uses the Gaussian dispersion equation with Pasquill-Gifford horizontal and vertical dispersion parameters. These dispersion coefficients were derived experimentally over monitoring periods ranging between 3- and 15 minutes (Turner 1970). Turner therefore states that the predicted concentrations from the Gaussian dispersion equation employing these coefficients represent 3- to 15-minute averages. An American Petroleum Institute publication (API 1977)) believes that the predicted concentrations represent 10- to 30-minute averages, whereas Hanna and Drivas (1987) states that it represents a 10-minute average. The Tennessee Valley Authority (Montgomery and Coleman, 1975) attributes a 5-minute average to their concentration calculations. However, developers of ISCST3 assumed that this equation and corresponding parameters resulted in 60 minute average concentrations. Research by Beychok (1994) showed that this assumption can cause the downwind concentrations predicted by ISCST3 to be over predicted by as much as 2.5 times the actual concentration.

Since there is strong evidence that the air concentrations calculated by the ISCST3 model represent 10-minute averages, a direct comparison to the 10 minute sulphur dioxide standard of 500 μg/m³ can be made.

Models that do not employ experimental data such as the Pasquill-Gifford parameters do not have this limitation. These model results represent the meteorological mean utilised in the simulations. However, since most simulations are completed with hourly averages, the EC developed an hourly average surrogate value from the original World Health Organisations 10-minute average. This value was set at a level appropriate to ensure that compliance with this level is likely to ensure a 99.9 % compliance with the limit value indicated for 10 min average exposures. Since no local study has been completed to obtain a similar surrogate value, the EC concentration of 350 μg/m³ was adopted in this study (as also recommended in SANS 1929).

So, as a conservative approach, it was assumed that the ISCST3 hourly average actually represents an hourly average, and these values were subsequently compared against the surrogate 350 µg/m³.

2.1.3 Oxides of Nitrogen

NO_x, primarily in the form of NO, is one of the primary pollutants emitted during combustion. NO_2 is formed through oxidation of these oxides once released in the air. NO_2 is an irritating gas that is absorbed into the mucous membrane of the respiratory tract. The most adverse health effect occurs at the junction of the conducting airway and the gas exchange region of the lungs. The upper airways are less affected because NO_2 is not very soluble in aqueous surfaces. Exposure to NO_2 is linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics and decreased pulmonary function.

The standards and guidelines of most countries and organisations are given exclusively for NO_2 concentrations. South Africa's NO_2 standards are compared to various widely referenced foreign standards and guidelines in Table 2-6. In addition, South Africa also publishes standards for oxides of nitrogen (NO_x).

Table 2-6: Ambient air quality guidelines and standards for nitrogen dioxide for various countries and organisations

Authority	Instantaneous Peak (µg/m³)	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Maximum 1-month Average (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)[2]	940(a)	376(a)	188(a)	150(a)	94
RSA SANS limits (SANS:1929,2004)	-	200(b)	-	-	40(b)
Australian standards		226(c)			56
European Community (EC)	-	200(d)	-	-	40(e)
World Bank	-	-	150 (as NO_x)(f)	-	-
United Kingdom	-	200(g)	-	-	40(h) 30(i)
United States EPA	-	-	-	-	100(j)
World Health Organisation (2000, 2005)	-	200(k)		-	40(k)

Notes:
(a) No permissible frequencies of exceedance specified
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.
(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Not to be exceeded more than 18 times per year. This limit is to be complied with by 1 January 2010.
(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value for the protection of human health, to be complied with by 1 January 2010.
(f) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(g) UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 18 times per year. Compliance by 31 December 2005.
(h) UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2005.
(i) UK Air Quality Objective for NOx for protection of vegetation (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2000.
(j) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html).
(k) WHO Guidelines for the protection of human health (WHO, 2000). AQGs remain unchanged according to WHO (2005).

2.1.4 Carbon Monoxide

Carbon monoxide absorbed through the lungs reduces the blood's capacity to transport available oxygen to the tissues. Approximately 80-90 % of the absorbed CO binds with haemoglobin to form carboxyhaemoglobin (COHb), which lowers the oxygen level in blood. Since more blood is needed to supply the same amount of oxygen, the heart needs to work harder. These are the main causes of tissue hypoxia produced by CO at low exposure levels. At higher concentrations, the rest of the absorbed CO binds with other heme proteins such as myoglobin and with cytochrome oxidase and cytochrome P-450. CO uptake impairs perception and thinking, slows reflexes, and may cause drowsiness,

[2] On 9 June 2006 the Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (90 day comment period given). The proposed NO_2 standards are given as 200 µg/m³ for highest daily and 40 µg/m³ for annual averages (in line with the SANS limits) (Government Gazette No. 28899, 9 June 2006).

angina, unconsciousness, or death. The ambient air quality guidelines and other standards issued for various countries and organisations for carbon monoxide are given in Table 2-7.

Table 2-7: Ambient air quality guidelines and standards for carbon monoxide for various countries and organisations

Authority	Maximum 1-hourly Average (µg/m³)	Maximum 8-hour Average (µg/m³)
SA Guideline(a)	40 000(a)	10 000(a)
SA SANS limits (SANS:1929,2004)	30 000(b)	10 000(b)
Australian standards	-	10 000 (c)
European Community (EC)	-	10 000(d)
World Bank	-	-
United Kingdom	-	10 000(e)
United States EPA	40 000(f)	10 000(f)
World Health Organisation	30 000(g)	10 000(g)

Notes:
(a) Issued in 1990s by CAPCO. No air quality standards for CO were included in the National Environmental Management: Air Quality Act.
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.
(d) EC Second Daughter Directive, 2000/69/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value to be complied with by 1 January 2005.
(e) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Maximum daily running 8-hourly mean. Compliance by 31 December 2003.
(f) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than one per year.
(g) WHO Guidelines for the protection of human health (WHO, 2000).

2.1.5 Mineral Spirits (Kerosene or Diesel)

No SA standards are available for diesel or kerosene, the proposed fuel for the OCGT power station.

The Ontario Ministry of the Environment (March 2001) has determined the following Ambient Air Quality Criterion for mineral spirits:

2 600 µg/m³ (24 hour average) based on adverse health effects;
7 800 µg/m³ (half-hour average) based on adverse health effects.

3. TECHNIQUES TO REDUCE NITROGEN OXIDE EMISSIONS (IPPC, 2004)

To control emissions to air from liquid fuel-fired gas turbines, NOx formation can be restricted by decreasing the combustion temperature. This is accomplished by the pre-mix burner technique, where fuel is blended with the combustion air in order to avoid excessive peak flame temperatures. This, however, only operates when the unit is operating near full load. A different combustion method must be applied for part-load operation, start-up and shutdown, in order to avoid flashbacks. Steam injection and water injection are also used to reduce combustion temperatures and consequently NOx.

Applying stage combustion in gas turbines at lower temperatures needs a different design of gas turbines as two pressure stages with separate fuel supplies are needed.

Wet reduction processes: Water or steam is injected into the combustion chambers in order to reduce the combustion temperature, thus avoiding the formation of thermal NOx. For gas turbines operating in the ‘open cycle’ system, water is used for injection, whereas for gas turbines operating in a ‘combined cycle’ or co-generation system, steam is more often chosen for the injection.

Secondary measures are end-of-pipe techniques to reduce the nitrogen oxides (NOx) already formed. Most flue-gas technologies to reduce NOx emissions rely on the injection of ammonia, urea or other compounds, which react with the NOx in the flue-gas to reduce it to molecular nitrogen. Selective catalytic reduction (SCR) is one of the secondary measures to reduce NOx.

Some gas turbine cycle plants in Europe, particularly in Austria, France, Germany, Italy, and the Netherlands, have also applied SCR systems to reduce NOx emissions. In the US, SCR is commonly used for gas turbines, including those operated with liquid fuels.

One possible disadvantage of the SCR is related to the ammonia-slip. This occurs due to the incomplete reaction of NH_3 with NOx, when small amounts of NH_3 leave the reactor with the flue-gas. The main advantages of the SCR technology are:

- The SCR process can be used for many of the fuels used in combustion processes, e.g. natural gas and light oils, as well as process gases and coal.
- The conversion of NOx does not create any secondary pollution components.
- The emission of NOx can be reduced by 90% or more.
- The overall NOx reduction depends on SCR and primary measures.
- To meet air quality requirements SCR can be applied with adapted NH_3 consumption to reduce NH_3 slip effects and to increase catalyst lifetime.

4. BASELINE CHARACTERISATION

The characterisation of existing air quality is crucial for assessing the potential for cumulative impacts due to the emissions from the additional units at the Eskom power station.

4.1 Regional atmospheric dispersion

The meteorological characteristics of a site govern the dispersion, transformations and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990).

Parameters, which needed to be taken into account includes wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. Hourly average wind speed, wind direction and air temperature data were available from PetroSA. Mixing depths and atmospheric stabilities were not measured and needed to be calculated. The parameterisation of the meso-scale ventilation potential of the site necessitates the analysis of meteorological data observed within the vicinity of the site.

4.1.1 Surface winds

Period, day-time and night-time average wind roses are depicted in Figure 4-1. Wind roses represent wind frequencies for the 16 cardinal wind directions. Frequencies are indicated by the length of the shaft when compared to the circles drawn to represent a 5% frequency of occurrence. The figure given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

Diurnal wind variations due to the influence of land-sea breeze circulations on the airflow of the region are clearly evident in the night-time and day-time wind fields. Land-sea breeze circulation arises due to the differential heating and cooling of land and water surfaces. During the day, the land is heated more rapidly than the sea surface, a horizontal pressure gradient develops with surface convergence and ascent over the land and descent and surface divergence over the sea. Sea breezes therefore characterise the daytime surface circulation. By night, land cools more quickly than the sea surface resulting in a reversal of the daytime sea breeze and upper air return currents and the onset of land breezes at the surface.

Night-times are characterised by an increase in the number of calms (13.1 %) as is typical of the night-time flow regime in most regions, and by the predominance of winds from the north-northwesterly sector.

During the day-time, winds from the northwestern and southeastern sectors predominates. Increased wind velocities are noted for day-time hours. SE winds are predominant, especially in summer. The wind in winter (June to August) blows mainly from a northwesterly direction. The windiest season is mid-winter (July) to spring (September), which has an average wind speed of 20 km/hr. The average wind speed in summer is 15 km/hr.

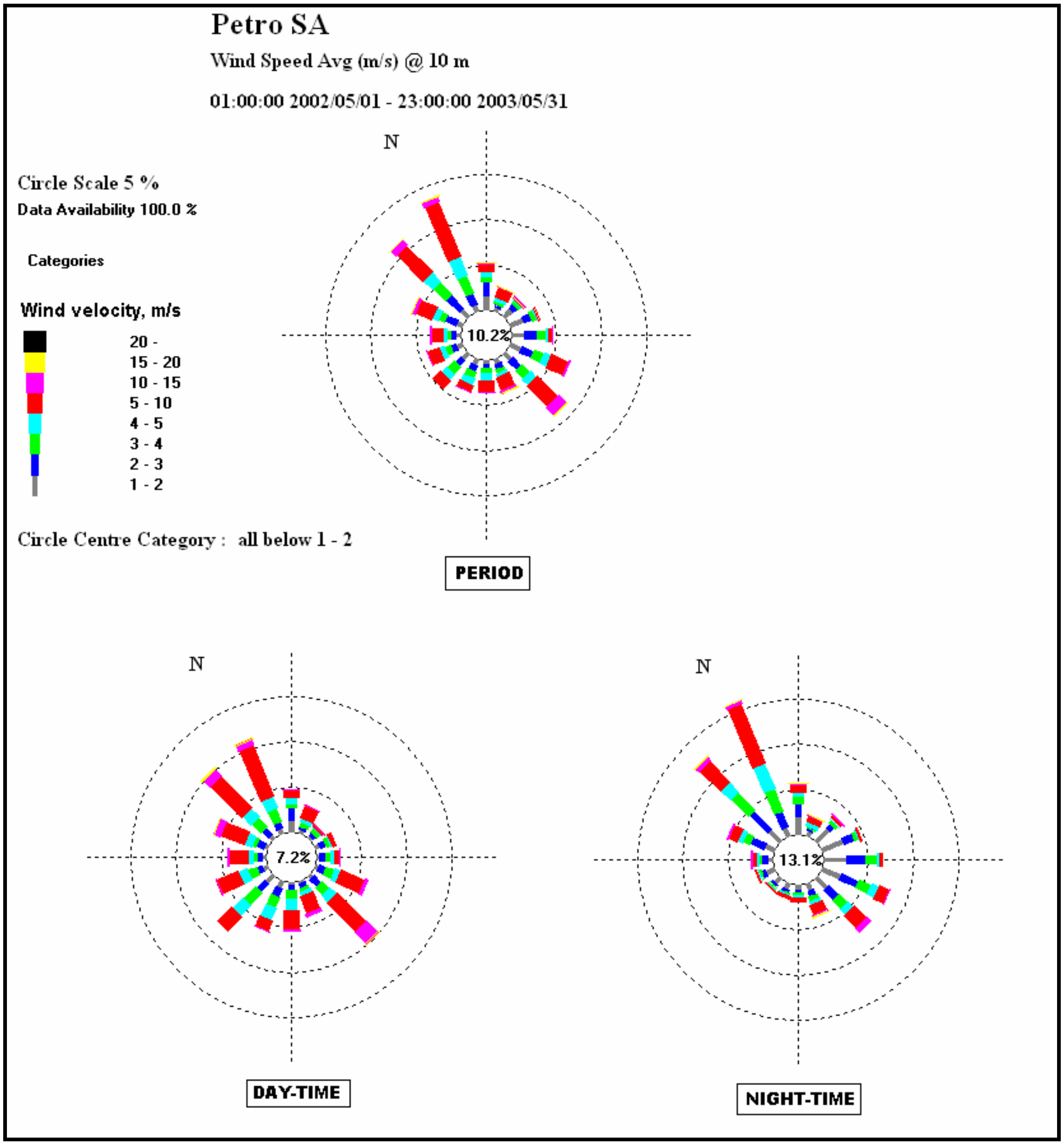

Figure 4-1: Wind roses for PetroSA for the period May 2002 – May 2003.

4.1.2 Temperature

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 the mixing and inversion layers. Long-term average maximum, mean and minimum temperatures for Mossel Bay for the period 1920-1984 is given in Table 4-1 (Schulze, 1986).

Table 4-1: Long-term minimum, maximum and mean temperature for Mossel Bay (Schulze, 1986).

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mossel Bay	Maximum	23.9	23.8	22.8	21.4	20.2	19.4	18.6	18.6	18.9	19.6	21.1	22.8
	Mean	21.0	21.0	20.0	18.3	16.8	15.7	14.9	14.9	15.4	16.5	18.1	19.9
	Minimum	18.0	18.2	17.1	15.1	13.3	12.0	11.1	11.1	12.1	13.5	15.2	16.9

A monthly-average diurnal ambient temperature trend, generated on the basis of measurements at PetroSA, is illustrated in Figure 4-2.

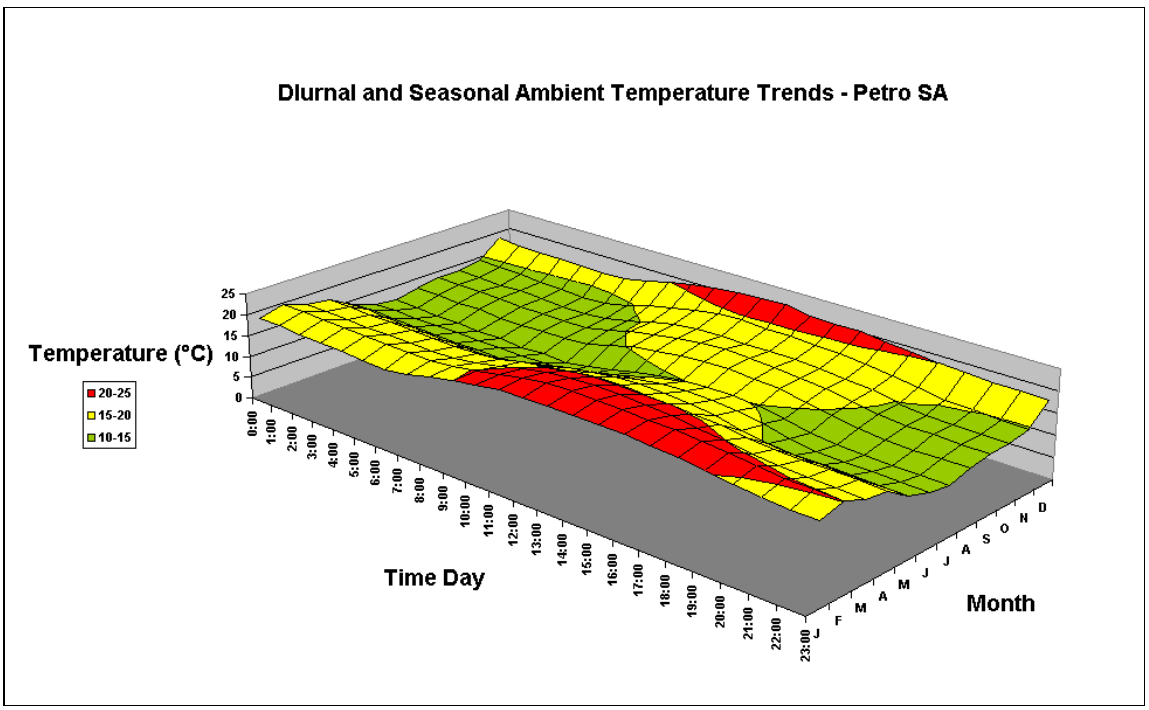

Figure 4-2: Monthly average diurnal temperature plot for PetroSA (2002 – 2003).

4.1.3 Precipitation

Precipitation represents an effective removal mechanism of atmospheric pollutants. The number of rainfall days (recorded when 0.1 mm or more is monitored) for Mossel Bay is 91.2 per annum. The long-term annual average rainfall for Mossel Bay for the period 1878-1984 is given in Table 4-2 (Schulze, 1986).

Table 4-2: Long-term average monthly rainfall for Mossel Bay (Schulze, 1986).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ave rainfall (mm)	28	31	36	40	37	31	32	36	39	38	34	28	410
Ave no. of rain days	6.7	7.0	8.3	7.9	7.6	7.2	7.0	7.8	8.2	9.1	8.0	6.4	91.2

4.1.4 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. Day-time mixing heights were calculated with the prognostic equations of Batchvarova and Gryning (1990), while night-time boundary layer heights were calculated from various diagnostic approaches for stable and neutral conditions. Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 4-3.

Table 4-3: Atmospheric stability classes.

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

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 predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. This 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.

4.2 Ambient Air Quality Data

The ambient air monitoring results from different locations at and around PetroSA for sulphur dioxide for the period 6 August 2002 to 19 August 2003 are shown in the graph below. No ambient data for oxides of nitrogen (NO_x), carbon monoxide (CO) and inhalable particulates (PM10) were available.

4.2.1 Sulphur Dioxide Concentrations (SO_2)

As shown in Figure 4-3 the SO_2 concentrations measured on and around PetroSA (range between 0.4 and 11.8 µg/m^3) and are low when compared to the SA annual standard of 50 µg/m^3.

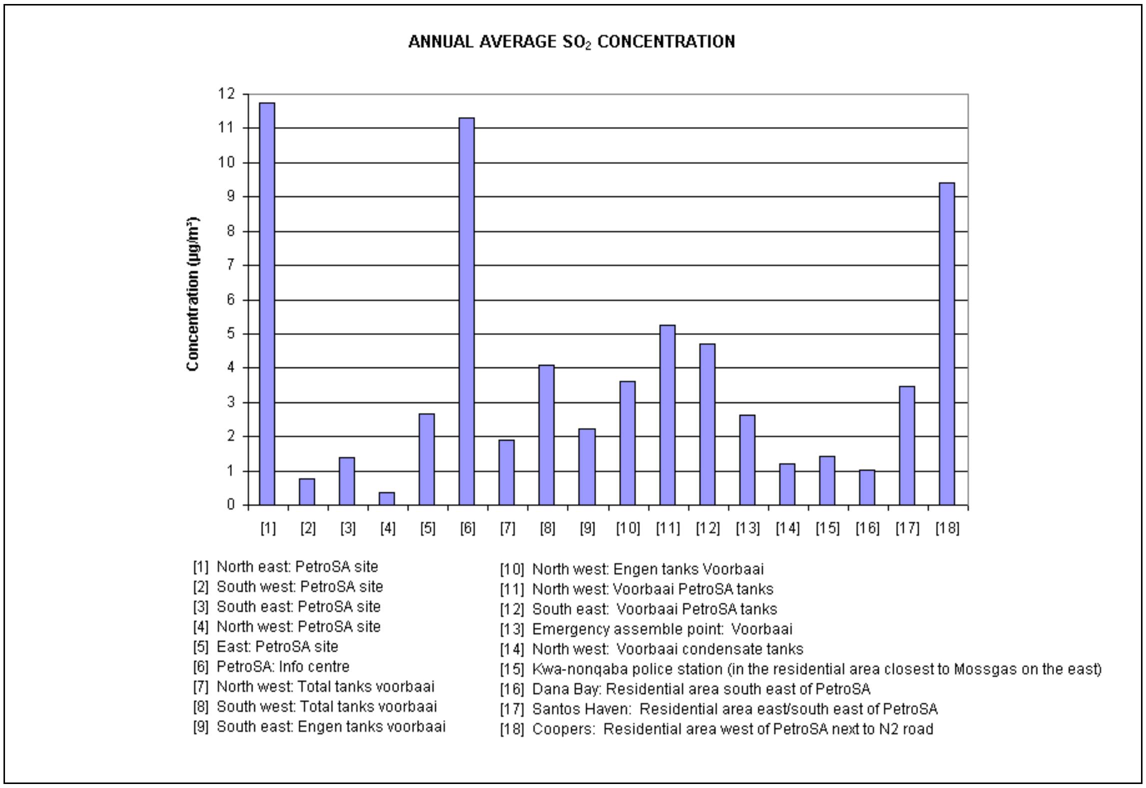

Figure 4-3 Annual average SO_2 concentrations measured at various locations at and around PetroSA.

4.2.2 Oxides of Nitrogen, Carbon Monoxide and Inhalable Particulate concentrations

No ambient data for oxides of nitrogen (NO_x), carbon monoxide (CO) and inhalable particulates (PM10) were available.

4.3 Emissions Inventory of Baseline Conditions

4.3.1 PetroSA refinery

Emissions produced by the PetroSA facilities were calculated by ILITHA (Background Emissions Study for the PetroSA Facilities at the Mossel Bay Refinery and Voorbaai Tank Farm, 2004).

Table 4-4 represents the total average annual PetroSA emissions used in the simulations. The instantaneous emissions represent the average emissions from a point or area source at any one time during operation. However, not all operations are continuous. For highest hourly concentrations, the instantaneous emissions were used. To simulate the highest daily and annual average concentrations, the average annual emissions were used.

SO_2 emissions from fired heaters and flares are negligible, as there is little or no sulphur present in the PetroSA fuel gas. Approximately 2771 tons of NO_2 gases are emitted from fired heaters and flares per annum, and 109 tons of particulate matter.

Nitrogen oxides (NOx) emitted from the refinery are expressed and simulated as nitrogen dioxide (NO_2). However, it is not understood exactly how much of the NOx is NO_2, perhaps only 10% of the total NOx emissions would be NO_2. The assumption that all NOx is NO_2 is therefore a conservative approach.

Table 4-4: Total average emissions per annum from PetroSA.

Source	CO	SO_2	NO_2	PM10
	tpa	tpa	tpa	tpa
Methane reformer	678		1534	61.35
Fired heater / boilers	258	0.47	617	22.82
Flares	274		620	24.80
TOTAL	1210	0.47	2771	109

4.3.2 OCGT power plant currently under construction

For the Eskom OCGT power station the following 4 scenarios were considered:

- Scenario 1: Plant operating 2 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
- Scenario 2: Plant operating 2 hours per day with NOx = 600 mg/Nm³;
- Scenario 3: Plant operating 6 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
- Scenario 4: Plant operating 6 hours per day with NOx = 600 mg/Nm³.

It was assumed that when the three turbines operate for two hours per day it would be between 6am-7am and 6pm-7pm, and for six hours per day between 6am-9am and 6pm-9pm. The stack parameters and emission rates used in the simulations are shown in Table 4-5 below.

Table 4-4-5: Emission rates and stack parameters for the OCGT Eskom power station units.

Parameter	Value (per turbine)	Units
Stack height	30	m
Stack diameter	6.1	m
Exit velocity	40	m/s
Exit temperature	833	K
Exit pressure	1.022	bar
Exit mass flow	520	kg/s
Density	1.2	kg/m³
Sulphur dioxide emission rate (assuming S = 0.05% weight)	10.45	g/s
Nitrogen dioxide emission rate (165 mg/Nm³)	82.7	g/s
Nitrogen dioxide emission rate (600 mg/Nm³)	300.74	g/s
Particulate matter emission rate (50 mg/Nm³)	21.67	g/s
Carbon monoxide emission rate (31.25 mg/Nm³)	15.66	g/s

Table 4-6: Total average emissions per annum from the OCGT power plant.

Source	CO	SO_2	NO_2 (165 mg/Nm³)	NO_2 (600 mg/Nm³)	PM10
	tpa	tpa	tpa	tpa	tpa
3 OCG turbines operating two hours per day	123	82	652	2371	171
3 OCG turbines operating six hours per day	370	247	1956	7113	513

4.4 Dispersion Simulations of Baseline Conditions

Air dispersion simulations were undertaken to determine inhalable particulate (PM10), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide.

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

For the purpose of the current study, it was decided to use the well-known US-EPA Industrial Source Complex Short Term model (ISCST3). The ISCST3 model is included in a suite of models used by the US-EPA for regulatory purposes. ISCST3 (EPA, 1995a and 1995b) is a steady state Gaussian Plume model, which is applicable to multiple point, area and volume sources. Gently rolling topography may be included to determine the depth of plume penetration by the underlying surface. A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. A further limitation of the model arises from the models treatment of low wind speeds. Wind speeds below 1 m/s produce unrealistically high concentrations when using the Gaussian plume model, and therefore all wind speeds below 1 m/s are simulated using 1 m/s.

The Industrial Source Complex model is perhaps the subject of most evaluation studies in the United States. Reported model accuracies vary from application to application. Typically, complex topography with a high incidence of calm wind conditions, produce predictions within a factor of 2 to 10 of the observed concentrations. When applied in flat or gently rolling terrain, the USA-EPA (EPA, 1986) considers the range of uncertainty to be -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

Input data types required for the ISCST3 model include: source data, meteorological data, terrain data and information on the nature of the receptor grid.

4.4.1 Meteorological Requirements

ISCST3 requires hourly average meteorological data as input, including wind speed, wind direction, a measure of atmospheric turbulence, ambient air temperature and mixing height. Meteorological information recorded at the meteorological station at PetroSA for the period, May 2002 to May 2003 was used.

The mixing height for each hour of the day was estimated for the simulated ambient temperature and solar radiation data. Daytime mixing heights were calculated with the prognostic equations of Batchvarova and Gryning (1990), while night-time boundary layer heights were calculated from various diagnostic approaches for stable and neutral conditions, as mentioned previously.

4.4.2 Source Data Requirements

The ISCST3 model is able to model point, area, volume and open pit sources. The PetroSA sources and the power station turbines were modelled as point sources.

4.4.3 Receptor Grid

The dispersion of pollutants emanating from the site was modelled for an area covering ~10 km (north-south) by ~12 km (east-west). The area was divided into a grid matrix with a resolution of 200 m by 200 m. The ISCST3 simulates ground-level concentrations for each of the receptor grid point.

Highest hourly, daily and period average concentration levels were simulated based on the emissions quantified for each source. These results represent interpolated values for each receptor grid point for the various averaging periods.

The ground level concentrations are displayed as isopleth plots indicating the baseline conditions. All predictions are compared to both local and international guidelines and standards. All the concentration plots are provided in Appendix A and a summary of the results in are given in Table 4-7 and Table 4-8.

It should be noted that the plots reflecting hourly and daily averaging periods contain only the highest predicted ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high hourly or daily average concentration is predicted to occur at certain locations, that this may only be true for one hour or one day during the year.

Table 4-7: Maximum predicted concentrations from the Eskom power station (3 units currently under construction) and both the Eskom power station (operating 2 hours per day) and the PetroSA Refinery (Scenarios 1 and 2).

Pollutant	Impact Period	Guideline/ Standard ($\mu g/m^3$)[3]	Maximum off-site impact from the Power station		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc ($\mu g/m^3$)	% of standard	conc ($\mu g/m^3$)	% of standard	conc ($\mu g/m^3$)	% of standard
PM10[1]	Highest Daily	75[4]	0.15	<1	1.2	1.6	1.2	1.6
	Annual	40[4]	0.006	<1	0.18	<1	0.18	<1
SO_2[1]	Highest Hourly	350[5]	1.7	<1	0.05	<1	1.7	<1
	Highest Daily	125[4]	0.07	<1	0.009	<1	0.07	<1
	Annual	50[4]	0.003	<1	0.001	<1	0.003	<1
CO[1]	Hourly	30 000[4]	2.6	<1	75	<1	75	<1
NO_2[1] (165 mg/Nm³)	Highest Hourly	200[4]	14	7	170	85	170	85
	Highest Daily	150[6]	0.5	<1	30	20	30	20
	Annual	40[4]	0.025	<1	4.5	11	4.5	11
NO_2[2] (600 mg/Nm³)	Highest Hourly	200[4]	50	25	170	85	170	85
	Highest Daily	150[6]	2	1.3	30	20	30	20
	Annual	40[4]	0.1	<1	4.5	11	4.5	11

Notes: [1] Scenario 1.
[2] Scenario 2.
[3] Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.
[4] South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.
[5] EC.
[5] World Bank.

Table 4-8: Maximum predicted concentrations from the Eskom power station (3 units currently under construction) and both the Eskom power station (operating 6 hours per day) and the PetroSA Refinery (Scenarios 3 and 4).

Pollutant	Impact Period	Guideline/ Standard (µg/m³)[3]	Maximum off-site impact from the Power station		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc (µg/m³)	% of standard	conc (µg/m³)	% of standard	conc (µg/m³)	% of standard
PM10[1]	Highest Daily	75[4]	0.25	<1	1.2	1.6	1.2	1.6
	Annual	40[4]	0.015	<1	0.18	<1	0.18	<1
SO_2[1]	Highest Hourly	350[5]	1.8	<1	0.05	<1	1.8	<1
	Highest Daily	125[4]	0.12	<1	0.009	<1	0.12	<1
	Annual	50[4]	0.007	<1	0.001	<1	0.007	<1
CO[1]	Hourly	30 000[4]	2.8	<1	75	<1	75	<1
NO_2[1] (165 mg/Nm³)	Highest Hourly	200[4]	14	7	170	85	170	85
	Highest Daily	150[6]	1	<1	30	20	30	20
	Annual	40[4]	0.05	<1	4.5	11	4.5	11
NO_2[2] (600 mg/Nm³)	Highest Hourly	200[4]	50	25	170	85	170	85
	Highest Daily	150[6]	3.6	2.4	30	20	30	20
	Annual	40[4]	0.2	<1	4.5	11	4.5	11

Notes: [1] Scenario 3.
[2] Scenario 4.
[3] Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.
[4] South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.
[5] EC.
[6] World Bank.

4.5 Impact Assessment of Baseline

4.5.1 Inhalable particulates (PM10)

The daily and annual average concentration plots are shown in Appendix A. The predicted results from simulations were very low when compared to the SA standard as well as the SANS limit and target values at the power station, the PetroSA refinery and the cumulative scenario. The impacts did not exceed the SANS limits for highest daily (75 $\mu g/m^3$) and the annual (40 $\mu g/m^3$) averaging periods and were less than 1% of the respective standards. The Eskom power station contributes 3% to the predicted cumulative annual average ground level concentrations for operating 2 hours per day, and 8% for operating 6 hours per day. The PetroSA refinery has lower PM10 emissions (109 tpa) compared to the power station (171 tpa for two hours and 513 tpa for six hours of operation). However the maximum cumulative impact is due to the refinery's sources. This is due to the fact that the power station is an elevated source with high exit temperatures, which assists in effective dispersion, whereas the refinery emissions are released at lower heights, and lower temperatures. The predicted concentrations from the power station for the 6 hour scenario are 1.7 (daily) and 2.5 (annual) times higher than for the 2 hour scenario.

4.5.2 Sulphur dioxide (SO_2)

The hourly, daily and annual average concentration plots are shown in Appendix A. There is no SA hourly standard for SO_2 and only an instantaneous (10-minute) standard of 500 $\mu g/m^3$ is given. The dispersion model can only simulate for an hourly averaging period (shortest averaging period), and therefore the European Community (EC) guideline for hourly averages are used (see Table 2.4).

The EC hourly guideline (350 $\mu g/m^3$) and the SA daily and annual standards (125 $\mu g/m^3$ and 50 $\mu g/m^3$) are not exceeded for the power station, or for the cumulative scenario. The highest hourly predicted ground level concentration for the power station is less than 1% of the EC limit (350 $\mu g/m^3$). The predicted ground level concentrations for the highest daily and annual averaging periods are also less than 1% of the SA standards. The power station is the main contributor of SO_2 (82 tpa and 247 tpa for the two hour and six hour scenarios respectively) as there is little or no sulphur present in the PetroSA fuel gas (0.47 tpa). The predicted concentrations for the 6 hour scenario are 1.7 (daily) and 2.3 (annual) times higher than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (1.7 and 1.8 $\mu g/m^3$ respectively).

4.5.3 Nitrogen dioxide (NO_2) (165 mg/Nm³)

The hourly, daily and annual average concentration plots are given in Appendix A. The hourly (200 µg/m^3), daily (150 µg/m^3) and annual (40 ug/m^3) SANS limits (hourly and annual) and World Bank guidelines (daily) are not exceeded at either the power station or for the cumulative scenario. The highest hourly, daily and annual ground level concentrations for the cumulative scenario were 85%, 20% and 11% of the standards, respectively. The predicted ground level concentrations at the power station for the highest daily and annual averaging periods are less than 1% of the SANS limits, while the predicted concentration for the highest hourly averaging period was 7% of the limit of 200 µg/m³. The Eskom power station contributes 1% for the predicted cumulative annual average ground level concentrations (for the 6 hour scenario). The PetroSA refinery is the source of the maximum impact and emissions (2771 tpa). The power station's NOx emissions are 652 tpa for the two hour scenario, and 1956 tpa for the six hour scenario. The predicted concentrations for the 6 hour scenario are 2 times higher (daily and annual) than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (14 µg/m³).

4.5.4 Nitrogen dioxide (NO_2) (600 mg/Nm³)

The hourly (200 µg/m^3), daily (150 µg/m^3) and annual (40 ug/m^3) SANS limits (hourly and annual) and World Bank guidelines (daily) are not exceeded at either the power station or for the cumulative scenario. The cumulative scenario stays the same as the NO_2 scenario of 165 mg/Nm³, as the PetroSA refinery is the main contributor to the cumulative impact. The predicted ground level concentrations at the power station for the annual averaging periods is less than 1% of the SANS limits, while the predicted concentration for the highest hourly averaging period was 25% of the limit of 200 µg/m³. The Eskom power station contributes 4% of the predicted cumulative annual average ground level concentrations (for the 6 hour scenario). The predicted concentrations for the 6 hour scenario are 1.8 (daily) and 2 (annual) times higher than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (50 µg/m³).

4.5.5 Carbon monoxide (CO)

The highest predicted hourly CO concentration from the power station is 2.6 µg/m^3 (two hours) and 2.8 µg/m^3 (six hours) and 75 µg/m^3 at the power station and the cumulative scenario (as shown in Appendix A); which is less than 1% of the SANS limit. The refinery is the main contributor of CO emissions (1210 tpa), whereas the power station contributes 123 tpa and 370 tpa for the two, and six hour scenario respectively.

5. IMPACT ASSESSMENT FOR THE ADDITIONAL UNITS

The impact assessment of the three additional turbine units follows the same approach as the baseline assessment. Identical stack parameters and emissions rates were assumed as for the initial units. The location of the proposed units was assumed to be immediately west of the units currently under construction.

5.1 Emissions inventory

5.1.1 Routine emissions

For the Eskom OCGT power station's 3 additional units the following 4 scenarios were considered:

- Scenario 1: Plant operating 2 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
- Scenario 2: Plant operating 2 hours per day with NOx = 600 mg/Nm³;
- Scenario 3: Plant operating 6 hours per day with NOx = 165 mg/Nm³, CO = 31.25 mg/Nm³, PM10 = 50 mg/Nm³ and SO_2 = 10.45 g/s;
- Scenario 4: Plant operating 6 hours per day with NOx = 600 mg/Nm³.

The stack parameters and emission rates used in the simulations are shown in Table 5-1 below.

Table 5-1: Emission rates and stack parameters for the OCGT Eskom power station stacks.

Parameter	Value	Units
Stack height	30	m
Stack diameter	6.1	m
Exit velocity	40	m/s
Exit temperature	833	K
Exit pressure	1.022	bar
Exit mass flow	520	kg/s
Density	1.2	kg/m³
Sulphur dioxide emission rate (assuming S = 0.05% weight)	10.45	g/s
Nitrogen dioxide emission rate (165 mg/Nm³)	82.7	g/s
Nitrogen dioxide emission rate (600 mg/Nm³)	300.74	g/s
Particulate matter emission rate (50 mg/Nm³)	21.67	g/s
Carbon monoxide emission rate (31.25 mg/Nm³)	15.66	g/s

5.1.2 *Start-up and Shut-down emissions*

Measured concentrations of NOx and CO were provided by Eskom. These are summarised in Table 5-2. Start-up takes approximately 20 minutes, and shut-down 8 minutes.

For NOx, the time around start-up (11 AM) and shut-down (10 PM) the concentrations are lower than during routine operation. It is therefore not anticipated that concentrations of NOx during start-up and shut-down would relate to any higher concentrations than modelled for routine operations. CO does show elevated concentrations during start-up (5 times higher than routine modelled concentrations) and shut-down (approximately double the concentration modelled for routine). However, the predicted impacts from CO are well below the standards (< 1%, see section 5.2 and 5.3), so no exceedences are expected for CO during start-up and shut-down. No data is available for PM10 and SO_2 during start-up and shut-down, however as for CO; PM10 and SO_2 predicted concentrations are well below the relevant standard for routine operations.

Table 5-2: Concentrations measured during start-up, routine operation and shut-down

Time measured	NOx	CO
	mg/m³	
11:00 AM	1.1	0.5
11:30 AM	83.3	155
12:00 PM	108.1	0.8
12:30 PM	104.2	0.6
01:00 PM	96.4	37.7
01:30 PM	104.7	1
02:00 PM	103.7	1.1
02:30 PM	103.4	1.2
03:00 PM	104	1
03:30 PM	86.4	7
04:00 PM	115.2	19
04:30 PM	82.3	1.2
05:00 PM	84.1	1.1
05:30 PM	83.3	1.1
06:00 PM	103	1.2
06:30 PM	101.5	1.3
07:00 PM	300.2	1.5
07:30 PM	110.7	1.4
08:00 PM	100.4	1.5
08:30 PM	100.2	1.4
09:00 PM	100	1.6
09:30 PM	97.7	1.5
10:00 PM	25.7	59
Routine modelled concentration	**165**	**31.25**

5.1.3 Fugitive emissions

Emissions factors were obtained from "Table 2-2: Refinery Average Emission Factors (US EPA, 1995)", where fugitive emissions from valves, pumps, etc. are calculated as follows:

Fugitive emissions (kg/hr) = Emission factor (kg/hr/source) x Count (Sources)

Table 5-3: Fugitive emissions from fuel transfer and handling

Type element	Number of elements	Fugitive emission factor non-methane organic compound (kg/hr/source)	Diesel fraction	Diesel emissions (kg/hr)
Valves (light liquid)	30	0.0109	1.0	0.327
Pump seals (light liquid)	6	0.114	1.0	0.684
Connectors	20	0.00025	1.0	0.005
TOTAL				**1.016**

Tank emissions were calculated using the US EPA TANK program. Standing losses were estimated to be 0.015 tpa, and working losses 0.625 tpa per tank.

5.2 Dispersion Simulations

The same methodology was used as discussed in section 4.4.

All the concentration plots are provided in Appendix A and a summary of the results is given in Table 5-4 (operating 2 hours per day) and 5-5 (operating 6 hours per day).

Table 5-4: Maximum predicted concentrations from the Eskom power station (6 units) and from both the Eskom power station (operating 2 hours per day) and the PetroSA Refinery (Scenarios 1 and 2).

Pollutant	Impact Period	Guideline/ Standard (µg/m³)[3]	Maximum off-site impact from the Power station [7]		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc (µg/m³)	% of standard	conc (µg/m³)	% of standard	conc (µg/m³)	% of standard
PM10[1]	Highest Daily	75[4]	0.3	<1	1.2	1.6	1.2	1.6
	Annual	40[4]	0.012	<1	0.18	<1	0.18	<1
SO_2[1]	Highest Hourly	350[5]	3.4	<1	0.05	<1	3.4	<1
	Highest Daily	125[4]	0.14	<1	0.009	<1	0.14	<1
	Annual	50[4]	0.006	<1	0.001	<1	0.006	<1
CO[1]	Hourly	30 000[4]	5.2	<1	75	<1	75	<1
NO_2[1] (165 mg/Nm³)	Highest Hourly	200[4]	28	14	170	85	170	85
	Highest Daily	150[6]	1.0	<1	30	20	30	20
	Annual	40[4]	0.05	<1	4.5	11	4.5	11
NO_2[2] (600 mg/Nm³)	Highest Hourly	200[4]	100	50	170	85	170	85
	Highest Daily	150[6]	4	2.7	30	20	30	20
	Annual	40[4]	0.19	<1	4.5	11	4.5	11

Notes: [1] Scenario 1.
[2] Scenario 2.
[3] Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.
[4] South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.
[5] EC.
[6] World Bank.
[7] The impact from the three additional units alone is the same as the impact from the three units currently under construction. The impact for all six units is double the impact for the three units currently under construction.

Table 5-5: Maximum predicted concentrations from the Eskom power station (6 units) and from both the Eskom power station (operating 6 hours per day) and the PetroSA Refinery (Scenarios 3 and 4).

Pollutant	Impact Period	Guideline/ Standard (μg/m³)[3]	Maximum off-site impact from the Power station[7]		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc (μg/m³)	% of standard	conc (μg/m³)	% of standard	conc (μg/m³)	% of standard
PM10[1]	Highest Daily	75[4]	0.5	<1	1.2	1.6	1.2	1.6
	Annual	40[4]	0.03	<1	0.18	<1	0.18	<1
SO_2[1]	Highest Hourly	350[5]	3.6	1	0.05	<1	3.6	1
	Highest Daily	125[4]	0.24	<1	0.009	<1	0.24	<1
	Annual	50[4]	0.014	<1	0.001	<1	0.014	<1
CO[1]	Hourly	30 000[4]	5.6	<1	75	<1	75	<1
NO_2[1] (165 mg/Nm³)	Highest Hourly	200[4]	28	14	170	85	170	85
	Highest Daily	150[6]	2	1.3	30	20	30	20
	Annual	40[4]	0.1	<1	4.5	11	4.5	11
NO_2[2] (600 mg/Nm³)	Highest Hourly	200[4]	100	50	170	85	170	85
	Highest Daily	150[6]	7.2	4.8	30	20	30	20
	Annual	40[4]	0.4	1	4.5	11	4.5	11

Notes: [1] Scenario 3.
[2] Scenario 4.
[3] Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.
[4] South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.
[5] EC.
[6] World Bank.
[7] The impact from the three additional units alone is the same as the impact from the three units currently under construction. The impact for all six units is double the impact for the three units currently under construction.

Upset conditions will occur when the plant is operational 24 hours per day. Table 5-6 illustrates predicted concentrations should upset conditions occur.

Table 5-6: Maximum predicted concentrations from the Eskom power station (6 units, operating 24 hours per day) and from both the Eskom power station and the PetroSA Refinery (cumulative impact).

Pollutant	Impact Period	Guideline/ Standard (µg/m³)(3)	Maximum off-site impact from the Power station(7)		Maximum off-site impact from the PetroSA		Maximum off-site cumulative impact (Power station and PetroSA)	
			conc (µg/m³)	% of standard	conc (µg/m³)	% of standard	conc (µg/m³)	% of standard
PM10	Highest Daily	75(4)	1.6	2.1	1.2	1.6	1.8	2.4
	Annual	40(4)	0.15	<1	0.18	<1	0.24	<1
SO_2	Highest Hourly	350(5)	7	2	0.05	<1	7	2
	Highest Daily	125(4)	0.7	<1	0.009	<1	0.7	<1
	Annual	50(4)	0.07	<1	0.001	<1	0.07	<1
CO	Hourly	30 000(4)	10	<1	75	<1	75	<1
NO_2 (165 mg/Nm³)	Highest Hourly	200(4)	56	28	170	85	170	85
	Highest Daily	150(6)	6	4	30	20	30	20
	Annual	40(4)	0.5	1.3	4.5	11	4.5	11
NO_2 (600 mg/Nm³)	Highest Hourly	200(4)	200	**100**	170	85	200	**100**
	Highest Daily	150(6)	21	14	30	20	30	20
	Annual	40(4)	2	5	4.5	11	5	12.5

Notes: (3) Comparison was made to the stricter SANS limits, instead of the SA standard as a conservative approach.

(4) South African limit values, reference: SANS 1929 - Ambient air quality - Limits for common pollutants.

(5) EC.

(6) World Bank.

(7) The impact from the three additional units alone is the same as the impact from the three units currently under construction. The impact for all six units is double the impact for the three units currently under construction.

5.3 Impact Assessment (Routine operations)

5.3.1 Inhalable particulates (PM10)

The daily and annual average concentration plots are shown in Appendix A. PM10 predicted cumulative concentrations are the same as for the baseline conditions, as the PetroSA refinery is the main contributor to the cumulative impact. However, the cumulative concentrations are well below the SANS limits for both daily and annual averaging periods.

The Eskom power station contributes 7% to the predicted cumulative annual average ground level concentrations for operating 2 hours per day, and 17% for operating 6 hours per day. The predicted concentrations for all six units are twice the concentration predicted for the initial three units. The predicted highest daily concentration from the power station's six units is 0.3 µg/m³, and for annual 0.012 µg/m³ (operating two hours per day), and 0.5 µg/m³ and 0.03 µg/m³ respectively (operating six hours per day).

5.3.2 Sulphur dioxide (SO_2)

The hourly, daily and annual average concentration plots are shown in Appendix A. The EC hourly guideline (350 µg/m³) and the SA daily and annual standards (125 µg/m³ and 50 µg/m³) are not exceeded for the power station. The highest hourly predicted ground level concentration for the power station (operating six hours per day) is 1% of the EC limit (350 µg/m³). The predicted ground level concentrations for the highest daily and annual averaging periods are less than 1% of the SA standards. The power station is still the main contributor of SO_2. As for PM10, the predicted concentrations for all six units are twice the concentration predicted for the initial three units. The predicted concentrations for the 6 hour scenario are 1.7 (daily) and 2.3 (annual) times higher than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (3.4 and 3.6 µg/m³ respectively).

5.3.3 Nitrogen dioxide (NO_2) (165 mg/Nm³)

The hourly, daily and annual average concentration plots are given in Appendix A. NOx predicted cumulative concentrations are the same as for the baseline conditions, as the PetroSA refinery (as with PM10) is the main contributor to the cumulative impact. The predicted ground level concentrations at the power station for the highest daily and annual averaging periods are less than 1% of the SANS limits, while the predicted concentration for the highest hourly averaging period (28 µg/m³) was 14% of the limit of 200 µg/m³. The Eskom power station contributes 2% to the predicted cumulative annual average ground level concentrations (for the 6 hour scenario). The predicted concentrations for all six units are twice the concentration predicted for the initial three units. The predicted concentrations for the 6 hour scenario are 2 times higher (daily and annual) than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (28 µg/m³).

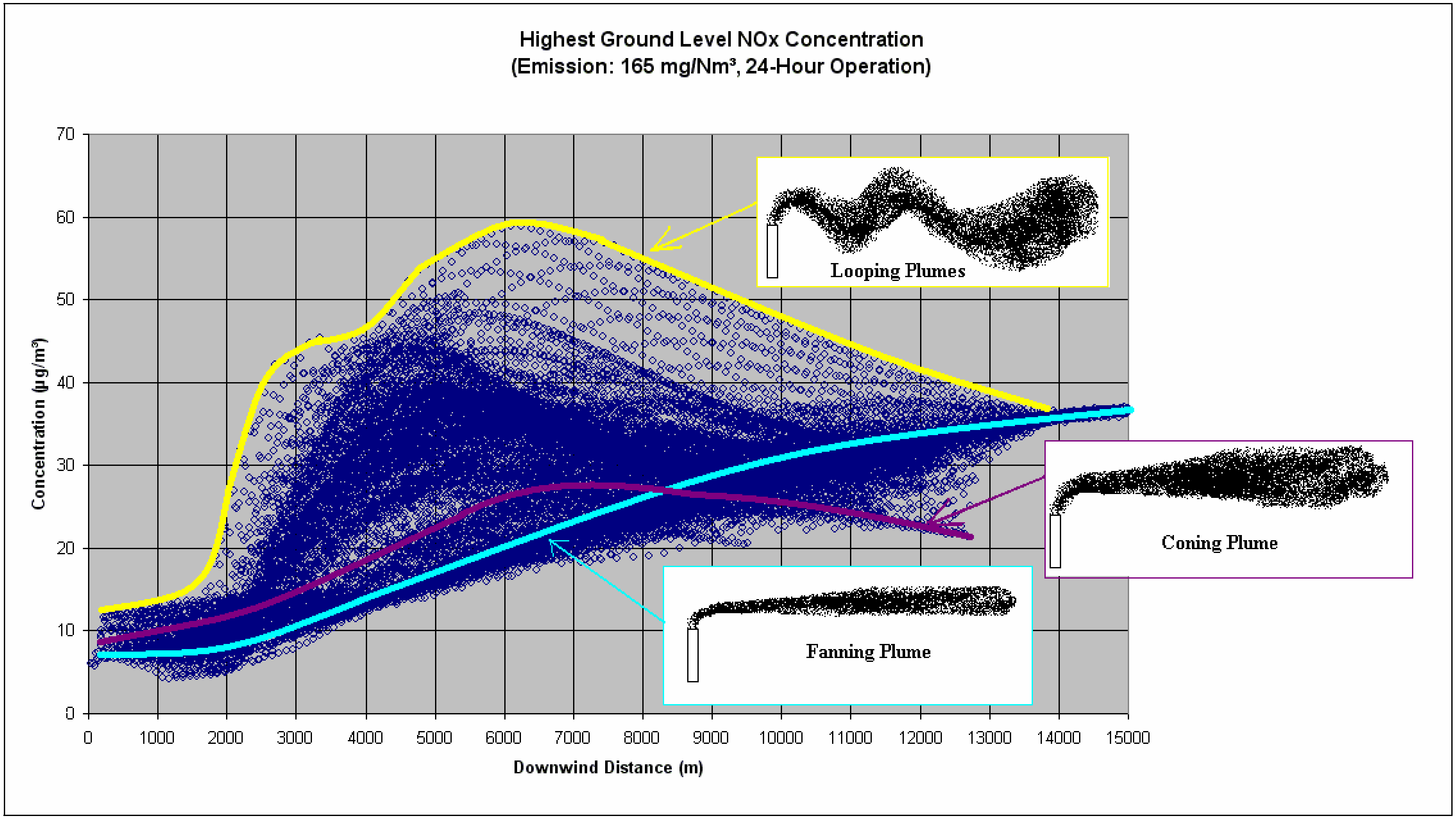

Figure 5-1: Predicted downwind maximum ground level hourly average NOx concentrations (24-hour operation with 165 mg/Nm³ emission).

The plume rise from the power station would be very significant due to the very high momentum (exit gas velocity of 40 m/s). As a result, stable, night-time conditions ("fanning plume") would cause in the plume impacting relatively far downwind (beyond 10 km). Furthermore, this impact would be relatively high since the plume remains concentrated for longer distances than during convective conditions, as shown in Figure 5-1.

However, ground level concentrations would be more significant during convective conditions, i.e. low/calm wind, daytime conditions. Maximum concentrations would occur at about 6 km downwind.

Significant dilution occurs with stronger wind speeds (>5 m/s). Ground level concentrations would therefore be relatively low ("coning plume").

5.3.4 Nitrogen dioxide (NO_2) (600 mg/Nm³)

With an increase in NOx emissions from the power station (600 mg/Nm³) the predicted ground level concentrations at the power station for the highest hourly averaging period (100 µg/m³) was 50% of the limit of 200 µg/m³. The Eskom power station contributes 4% for the predicted cumulative annual average ground level concentrations (for the 6 hour scenario). The predicted concentrations for all six units are twice the concentration predicted for the initial three units. The predicted concentrations for the 6 hour scenario are 1.8 (daily) and 2.1 (annual) times higher than for the 2 hour scenario, while the predicted ground level concentration for the highest hourly stays similar for both scenarios (100 µg/m³).

5.3.5 Carbon monoxide (CO)

The highest predicted hourly CO concentration is 5.6 µg/m^3 (twice the concentration predicted for three units) and 75 µg/m^3 at the power station (all six units) and the cumulative scenario, respectively (as shown in Appendix A); which is less than 1% of the SANS limit.

5.4 Impact assessment (Upset conditions)

Assuming the plant is operational 24 hours per day, the only pollutant that exceeds or equals the relevant standards is NOx at 600 mg/Nm³ (i.e. assuming no low NOx burner is operational). This is also based on the conservative assumption that all NOx is NO_2, when it may only be as little as 10% of the total NOx emissions. It can be concluded that NO_2 would then be below the respective guidelines and standards.

5.5 Fugitive emissions

The highest predicted hourly diesel concentration from fugitive emissions from the fuel transfer and handling (pumps, valves, flanges and tanks) is 700 µg/m³, 9 % of the Ontario half-hour standard of 7 800 µg/m³ for mineral spirits. The highest predicted daily concentration is 100 µg/m³, approximately 4 % of the Ontario daily standard of 2 600 µg/m³.

5.6 Greenhouse gases

The proposed power station will produce 77 ton CO_2/TJ fuel used (IPPC, 2004), i.e. 123 ton CO_2 per hour per unit, resulting in an annual emission of 539 228 tpa assuming 6 units are operational 2 hours per day and 1 617 684 tpa assuming 6 hours per day.

The annual South Africa emission rate of CO_2 is approximately 365 million metric tons expressed as carbon dioxide (CO_2) equivalent (CO_2E) (Marland, et al. 2006). CO_2 emissions from the proposed power station will be between 0.15 – 0.44 % of South Africa's total CO_2 emissions, depending on operational hours.

6. CONCLUSIONS AND RECOMMENDATIONS

The main aim of this study was to determine the impacts associated with the proposed additional units at the OCGT power station. All sources of pollutants were identified and emission rates quantified. Dispersion simulations were undertaken to reflect ambient air concentrations and the results thereof were compared to local and international guidelines and standards.

6.1 Conclusions

In general, with an additional three units operating, i.e. six units in total, the predicted concentrations from the power station alone, would be double the predicted concentrations from the three units currently under construction.

Scenario 1

- It is predicted that the OCGT would contribute 1 % to the cumulative predicted annual average NO_2 ground level concentrations due to the power station and the PetroSA refinery.

- The nitrogen dioxide concentrations would not exceed the guidelines or standards for the hourly, daily or annual averaging periods and would be 14%, <1% and <1% of the guidelines and standards, respectively for the power station, and 85%, 20% and 11% for the cumulative scenario. Given that these emissions were all assumed to be NO_2, when it may only be as little as 10% of the total NOx emissions, it can be concluded that NO_2 would be further below the respective guidelines and standards.

- The OCGT would be the main source of sulphur dioxide impacts; however the predicted concentrations are well below the standards (less than 1%).

- The inhalable particulates and carbon monoxide concentrations from the OCGT also would not exceed the respective standards (less than 1%). The PetroSA refinery would be the main source of impact for these pollutants, but even cumulative predicted concentrations are well below the standards and SANS limits.

Scenario 2

- It is predicted that the OCGT would contribute 4 % to the cumulative predicted annual average NO_2 ground level concentrations due to the power station and the PetroSA refinery.

- The nitrogen dioxide concentrations would not exceed the guidelines or standards for the hourly, daily or annual averaging periods and would be 50%, 2.7% and <1% of the guidelines and standards, respectively for the power station, and 85%, 20% and 11% for the cumulative scenario.

- The predicted ground level concentrations would be 3.6 times higher for the NOx at 600 mg/Nm³ scenario compared to the NOx at 165 mg/Nm³ scenario.

Scenario 3

- For an increase in operating hours from 2 hours per day to six hours per day, predicted highest hourly ground level concentrations would remain similar, whereas highest daily and annual average concentrations would be approximately 2 times higher respectively.

Scenario 4

- It is predicted that the OCGT would contribute 9 % to the cumulative predicted annual average NO_2 ground level concentrations due to the power station and the PetroSA refinery.

- The nitrogen dioxide concentrations would not exceed the guidelines and standards for the hourly, daily or annual averaging periods and would be 50%, 5% and 1% of the guidelines and standards, respectively for the power station, and 85%, 20% and 11% for the cumulative scenario.

Even for the worst case scenario (operating 6 hours per day and NOx at 600 mg/Nm³) the Eskom power station would only contribute 9 % to the cumulative predicted annual average concentrations, and would not exceed any of the standards or guidelines. Additionally, given that the emissions were all assumed to be NO_2, when it may only be as little as 10% of the total NOx emissions, a conservative approach has been adopted and levels may be even lower than predicted. Therefore NOx concentrations could be up to 600 mg/Nm³ and the plant could operate for 6 hours per day without exceeding any guidelines or standards.

6.2 Recommendations

It is recommended that once the power station is operational the emissions concentrations for NO_2 be verified.

Since oxides of nitrogen is the only significant pollutant, it is recommended to investigate the possibility of expand the existing PetroSA monitoring programme by including NOx monitors in the vicinity of the power station and in the areas of maximum predictions.

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