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Atmospheric Impact Report: Sasol Sasolburg Operations

Project done on behalf of **Sasol South Africa (Pty) Ltd.**

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Revision Record

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Rev 0	October 2018	Draft for client review
Rev 1	November 2018	Grammatical changes
Rev 2	December 2018	Grammatical changes

Preface

Sasol's Sasolburg Operations (SO) is required to comply with the Minimum Emission Standards, which came into effect in terms of Section 21 of the National Environment Management: Air Quality Act (Act No 39 of 2004) on 1 April 2010 and subsequently replaced by GN893, of 22 November 2013. These standards require the operations to comply with "existing plant" limits by 1 April 2015, and with more stringent "new plant" limits by 1 April 2020. Technical investigations were conducted by SO to establish feasibility and practicality of improving its existing process plants operations in order to comply with the standards as set out in the Minimum Emission Standards. SO intends to request a postponement of the "new plant" limits for some of their sources. In support of the submissions and to fulfil the requirements for this application stipulated in the Air Quality Act and the Minimum Emission Standards, air quality studies are required to substantiate the motivations for the postponement application.

At the Sasolburg facility, SO is responsible to supply utilities as well as reformed and synthesis gas to the other Sasol Business Units operating on the site. Apart from coal-fired steam stations supplying steam and electricity, natural gas is reformed in two auto thermal reformers (ATRs) with oxygen at high temperature to produce synthesis gas (syngas). This syngas is distributed to Sasol Wax, to produce a range of waxes and paraffins, and to Sasol Solvents, to produce methanol, butanol and acrylates. Tail gases from various gas units are used in the ammonia plant to produce ammonia which in turn is used to produce nitric acid, ammonium nitrate and ammonium nitrate-based explosives and fertilisers.

The main air pollutants from SO are sulfur dioxide (SO_2) and oxides of nitrogen (NO_x), and particulates. Other minor pollutants to consider, include ammonia (NH_3), hydrochloric acid (HCl), hydrogen fluoride (HF), dioxins/furans and metals.

Airshed Planning Professionals (Pty) Ltd (hereafter referred to as Airshed) was appointed by SO to provide independent and competent services for the compilation of an Atmospheric Impact Report as set out in the Draft Regulations and detailing the results of the dispersion model runs. The tasks to be undertaken consisted of:

1) Review of emissions inventory for the identified point sources and identification of any gaps in the emissions inventory. Where possible, it is preferable that gaps be estimated using an agreed emission estimation technique. No emission factors may be used without the written consent from Sasol that the emission factors are deemed acceptable. Should measurements be required, Sasol will source the required information.
2) Prepare meteorological input files for use in one or more dispersion models to cover all applicable Sasol sites. Sasol will provide surface meteorological data and ambient air quality data from the Sasol ambient air quality monitoring stations. Surface meteorological data for three years, as required by the Dispersion Modelling Guidelines for Level 3 Assessments, is available for ambient air quality monitoring stations situated in both Sasolburg and Secunda.
3) Preparation of one or more dispersion models set up with SO's emissions inventory capable of running various scenarios for each of the point sources as specified by SO. The intent is to model delta impacts of the various emission scenarios against an acceptable emissions baseline.
4) Airshed will validate the dispersion model based on an acceptable and agreed approach. The validation methodology must be agreed between the SO and Airshed. It is anticipated that each point source identified above will require 3 scenarios per component per point source to be modelled, in order to establish the delta impacts against the baselines. i.e.:
    a. Baseline – modelling is conducted based on the current inventory and impacts
    b. Future – modelling must be conducted based on the legislative requirement as stipulated within the Listed Activities and Minimum Emission Standards (for 2020 standards).
    c. Alternative emission limits – the actual SO proposed reductions, where applicable.

5) Comparison of dispersion modelling results with the National Ambient Air Quality Standards (NAAQS).
6) A report detailing the methodology used and model setup must be compiled for purposes of a peer review, which Sasol will contract independently.
7) Interactions with Environmental Assessment Practitioner (EAP) to provide all necessary inputs into the EAP's compilation of documentation in support of Sasol's postponement applications. Airshed will attend all Public Participation meetings scheduled by the EAP to address any queries pertaining to the dispersion model.

Table of Contents

1 Enterprise Details 1
1.1 Enterprise Details 1
1.2 Location and Extent of the Plant 2
1.3 Atmospheric Emission Licence and other Authorisations 2
2 Nature of the Process 3
2.1 Listed Activities 3
2.2 Process Description 4
2.3 Unit Processes 9
3 Technical Information 18
3.1 Raw Materials Used and Production Rates 18
3.2 Appliances and Abatement Equipment Control Technology 19
4 Atmospheric Emissions 20
4.1 Point Source Parameters 21
4.2 Point Source Maximum Emission Rates during Normal Operating Conditions 24
4.3 Point Source Maximum Emission Rates during Start-up, Maintenance and/or Shut-down 27
4.4 Fugitive Emissions 28
4.4.1 Fallout Dust 28
4.4.2 Fugitive VOCs 28
4.5 Emergency Incidents 28
5 Impact of Enterprise on the Receiving Environment 30
5.1 Analysis of Emissions' Impact on Human Health 30
5.1.1 Study Methodology 30
5.1.2 Legal Requirements 37
5.1.3 Regulations Regarding Air Dispersion Modelling 38
5.1.4 Atmospheric Dispersion Processes 40
5.1.5 Atmospheric Dispersion Potential 52
5.1.6 Model Performance 84
5.1.7 Scenario Emission Inventory 100
5.1.8 Model Results 102
5.1.9 Uncertainty of Modelled Results 135
5.2 Analysis of Emissions' Impact on the Environment 136
5.2.1 Critical Levels for Vegetation 136
5.2.2 Dustfall 140

5.2.3 Corrosion 142
5.2.4 Sulfur and Nitrogen Deposition Impacts 147
6 Complaints 149
7 Current or planned air quality management interventions 150
8 Compliance and Enforcement Actions 151
9 Additional Information 152
10 Annexure A 154
11 Annexure B 155
12 References 156
APPENDIX A: Competencies for Performing Air Dispersion Modelling 159
APPENDIX B: Comparison of Study Approach with the Regulations Prescribing The Format Of The Atmospheric Impact Report and the Regulations regarding Air Dispersion Modelling (Gazette No 37804 published 11 July 2014) 161
APPENDIX C: Raw Materials, Abatement Equipment, Atmospheric Emissions and Measured Dustfall at Sasol's Sasolburg Operations 164
APPENDIX D: CALMET Model Control Options 194
APPENDIX E: CALPUFF Model Control Options 196
APPENDIX F: The NO_2/NO_x Conversion Ratios for NO_2 Formation 199
APPENDIX G: Time Series Plots for the Measured Ambient Air Quality in the Study Area 203
APPENDIX H: Predicted Baseline and Observed Air Concentrations 210
APPENDIX I: Management of Uncertainties 214
APPENDIX J: Guidance Note on treatment of uncertainties 220
APPENDIX K: Sensitive Receptors included in the Dispersion Model Simulations 222
APPENDIX L: WRF Model Setup 223

List of Tables

Table 1-1: Enterprise details 1
Table 1-2: Contact details of responsible person 1
Table 1-3: Location and extent of the plant 2
Table 2-1: Listed activities 3
Table 2-2: Unit processes at Sasol Sasolburg 10
Table 3-1: Raw materials used in the listed activities seeking MES postponement 18
Table 3-2: Appliances and abatement equipment control technology 19
Table 4-1: Point source parameters 21
Table 4-2: Point source emission rates during normal operating conditions (units: g/s) 24
Table 5-1: Summary description of CALPUFF/CALMET model suite with versions used in the investigation 36
Table 5-2: National Ambient Air Quality Standards 37
Table 5-3: Acceptable dustfall rates 38
Table 5-4: Definition of vegetation cover for different developments (US EPA 2005) 42
Table 5-5: Benchmarks for WRF Model Evaluation 46
Table 5-6: Daily evaluation results for the WRF simulations for the 2015-2017 extracted at OR Tambo[(a)] 46
Table 5-7: Meteorological parameters provided for the Sasol monitoring stations in the Sasolburg area 48
Table 5-8: Daily evaluation results for the WRF simulations for the 2015-2017 extracted at Eco Park[(a)] 49
Table 5-9: Parameters of buildings on the SO facility included in the dispersion modelling 52
Table 5-10: Monthly temperature summary (2015 - 2017) 55
Table 5-11: Summary of the ambient NH_3 measurements at Fence Line for the period 2010-2012 (units: $\mu g/m^3$) 58
Table 5-12: Summary of the ambient measurements at Leitrim for the period 2015-2017 (units: $\mu g/m^3$) 58
Table 5-13: Summary of the ambient measurements at AJ Jacobs for the period 2015-2017 (units: $\mu g/m^3$) 59
Table 5-14: Summary of the ambient measurements at Eco Park for the period 2015-2017 (units: $\mu g/m^3$) 59
Table 5-15: Summary of the ambient measurements at Three Rivers for the period 2015-2017 (units: $\mu g/m^3$) 60
Table 5-16: Summary of the ambient measurements at Sharpeville for the period 2015-2017 (units: $\mu g/m^3$) 61
Table 5-17: Summary of the ambient measurements at Zamdela for the period 2015-2017 (units: $\mu g/m^3$) 62
Table 5-18: Comparison of predicted and observed SO_2 concentrations at monitoring station in Sasolburg 96
Table 5-19: Comparison of predicted and observed NO_2 concentrations at monitoring stations in Sasolburg 98
Table 5-20: Varying source emissions per scenario provided for SO (units: g/s) 101
Table 5-21: Receptors identified for assessment of impact as a result of SO emissions 103
Table 5-22: Simulated baseline hourly SO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 106
Table 5-23: Simulated baseline daily SO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 107
Table 5-24: Simulated baseline annual SO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 108
Table 5-25: Simulated baseline hourly NO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 115
Table 5-26: Simulated baseline annual NO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 116
Table 5-27: Simulated baseline daily PM concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 122

Table 5-28: Simulated baseline annual PM concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 123
Table 5-29: Simulated baseline hourly CO concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors 129
Table 5-30: Most stringent health-effect screening level identified for all non-criteria pollutants assessed...........................131
Table 5-31: Screening of non-criteria pollutants against health risk guidelines 133
Table 5-32: Proposed unit risk factors for pollutants of interest in the current assessment..134
Table 5-33: Excess Lifetime Cancer Risk (New York Department of Health)..135
Table 5-34: Critical levels for SO_2 and NO_2 by vegetation type (CLRTAP, 2015) 136
Table 5-35: Summary of dustfall deposition rates as a result of operations at SO 140
Table 5-36: ISO 9223 Classification of the Time of Wetness 143
Table 5-37: ISO 9223 classification of pollution by sulfur-containing substances represented by SO_2 144
Table 5-38: ISO 9223 classification of pollution by sulfur-containing substances represented by SO_2 as a result of SO 144
Table 5-39: ISO 9223 classification of pollution by airborne chloride containing substances..144
Table 5-40: ISO 9223 classification of pollution by airborne chloride containing substances for SO 145
Table 5-41: Estimated corrosivity categories of the atmosphere 145
Table 5-42: Estimated corrosivity categories of the atmosphere associated with SO 145
Table 5-43: Average and steady state corrosion rates for Different Metals and Corrosivity Categories 146
Table 5-44: ISOCORRAG regression model constants (Knotkova *et al.*, 1995)..146
Table 5-45: Corrosion rate of metals associated with SO calculated according to the ISOCORRAG method......................147

List of Figures

Figure 4-1: Locality map of SO in relation to surrounding residential and industrial areas 20
Figure 5-1: The basic study methodology followed for the assessment 33
Figure 5-2: Schematic displaying how the dispersion modelling scenarios are presented, for each monitoring station receptor in the modelling domain 35
Figure 5-3: Plume buoyancy 42
Figure 5-4: Period, day- and night-time wind rose for OR Tambo for the period 2015 - 2017...47
Figure 5-5: Period, day- and night-time wind rose for WRF data as extracted at OR Tambo for the period 2015 - 2017 47
Figure 5-6: Monthly temperature profile for WRF data as extracted at OR Tambo and measured data from OR Tambo SAWS station data for the period 2015 – 2017..48
Figure 5-7: CALMET Layer 1 wind vector plot for 15 May 2015 at 05:00 49
Figure 5-8: CALMET Layer 1 wind vector plot for 2 February 2016 at 05:00 50
Figure 5-9: Land use categories, terrain contours, meteorological WRF grid points and surface station locations displayed on 200 x 200 km CALMET domain (1 km resolution) 51
Figure 5-10: Period, day- and night-time wind rose for Eco Park for the period 2015 - 2017 54
Figure 5-11: Period, day- and night-time wind rose for AJ Jacobs for the period 2015 - 2017...54
Figure 5-12: Period, day- and night-time wind rose for Leitrim for the period 2015 - 2017..55
Figure 5-13: Monthly average temperature profile for Eco Park (2015 – 2017)..56
Figure 5-14: Monthly average temperature profile for Leitrim (2015 – 2017) 56
Figure 5-15: Diurnal atmospheric stability (extracted from CALMET at the Eco Park monitoring point) 57
Figure 5-16: Observed hourly average SO_2 concentrations at Leitrim 63
Figure 5-17: Observed hourly average SO_2 concentrations at AJ Jacobs...63
Figure 5-18: Observed hourly average SO_2 concentrations at Eco Park...64
Figure 5-19: Observed hourly average SO_2 concentrations at Three Rivers...64
Figure 5-20: Observed hourly average SO_2 concentrations at Sharpeville 65
Figure 5-21: Observed hourly average SO_2 concentrations at Zamdela 65
Figure 5-22: Observed daily average SO_2 concentrations at Leitrim 66
Figure 5-23: Observed daily average SO_2 concentrations at AJ Jacobs 66
Figure 5-24: Observed daily average SO_2 concentrations at Eco Park 67
Figure 5-25: Observed daily average SO_2 concentrations at Three Rivers 67
Figure 5-26: Observed daily average SO_2 concentrations at Sharpeville 68
Figure 5-27: Observed daily average SO_2 concentrations at Zamdela..68
Figure 5-28: Observed hourly average NO_2 concentrations at Leitrim 69
Figure 5-29: Observed hourly average NO_2 concentrations at AJ Jacobs...69
Figure 5-30: Observed hourly average NO_2 concentrations at Eco Park 70
Figure 5-31: Observed hourly average NO_2 concentrations at Three Rivers 70
Figure 5-32: Observed hourly average NO_2 concentrations at Sharpeville 71
Figure 5-33: Observed hourly average NO_2 concentrations at Zamdela 71
Figure 5-34: Observed daily average PM_{10} concentrations at Leitrim 72
Figure 5-35: Observed daily average PM_{10} concentrations at AJ Jacobs...72
Figure 5-36: Observed daily average PM_{10} concentrations at Eco Park...73
Figure 5-37: Observed daily average PM_{10} concentrations at Three Rivers..73
Figure 5-38: Observed daily average PM_{10} concentrations at Sharpeville 74
Figure 5-39: Observed daily average PM_{10} concentrations at Zamdela 74

Figure 5-40: Time variation plot of observed SO_2 and NO_2 concentrations at Leitrim (shaded area indicates 95th percentile confidence interval) 76
Figure 5-41: Time variation plot of observed SO_2 and NO_2 concentrations at AJ Jacobs (shaded area indicates 95th percentile confidence interval) 77
Figure 5-42: Time variation plot of observed SO_2 and NO_2 concentrations at Eco Park (shaded area indicates 95th percentile confidence interval) 78
Figure 5-43: Time variation plot of observed SO_2 and NO_2 concentrations at Three Rivers (shaded area indicates 95th percentile confidence interval) 79
Figure 5-44: Time variation plot of observed SO_2 and NO_2 concentrations at Sharpeville (shaded area indicates 95th percentile confidence interval) 80
Figure 5-45: Time variation plot of observed SO_2 and NO_2 concentrations at Zamdela (shaded area indicates 95th percentile confidence interval) 81
Figure 5-46: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Leitrim 82
Figure 5-47: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at AJ Jacobs 82
Figure 5-48: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Eco Park 82
Figure 5-49: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Three Rivers 83
Figure 5-50: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Sharpeville 83
Figure 5-51: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Zamdela 83
Figure 5-52: Polar plot of hourly median SO_2 concentration observations at Leitrim for 2015 to 2017 86
Figure 5-53: Polar plot of hourly median SO_2 concentration observations at AJ Jacobs for 2015 to 2017 86
Figure 5-54: Polar plot of hourly median SO_2 concentration observations at Eco Park for 2015 to 2017 87
Figure 5-55: Polar plot of hourly median SO_2 concentration observations at Three Rivers for 2015 to 2017 87
Figure 5-56: Polar plot of hourly median SO_2 concentration observations at Sharpeville for 2015 to 2017 88
Figure 5-57: Polar plot of hourly median SO_2 concentration observations at Zamdela for 2015 to 2017 88
Figure 5-58: Polar plot of hourly median NO_2 concentration observations at Leitrim for 2015 to 2017 89
Figure 5-59: Polar plot of hourly median NO_2 concentration observations at AJ Jacobs for 2015 to 2017 89
Figure 5-60: Polar plot of hourly median NO_2 concentration observations at Eco Park for 2015 to 2017 90
Figure 5-61: Polar plot of hourly median NO_2 concentration observations at Three Rivers for 2015 to 2017 90
Figure 5-62: Polar plot of hourly median NO_2 concentration observations at Sharpeville for 2015 to 2017 91
Figure 5-63: Polar plot of hourly median NO_2 concentration observations at Zamdela for 2015 to 2017 91
Figure 5-64: Polar plot of hourly median PM_{10} concentration observations at Leitrim for 2015 to 2017 92
Figure 5-65: Polar plot of hourly median PM_{10} concentration observations at AJ Jacobs for 2015 to 2017 92
Figure 5-66: Polar plot of hourly median PM_{10} concentration observations at Eco Park for 2015 to 2017 93
Figure 5-67: Polar plot of hourly median PM_{10} concentration observations at Three Rivers for 2015 to 2017 93
Figure 5-68: Polar plot of hourly median PM_{10} concentration observations at Sharpeville for 2015 to 2017 94
Figure 5-69: Polar plot of hourly median PM_{10} concentration observations at Zamdela for 2015 to 2017 94
Figure 5-70: Fractional bias of means and standard deviation for SO_2 97
Figure 5-71: Fractional bias of means and standard deviation for NO_2 99
Figure 5-72: Sensitive receptors identified for assessment of impact as a result of Sasol Operations, Sasolburg 102
Figure 5-73: Simulated hourly SO_2 concentrations (99th percentile) at AQMS for Sasolburg Operations 104
Figure 5-74: Simulated daily SO_2 concentrations (99th percentile) at AQMS for Sasolburg Operations 105
Figure 5-75: Simulated annual SO_2 concentrations at AQMS for Sasolburg Operations 105
Figure 5-76: Simulated hourly SO_2 concentrations (99th percentile) as a result of baseline emissions 109
Figure 5-77: Simulated hourly SO_2 concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards 109
Figure 5-78: Simulated hourly SO_2 concentrations (99th percentile) as a result of alternative emissions 110
Figure 5-79: Simulated daily SO_2 concentrations (99th percentile) as a result of baseline emissions 110

Figure 5-80: Simulated daily SO_2 concentrations (99^{th} percentile) as a result of theoretical compliance with new plant emission standards 111
Figure 5-81: Simulated daily SO_2 concentrations (99^{th} percentile) as a result of alternative emissions 111
Figure 5-82: Simulated annual SO_2 concentrations as a result of baseline emissions 112
Figure 5-83: Simulated annual SO_2 concentrations as a result of theoretical compliance with new plant emission standards 112
Figure 5-84: Simulated annual SO_2 concentrations as a result of alternative emissions 113
Figure 5-85: Simulated hourly NO_2 concentrations (99^{th} percentile) at AQMS for Sasolburg Operations 114
Figure 5-86: Simulated annual NO_2 concentrations at AQMS for Sasolburg Operations 114
Figure 5-87: Simulated hourly NO_2 concentrations (99^{th} percentile) as a result of baseline emissions 117
Figure 5-88: Simulated hourly NO_2 concentrations (99^{th} percentile) as a result of theoretical compliance with new plant emission standards 117
Figure 5-89: Simulated hourly NO_2 concentrations (99^{th} percentile) as a result of alternative emissions 118
Figure 5-90: Simulated annual NO_2 concentrations as a result of baseline emissions 118
Figure 5-91: Simulated annual NO_2 concentrations as a result of theoretical compliance with new plant emission standards 119
Figure 5-92: Simulated annual NO_2 concentrations as a result of alternative emissions 119
Figure 5-93: Simulated daily PM concentrations (99^{th} percentile) at AQMS for Sasolburg Operations 121
Figure 5-94: Simulated annual PM concentrations at AQMS for Sasolburg Operations 121
Figure 5-95: Simulated daily PM concentrations (99^{th} percentile) as a result of baseline emissions 124
Figure 5-96: Simulated daily PM concentrations (99^{th} percentile) as a result of theoretical compliance with new plant emission standards 124
Figure 5-97: Simulated daily PM concentrations (99^{th} percentile) as a result of alternative emissions 125
Figure 5-98: Simulated annual PM concentrations as a result of baseline emissions 125
Figure 5-99: Simulated annual PM concentrations as a result of theoretical compliance with new plant emission standards 126
Figure 5-100: Simulated annual PM concentrations as a result of alternative emissions 126
Figure 5-101: Simulated hourly CO concentrations (99^{th} percentile) at AQMS for Sasolburg Operations 127
Figure 5-102: Observed hourly CO concentrations (99^{th} percentile) at AQMS for Sasolburg Operations 128
Figure 5-103: Simulated hourly CO concentrations (99^{th} percentile) as a result of baseline emissions 130
Figure 5-104: Simulated hourly CO concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards 130
Figure 5-105: Simulated hourly CO concentrations (99th percentile) as a result of alternative emissions 131
Figure 5-106: Simulated annual Mn concentrations as a result of baseline emissions 134
Figure 5-107: Annual SO_2 concentrations as a result of baseline emissions compared with CLRTAP critical levels 137
Figure 5-108: Annual SO_2 concentrations as a result of theoretical compliance with new plant emission standards compared with CLRTAP critical levels 137
Figure 5-109: Annual SO_2 concentrations as a result of alternative emissions compared with CLRTAP critical levels 138
Figure 5-110: Annual NO_2 concentrations as a result of baseline emissions compared with CLRTAP critical levels 138
Figure 5-111: Annual NO_2 concentrations as a result of theoretical compliance with new plant emission standards compared with CLRTAP critical levels 139
Figure 5-112: Annual NO_2 concentrations as a result of alternative emissions compared with CLRTAP critical levels 139
Figure 5-113: Simulated daily dustfall as a result of baseline emissions 140
Figure 5-114: Simulated daily dustfall as a result of theoretical compliance with new plant standards 141
Figure 5-115: Simulated daily dustfall as a result of alternative emissions 141

Abbreviations

AAA	Acrylic acid and acrylate
AEL	Atmospheric Emission Licence
AIR	Atmospheric Impact Report
AQA	Air quality act
AQMS	Air quality monitoring stations
As	Arsenic
ATR	Auto Thermal Reformer
APCS	Air pollution control systems
ARM	Ambient Ratio Method
ASG	Atmospheric Studies Group
BPIP	Building Profile Input Program
CH_4	Methane
Cl_2	Chlorine
Co	Cobalt
CO	Carbon monoxide
CO_2	Carbon dioxide
Cr	Chromium
Cu	Copper
DEA	Department of Environmental Affairs
EDC	1,2-dichloroethane
g	Gram
g/s	Gram per second
HCl	Hydrogen chloride
HCN	Hydrogen cyanide
HNO_3	Nitric acid
H_2	Hydrogen
H_2O	Water
H_2S	Hydrogen Sulfide
HSP	High Sulfur Pitch
IP	Intellectual property
IPCC	Intergovernmental Panel on Climate Change
kV	Kilo volt
LMo	Monin-Obukhov length
m	Meter
m^2	Meter squared
m^3	Meter cubed
MES	Minimum Emission Standards
MIBK	Methyl isobutyl ketone
Mn	Manganese
m/s	Meters per second
N_2	Nitrogen
NAAQS	National Ambient Air Quality Standards (as a combination of the NAAQ Limit and the allowable frequency of exceedance)
NaCN	Sodium cyanide

NaOH	Sodium hydroxide
NAP	Nirtic Acid Plant
NEMA	National Environmental Management Act
NEMAQA	National Environmental Management Air Quality Act
NH_3	Ammonia
Ni	Nickel
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
OH	Hydroxyles
OLM	Ozone Limiting Method
PBL	Planetary boundary layer
Pb	Lead
PM	Particulate matter
PM_{10}	Particulate matter with diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with diameter of less than 2.5 µm
ppb	Parts per billion
PVC	Polyvinyl chloride
RNO_3	Organic nitrates
Sb	Antimony
SO_2	Sulfur dioxide (1)
SO_3	Sulfur trioxide (1)
SO_4	Sulfates
SO_x	Oxides of sulfur (1)
SSBR	Sasol Slurry Bed Reactor
TEOS	Tetraethyl Orthosilcate
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
V	Vanadium
VOC	Volatile organic compound
WRF	The Weather Research and Forecasting Mesoscale Model
yr	Year
Z_o	Roughness length
µ	micro
°C	Degrees Celsius

Note:

(1) The spelling of "sulfur" has been standardised to the American spelling throughout the report. "The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled "sulfur". This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: http://goldbook.iupac.org (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.doi: 10.1351/goldbook)"

Glossary

Advection	Transport of pollutants by the wind
Airshed	An area, bounded by topographical features, within which airborne contaminants can be retained for an extended period
Algorithm	A mathematical process or set of rules used for calculation or problem-solving, which is usually undertaken by a computer
Alternative Emission Limit	Ceiling or maximum emission limit requested by Sasol, with which it commits to comply
Assessment of environmental effects	A piece of expert advice submitted to regulators to support a claim that adverse effects will or will not occur as a result of an action, and usually developed in accordance with section 88 of the Resource Management Act 1991
Atmospheric chemistry	The chemical changes that gases and particulates undergo after they are discharged from a source
Atmospheric dispersion model	A mathematical representation of the physics governing the dispersion of pollutants in the atmosphere
Atmospheric stability	A measure of the propensity for vertical motion in the atmosphere
Building wakes	Strong turbulence and downward mixing caused by a negative pressure zone on the lee side of a building
Calm / stagnation	A period when wind speeds of less than 0.5 m/s persist
Cartesian grid	A co-ordinate system whose axes are straight lines intersecting at right angles
Causality	The relationship between cause and effect
Complex terrain	Terrain that contains features that cause deviations in direction and turbulence from larger-scale wind flows
Configuring a model	Setting the parameters within a model to perform the desired task
Convection	Vertical movement of air generated by surface heating
Convective boundary layer	The layer of the atmosphere containing convective air movements
Data assimilation	The use of observations to improve model results – commonly carried out in meteorological modelling
Default setting	The standard (sometimes recommended) operating value of a model parameter
Diagnostic wind model (DWM)	A model that extrapolates a limited amount of current wind data to a 3-D grid for the current time. It is the ‘now’ aspect, and makes the model ‘diagnostic’.
Diffusion	Clean air mixing with contaminated air through the process of molecular motion. Diffusion is a very slow process compared to turbulent mixing.
Dispersion	The lowering of the concentration of pollutants by the combined processes of advection and diffusion
Dispersion coefficients	Variables that describe the lateral and vertical spread of a plume or a puff
Dry deposition	Removal of pollutants by deposition on the surface. Many different processes (including gravity) cause this effect.
Sasolburg Operations (SO)	Sasol South Africa (Pty) Limited operating through its Sasolburg Operations,

Atmospheric Impact Report:
Sasol Sasolburg Operations

1 ENTERPRISE DETAILS

1.1 Enterprise Details

The details of Sasol's Sasolburg Operations (SO) are summarised in Table 1-1. The contact details of the responsible person, the emission control officer, are provided in Table 1-2.

Table 1-1: Enterprise details

Enterprise Name	Sasol South Africa Limited operating through its Sasolburg Operations
Trading as	n/a
Type of Enterprise	Limited
Company Registration Number	1968/013914/07
Registered Address	50 Katherine Street Sandton 2196
Telephone Number (General)	016 960 1111
Fax Number (General)	016 920 2338
Company Website	www.sasol.com
Industry Type/Nature of Trade	Petrochemical industry
Land Use Zoning as per Town Planning Scheme	Industrial
Land Use Rights if Outside Town Planning Scheme	n/a

Table 1-2: Contact details of responsible person

Responsible Person Name:	Louis Fourie
Responsible Person Post:	Senior Vice President: Sasolburg Operations
Telephone Number:	016 960 8001
Cell Phone Number:	082 808 1971
Fax Number:	011 219 0004
E-mail Address:	louis.fourie@sasol.com
After Hours Contact Details:	082 808 1971
Name of VP SHE Sasolburg Operations:	Moses Arnolds

1.2 Location and Extent of the Plant

Table 1-3: Location and extent of the plant

Physical Address of the Plant	Sasol 1 Site 1 Klasie Havenga Street Sasolburg 1947
Description of Site (Where no Street Address)	Subdivision 6 of 2 of Driefontein No- 2 and certain subdivisions of the farm Saltberry Plain, Roseberry Plain Flerewarde and Antrim and subdivision 5 of 4 of Montrose, District of Sasolburg, Free State.
Coordinates of Approximate Centre of Operations	Sasol 1 Site: Latitude: S 26.82678 Longitude: E 27.84206
Extent	15.51 km^2
Elevation Above Sea Level	1 498 m
Province	Free State
Metropolitan/District Municipality	Fezile Dabi District Municipality
Local Municipality	Metsimaholo
Designated Priority Area	Vaal Triangle Priority Area

1.3 Atmospheric Emission Licence and other Authorisations

The following authorisations, permits and licences related to air quality management are applicable:

- Atmospheric Emission License:
  - FDDM-MET-2013-18
  - FDDM-MET-2013-20
  - FDDM-MET-2013-22
  - FDDM-MET-2013-23-P2
  - FDDM-MET-2013-24
- Other: None

2 NATURE OF THE PROCESS

2.1 Listed Activities

A summary of listed activities currently undertaken at SO is provided in Table 2-1.

Table 2-1: Listed activities

Category of Listed Activity	Subcategory of listed activity	Listed activity name	Description of the Listed Activity
1	1.1	Solid Fuel Combustion installations	Solid fuels (excluding biomass) combustion installations used primarily for steam raising or electricity generation
	1.5	Reciprocating Engines	Liquid and gas fuel stationary engines used for electricity generation
2	2.1	Petroleum Industry	Petroleum industry, the production of gaseous and liquid fuels as well as petrochemicals from crude oil, coal, gas or biomass
	2.4	Petroleum Industry (Storage and handling of petroleum products	All permanent immobile liquid storage facility on a single site with a combined storage capacity of greater than 1000 m^3
6	6.1	Organic Chemical Industry	The production, or use in production, of organic chemicals not specified elsewhere including acetylene, ecetic, maleic or phthalic anhydride or their acids, carbon disulphide, pyridine, formaldehyde, acetaldehyde, acrolein and its derivatives, acrylonitrile, amines and synthetic rubber. The production of organometallic compounds, organic dyes and pigments, surface-active agents. The polymerisation or co-polymerisation of any unsaturated hydrocarbons, substituted hydrocarbon (including Vinyl chloride). The manufacture, recovery or purification of acrylic acid or any ester of acrylic acid. The use of toluene di-isocyanate or other di-isocyanate of comparable volatility; or recovery of pyridine. All permanent immobile liquid storage facilities at a single site with a combined storage capacity of greater than 1 000 m^3.
7	7.1	Inorganic chemicals industry	The use of ammonia in the manufacturing of ammonia
	7.2		The primary production of nitric acid in concentrations exceeding 10%
	7.3		The manufacturing of ammonium nitrate and its processing into fertilisers
	7.4		Manufacturing activity involving the production, use or recovery of antimony, beryllium, cadmium, chromium, cobalt, lead, mercury, selenium, thalium and their salts
	7.7	Production of Caustic Soda	Production of Caustic Soda
8	8.1	Thermal treatment of hazardous and general waste	Facilities where general and hazardous waste are treated by the application of heat (Applicable : Capacity of Incinerator > 10 kg/hour)

2.2 Process Description

A description on the process units operating at SO is provided below.

Steam Stations

SO operates two steam/power stations. Pulverised coal is fired in boilers which are used for steam and power generation. All the steam and the majority of the power generated at these stations are used for Sasol's purposes, however Sasol do supply Eskom with electricity directly into the national grid to alleviate the pressure on the national grid, for which Steam Station 1 is critical. Emissions include combustion gases; sulfur dioxide (SO_2), nitrogen oxide (NO), nitrogen dioxide (NO_2), particulate matter (PM), carbon dioxide (CO_2) and carbon monoxide (CO).

Auto Thermal Reformers

SO operates two Auto Thermal Reformers (ATRs) on the Sasol One facility. Natural gas is reformed in the ATRs to form the building blocks of the Fischer Tropsch process. The heat required in the ATRs is obtained from the Fired Heaters which is fired with process tail gas, except during startup when they are fired with natural gas. Emissions from the two Fired Heaters are combustion gas products, such as NO, NO_2, CO and CO_2. No sulfur compounds are present.

Rectisol

SO operates a Rectisol plant on the Sasol One Site. The purpose of the Rectisol plant is "dew point correction" and "CO_2" removal. Due to the high concentration of methane and other hydrocarbons, the gas from the first two stages are sent to the flare and those from the last three stages are sent to atmosphere through the Steam Station 1 Stacks. Emissions include hydrocarbons specifically with high concentrations of CO_2 emitted from the Steam Station 1 stacks.

Thermal Oxidation

SO operates a thermal oxidation unit where various waste streams from various plants are thermally oxidized. The thermal oxidation facility consists of three incinerators, namely: the B6993, B6990 and B6930 incinerators. As part of the oxidation process, heat is recovered by means of steam, which supplements the steam supply to the plants from the Steam Stations. The B6930 incinerator has a bag house for particulate emission control, whilst the B6993 incinerator has a caustic scrubber for both SO_2 and PM emission control.

Benfield

SO operates a Benfield unit as part of the ammonia plant on the Sasol One Site. The Benfield unit consists of a CO_2 absorber column were CO_2 is removed from the process gas stream using the benfield solution. The benfield solution is regenerated in the desorber column were the CO_2 is desorbed to the atmosphere.

Nitric acid plant (NAP)

A nitric acid plant is operational at the Sasol Bunsen Street site. Ammonia is piped from the cold storage area to the nitric acid plant where it is reacted with oxygen to produce oxides of nitrogen (NO_x), as an intermediate product, which is fed to a catalyst to selectively convert NO to NO_2. The NO_2 is fed to a series of absorption columns where nitric acid is formed. The exhaust vent from the second tower, which contains NO_2, and N_2O is sent to the de-NO_x reactor, where the gas is reduced over a catalyst to nitrogen and oxygen, which is released to atmosphere.

Ammonium Nitrate solution

SO operates an ammonium nitrate solution plant. This plant is integrated into the NAP plant. The nitric acid from the NAP plant is reacted with ammonia in a reactor to form the ammonium nitrate solution.

Ammonium Nitrate Prill

SO also operates an ammonium nitrate prillian unit on the Sasol One Site. Aqueous ammonium nitrate is combined with off spec prill in a dissolving tank and then concentrated by means of parallel evaporators. The concentrated liquor is then fed to the top of the prill tower where after it is prayed through the prill nozzles to obtain a desired diameter. The spheres fall inside the prill tower through counter current air flow which cools the droplet and forming the prill. The upward air flow is passed through three scrubbers at the top of the prill plant before it is vented to atmosphere. The prill is fed to drying, cooling and screening units where off spec prill is recycled to the dissolving tank whilst the on spec prill is packaged as the final product. The air used for drying is passed through a scrubber before being vented to atmosphere. Emissions are particulates coming from the scrubbers on top of the Prill tower as well as from the drying scrubbers.

Ammonia

Nitrogen from the Air Products plant on site is combined with hydrogen from the Rectisol stream to form ammonia in the ammonia plant. Inert gasses and hydrogen are vented to ammonia flare and combustion gasses (CO_2, CO, NO_2 and NO) are vented to atmosphere from the super heater.

SCCM

Sasol Sasolburg Operations operates a Fischer-Tropsch Co-catalyst manufacturing plant on the Sasol One site. The plant consists of the steps described below:

1. Support Modification

During this process volatile organic compounds (VOC) (mainly ethanol) are removed from the reactor under vacuum through a cooling water condenser. After passing through a gas liquid separator and a knock out vessel, vapours are incinerated in the VOC incinerator while all liquid residues are collected in the spent ethanol tank.

2. 1st Calcination

The powder is fed to a calciner, which is heated by a gas burner. Ethanol groups are removed under air at elevated temperatures. At the calciner exit the product (roasted modified support powder) passes through a water cooler. Vapours from the hoppers and the calciner are fed to the VOC incinerator.

3. Impregnation

The calcined modified support powder is treated with impregnation liquid. The impregnation reactor is heated by a hot oil jacket and has a screw agitator. Aqueous vapours are removed from the reactor under vacuum through a cooling water condenser. The condensate is routed to the chemical sewer while clean vapours are released to atmosphere.

4. 2nd Calcination

During this step the nitrate salts in the powder are converted into oxides under release of NO_x. Preheated air acts as the fluidising medium which carries the nitrous vapours to the De-NO_x unit. This unit is also fed with an anhydrous ammonia solution and is equipped with a gas burner. It facilitates a two-step catalytic reduction of NO_x with NH_3 to nitrogen and water.

5. Reduction

The oxygen free powder enters a fluidised bed reduction reactor where hydrogen is used as a reduction medium and nitrogen is used for purging. After passing through the fluidised bed the gas stream is cooled in two steps. The coolers utilise water and a water/glycol mixture respectively. After removal of water and ammonia in an adsorption dryer, the regenerated reduction gas is fed into the compressor suction and recirculated. A regenerated gas bleed-off is located between the water cooler and water glycol chiller. Water and ammonia removed from the gas is routed to the chemical sewer.

6. Coating

The active catalyst requires coating to prevent auto-ignition. This is done by feeding the catalyst into the coating tank where it is suspended in molten wax (synthetic paraffins). Wax volatiles from the wax melt tank and coating tank are routed to a separate dedicated wax scrubber where they are stripped with water. Stripper water from the wax melt tank scrubber is routed to the storm water drain, while stripper water from the coating tank scrubber is routed to the chemical sewer as it may contain metals. Clean gas from both scrubbers is released to atmosphere. Both tanks and transfer lines have jackets with hot oil for heating.

7. Packaging

Finished product (active catalyst suspended in wax) runs through to the drum filling station using a nitrogen purge, to package the product for distribution and use.

Phenol, Cresol and TNPE Plants

The Phenol, cresol and TNPE plants extract and purifies a range of phenolic products from tar acid containing feed streams sourced from Sasol Synfuels Operations. Various process chemicals are used to extract the tar acids and to remove impurities where-after phenol, cresols and xylenols are recovered via distillation. Waste generated by the processes are either incinerated or treated at the Sasol Bio-works. All relieve valves and vents are connected to the plant's flare system and normal combustion products are emitted (CO_2, CO, NO, NO_2 and water (H_2O)). The fuel gas furnace emits combustion gas products and SO_2 and sulfur trioxide (SO_3) are emitted from the oxides of sulfur (SO_X) scrubber.

Solvents

All vents and hydrocarbon emissions from Solvents are sent to the flare with the exception of a few units which vent hydrocarbons to atmosphere which has been quantified.

Methanol High Purity

Gas and hydrogen is reacted in a synthesis reactor at Sasol Waxes where crude methanol is produced. The distillation of the crude methanol into high purity methanol takes place at Sasol Solvents, through atmospheric distillation. The purification is accomplished through degassing and the removal of low and high boiling point by-products.

Methanol Technical Grade

The methanol extracted from the reaction water (Chemical water treatment plant) is purified to methanol technical grade through a process of atmospheric distillation. The purification is accomplished through the removal of low and high boiling point by-products.

Chemical Water Recovery

Chemicals are recovered from the reaction water from the Sasol Waxes synthesis processes, as well as purge streams from Butanol and by-products from HP methanol, TG methanol, MIBK and FTDR. Recovery of chemicals takes place through a process of atmospheric distillation and degassing.

Methyl Iso Butyl Ketone (MIBK 1 and 2)

DMK (acetone) is converted over a palladium impregnated resin ion-exchange catalyst in the presence of hydrogen to MIBK via a single stage process. The reactor product is worked up and purified through a series of distillation columns. All impurities and co-products are removed through the distillation processes.

Solvents Blending Plant

Raw material from Secunda, Sasolburg and outside suppliers, transported via road tankers to the blending plant, are stored in on-site storage tanks. The raw products, mixed according to customers specifications, are supplied to the customer via road tankers or drums.

Heavy Alcohol Plant

Raw material from Secunda (Sabutol bottoms) is distilled through a single step distillation column into 2 final products, i.e. pentylol and hexylol. No by-products are removed in the process.

Solvents Mining Chemicals Plant

Raw material from Secunda, Sasolburg and outside suppliers, transported via road tankers to the blending plant, are stored in on-site storage tanks. The raw products, mixed according to customers specifications, are supplied to the customer via road tankers or drums.

AAA/Butanol

Sasol operates an Acrylic Acid and Acrylate (AAA) as well as a Butanol plant on the Sasol Midland Site.

Butanol

Synthesis gas is fed to a cold box separation phase where impurities are removed from the syngas. The impurities are recycled back into the gas loop and vented into an elevated flare. The purified syngas as well as propylene are fed into a series of reactive distillation units to produce n-butanol and i-butanol as the final product. All columns are vented to the flare.

AAA

Acrylic acid is manufactured by reacting propylene with air through a series of reactors and a distillation / purification process. The crude Acrylic Acid is fed to three processes. It can be purified to form Glacial Acrylic Acid, it can be reacted with n-Butanol to produce Butyl Acrylate or it can be reacted with Ethanol to produce Ethyl Acrylate. All vents from the AAA plant goes through high temperature incinerator to eliminate any Acrylates entering the atmosphere, especially due to the odorous nature of Ethyl Acrylate. Off gasses from the catalytic destruction unit and the vapour combustion unit contains CO_2, CO, NO and NO_2.

LOC

Liquid bulk storage contains/stores the various products produced on site. It is coupled to the loading bay which is covered to the vapour combustion. Drum, road and rail loading takes place. The fugitive organic vapour emitted during loading of road bulk haul trucks are extracted from the tanker hoods and incinerated at the vapour combustion unit. Emissions are normal combustion gasses such as CO2, CO and H_2O. No sulfur components are present.

Ethylene

Sasol, Sasolburg Chemical Operations operates a Monomer production and separation unit where ethylene is produced to be used within the polyethylene and polyvinylchloride manufacturing plants. A Mixture of ethane and ethylene is piped to Sasolburg from Secunda where it enters the Ethylene Purification Unit (S4500) where the ethylene is separated from the ethane by means of distillation. The ethylene is then routed to the customers.

The ethane product from the S4500 is then routed to the Cracking Unit (S4600) where it is cracked to ethylene. Once cracked, the ethylene/ethane gas mixture goes through a quenching, scrubbing and drying phase where after the gas is selectively hydrogenated to convert acetylene to ethylene. After this the C_2 mixture is purified by means of distillation processes where light and heavy components as well as unreacted ethane are removed. The ethylene is then stored in the ethylene tank to be distributed to the polythene and vinyl chloride monomer plants. Hydrocarbon off-gasses are sent to the plant's main flare where it is converted to CO_2, CO and H_2O. The cracking unit emits traces of H_2S from the caustic scrubber.

Polyethylene

SO operates two polyethylene plants on the Sasol Midland Site, namely the Poly 2 and Poly 3 plants.

Poly 2: The Poly 2 process involves the manufacture of linear low density polyethylene in a fluidized bed gas phase reactor. The materials used for the manufacture comprise ethylene which is the main component, hexene/butene as a density modifier, hydrogen as a melt index modifier, isopentane for temperature control, a silica based Ziegler Natta catalyst (manufacture in house in the catalyst plant, a catalyst activator and nitrogen for reactor pressure control. The feeds enter the reactor where the reaction process takes place and polymer together with some unreacted gas is transferred to the degassing bin for separation of hydrocarbons from the polymer. The liquid hydrocarbons (hexene, isopentane) is recovered in the monomer recovery section of the plant and recycled back to the reactor for re-use. The polymer pneumatically transferred from the degassing bin and is stored in intermediate storage silos and thereafter pelletised at the extruder. At the extruder, virgin polymer is mixed with additives, is melted and is thereafter cut it into pellets in an underwater cutter. This polymer pellets are thereafter dried and cooled before being pneumatically conveyed to the Pack Silos from which it is bagged at the packline and stored in the warehouse. Emergency venting occurs through the plant flare system where ethylene is converted to CO_2, CO and H_2O.

Poly 3: The Poly 3 plant produces medium and low density polyethylene. The ethylene is fed to a reactor where initiator and modifier depending on which grade (LDPE or MDPE) is added and the polymerization reaction take place. The excess ethylene is recycled and the polyethylene is separated, extruded, dried and transferred to degassing silos where the access ethylene is purged out with air. After degassing the product is transferred for packaging. Emergency venting occurs through the plant flare system where ethylene is converted to CO_2, CO and H_2O.

Chlorine

Sasol also operates a chlorine, hydrochloric acid, sodium hydroxide and sodium hypochlorite production facility on the Sasol Midlands Site. Salt is conveyed to a dissolving tank where the salt is dissolved up to a specific brine concentration. After several purification steps, the brine solution is fed to the chloro-caustic cells where chlorine, hydrogen and aqueous sodium hydroxide is manufactured. The chlorine manufactured is stored, reacted with sodium hydroxide to create sodium hypochlorite or reacted with hydrogen to create hydrochloric acid in the hydrogen chloride (HCl) burners. The hydrogen is either used at the HCl burners to manufacture HCl or sent to the VCM plant as a fuel gas. The hydrochloric acid produced in the HCl burners is stored and sold as a final product. Scrubbers and outlets might contain traces of HCl and chlorine (Cl_2).

Vinyl Chloride Monomer

Sasol operates a Vinyl Chloride Monomer (VCM) production facility on the Sasol Midland Site. The facility uses two different reactions for the manufacturing of the intermediate 1,2-dichloroethane (EDC). The first is the direct chlorination of ethylene to produce EDC. The second is the oxychlorination step where ethylene, oxygen, hydrogen and HCl react to produce crude EDC and water. The water is separated after the oxychlorination reactor and the crude EDC is sent to the EDC purification unit. The water stream is fed to the water recovery unit for purification before being exported to the Sasol Polymers Chlorine Plant for brine make up. EDC from the purification step is fed to the EDC cracker together with EDC from the direct chlorination step. In the EDC cracking unit EDC is cracked to VCM and HCl after which the cracked stream is fed to the VCM purification unit. Here the VCM and HCl are separated and HCl is recycled to the oxychlorination unit. The VCM is sent to storage in two spheres at the PVC Plant. By products from the EDC Purification Unit and plant vent gasses are incinerated and the recovered dilute hydrochloric acid exported to the Sasol Polymers Hydrochloric Acid Plant.

Polyvinyl Chloride

Sasol operates a Polyvinyl chloride plant on the Sasol Midland Site. VCM from the VCM plant storage spheres is suspended in water whilst the reaction is brought up to the desired temperature. The polymerization reaction takes place and the polyvinyl chloride (PVC) is formed. The reactor is discharged into a blow down vessel which feeds into the stripper, where unreacted VCM is recovered from the slurry and recycled. The PVC/water mixture is then fed to the slurry stock tank and then to the centrifuge where the PVC is separated. Once the PVC is separated, it is dried, screened and pneumatically fed to the storage area for packaging. The unreacted VCM is recovered by liquefaction and stored for reuse. The uncompressible tail gas from the latter unit is fed to the incinerator at the VCM Plant.

Cyanide

Sasol, furthermore, operates a Cyanide manufacturing plant on the Sasol Midland Site. Methane (CH_4) rich natural gas reacts with NH_3 in a fluidized coke bed reactor to form a hydrogen cyanide (HCN) rich synthesis gas. The energy required for the endothermic reactor is supply by a set of six graphite electrode connected to a 6.6kV electrical supply. The synthesis gas and large coke particles leaving the reactor are transferred through a cyclone where the particles are separated from the gas. After the cyclone, the gas is cooled and fed to fabric filters where any carbon soot entrained in the synthesis gas is removed. The "polished" gas is then fed to a pair of sodium hydroxide (NaOH) absorbers installed in series. Here the HCN reacts with the NaOH to form sodium cyanide (NaCN), which is the final product. The exhaust gasses from the second NaOH absorber is fed into a NaOH vent scrubber after which it is emitted to atmosphere via an elevated stack. Emissions contain mainly hydrogen, particulates from the bag houses and are measured for traces of HCN.

Wax

Sasol Wax operates a catalyst preparation plant as well as two wax production units namely the Sasol Slurry Bed Reactors (SSBR) and the Arge Reactors. In the catalyst preparation plant metals are dissolved in nitric acid and then precipitated after which the catalyst is dried and activated, where after it is ready for use. NO_x is emitted at one and particulates are emitted at three stacks in the area.

The three SSBRs and Arge reactors are fed with the active catalyst and synthesis gas to produce hydrocarbons. The hydrocarbons are worked up via hydrogenation, distillation and oxidation to liquid final products. The products are blended, solidified and packed. Organics and combustion gasses (CO_2, CO, H_2O, NO and NO_2) are emitted from various heaters within the process. Hydrocarbons from vents are sent to the factory main flare system where the organics are converted to CO_2, CO and H_2O before being emitted to atmosphere

2.3 Unit Processes

All unit processes for the SO complex are listed in Table 2-2. The listed activity for which the postponement is applied is indicated as bold text. Sasol's Sasolburg Operations also operates various activities including water treatment facilities, fine ash dams, research activities and various distillation and processing units that are not included in the Listed Activities and Minimum Emissions Standards (MES). The site is a gas plant and as such continuous emissions are limited to predominantly combustion gases where flares have been installed as safety mechanisms.

Table 2-2: Unit processes at Sasol Sasolburg

Unit Process	Function of Unit Process	Batch or Continuous Process
	ATR	
Auto Thermal reformers	Convert natural gas to reform gas	Continuous
Membrane separators	Purification of reformed gas	Continuous
Flares	Destruction of gas	Batch
Rectisol	CO_2 removal and dew point correction	Continuous
	Thermal oxidation	
B6993 Spent Caustic Incinerator	**The incineration of spent caustic solution and off specification solvent products including MIBK by-products in a down fired incinerator.**	**Continuous**
Spent Caustic Storage - F6903	Intermediate storage	Batch
Hydrocarbon Solvents - F6963 A/B F6927 B	Intermediate storage	Batch
Sodium Carbonate - F6954	Intermediate storage	Batch
Caustic - F6959 / F6975	Intermediate storage	Batch
B6930 High Sulfur Pitch Incinerator	**The incineration of High Sulfur Pitch, Organic solvents and High Organic waters in a limestone fluidized bed unit.**	**Continuous**
HSP Storage tanks - F6926 / F6990	Intermediate storage	Batch
HOW tank - F6938	Intermediate storage	Batch
BFW tank - F6939	Intermediate storage	Batch
B6990 Chemical Incinerator	**The incineration of heavy oils, off-specification waxes, Sasol spent catalyst, funda filter cake, slop solvents and high organic waste.**	**Continuous**
Product tank	Intermediate storage	Batch
	Steam Stations	
Fuel oil tanks	Holding fuel	Continuous
Coal bunkers/silos	Holding coal	Continuous
15 Boilers	Steam production	Continuous
Feed water tanks	Holding water	Continuous
Resins (HCL, caustic)	Holding chemicals	Continuous
NH_3 tank	Holding ammonia	Continuous
Blow down tank		Continuous
	Nitric Acid (NAP)	
NO reactor	Reaction of NH_3 and air to form NO	Continuous
Absorber columns	Absorbtion of NO_2 to HNO_3	Continuous
De-NOx reactor	Reduction of NOx to O_2 and N_2	Continuous
	Ammonium Nitrate	
AN reactor	Reaction to form ammonium nitrate	Continuous
Neutralizer	pH correction	Continuous
AN solution tank	Storage of AN solution	Continuous
	Prillan	
Wet section	Concentration of ammonium NH_4OH solution	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Dry section	Drying of prilled NH_4OH	Continuous
Storage	Storage of prilled NH_4OH	Continuous
Ammonia		
CO_2 capture	Remove moisture from the CO_2 stream	Continuous
CO-shift	Reacts CO + steam to form H_2	Continuous
Benfield	Removal of CO_2 from the process stream	Continuous
PSA	Production of LPH_2	Continuous
Deoxo	N_2 purification	Continuous
Ammonia synthesis	Production of NH_3	Continuous
BFW	Demineralized water	Continuous
SCCM		
Storage tanks/bags	Containing raw materials for the support modification step	Continuous
Reactor	Allow for chemical reactions	Batch
VOC destruction unit	Destroying VOC vapours	Continuous
Hoppers	Temporary storage of the support powder	Continuous
Water cooler	Cooling the roasted support powder for storage	Continuous
Mixing tank	Mixing cobalt nitrate, water and metal promoter	Batch
Heated reactor	Impregnating support powder with the metals and subsequent partial drying	Batch
DeNOx unit	Catalytic destruction of NOx fumes	Continuous
Sieve	Sizing of the particles	Continuous
Reverse pulse jet cartridge filters	Removing of dust particulates	Continuous
Purge hopper	Remove oxygen	Continuous
Reduction reactor	Activation step on the catalyst	Continuous
Coolers	Cooling of the activated catalyst	Continuous
Wax CoatingTank	Wax coating of the activated catalyst	Continuous
Packaging unit	Package of the activated catalyst for distribution	Continuous
Vent System	Removing of dust particles from step 1,4,6 and 7 hoppers off gas.	Continuous
Phenol, Cresol and TNPE		
Phenol producing column	Process NBF DTA material for phenol production	Continuous
Feedstock storage	Hold feed material	Batch
Rundown tanks	Hold product phenol	Batch
Final product tanks	Hold final product phenol	Batch
Product Stabiliser tanks	Hold chemicals	Batch
Tempered water system	Hold and provide condensate to phenol unit	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Relief system	Relief system in high pressure cases	Batch
HP steam	Provide heat to phenol unit reboilers/heater	Continuous
HOW Storage tanks	Holding high organic effluent materials	Batch
Sand Filtration	Filter solids from HOW water	Continuous
Extraction	Extract phenolics from the high organic wastewater	Continuous
C stream distillation	Recover butyl acetate (solvent)	Continuous
Stripping section	Strip out butyl acetate from final effluent	Continuous
Crude tar acids storage	Hold tar acids extracted from high organic effluent	Batch
Separators	Remove tar and oil from high organic stream	Continuous
Storage tanks	Holding raw materials – Formalin, Caustic Soda, O-cresol, Water	Batch
Atmospheric and Vacuum Dehydration	Removal of water from crude resin by heating Stripping of unreacted o-cresol from crude resin by direct steam injection under vacuum conditions	Batch
Pastillising	Pastillising of resin to form final product	Batch
Buffer storage	Intermediate storage of resin before pastillsing	Batch
Feed storage tanks	Holding raw materials as buffer between Secunda and Sasolburg	Batch
Drying and N-base removal	Removing excess water from the feed followed by a process step to remove unwanted nitrogen base compounds from the feed	Continuous
Phenol production	Phenol produced from cleaned-up cresol feed	Continuous
Phenol removal	Remaining phenol in bottom product from above unit has to be removed	Continuous
Product Splitter	Separates cresol products from feed based on boiling points differences	Continuous
Intermediate feed product storage	Between units products are temporarily stored to minimize the whole production train to be affected if one unit experiences problems	Batch / Continuous
Final product tanks	Bulk storage before shipment to customer	Batch / Continuous
Loading facility	Road tanker loading of intermediate or final products	Batch
Loading facility	Road tanker loading of pitch type material for transport to incineration plant	Batch
	Solvents – All plants	
Off-loading facility	Off-loading raw material to holding tank	Batch
Loading Facilities	Loading final product	Batch
Final product tanks	Holding product	Batch
	Solvents – AAA/Butanol	
Oxidation	Raw material to crude product	Continuous
Distillation	Purification of crude product	Continuous
Esterification	Reaction of crude product with specific alcohol	Continuous
Refrigeration unit - NH_3	Cooling in process	Continuous
Cryogenic separation	Conditioning of synthesis gas	Continuous
Chemical Dosing	In-process requirement	Continuous
Flare system	Process gas	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Off gas incineration	Incineration of process and tank waste gas	Continuous
Catalytic combustion	VOC combustion	Continuous
	Solvents – MIBK 1 and 2	
Raw material tank	Holding raw materials	Continuous
Compression	Preparation of raw material	Continuous
High pressure Reaction	Production of raw product	Continuous
Refrigeration Unit	Preparation of vapour (H_2) emissions to flare	Continuous
Distillation	Fractionation of product to desired spec.	Continuous
Prover tanks	Stores MIBK while being analysed before being pumped to final storage tank	Batch
Catalyst Loading Facilities	Loading and washing of catalyst for D551 A&B	Batch
	Solvents – Methanol	
Synthesis	Converting gas and hydrogen to crude methanol	Continuous
Raw crude methanol tank	Holding raw materials	Continuous
Prover product tanks	Holding product	Batch
Atmospheric distillation	Distill methanol from crude	Continuous
Caustic dozing	Corrosion control and neutralization of acids	Continuous
	Solvents – Methanol TG	
Atmospheric distillation	Distill methanol in reaction water to Technical grade purity	Continuous
Prover tanks	Storage of Methanol TG	Continuous
	Solvents – E1204	
Prover tanks	Holding product	Continuous
Atmospheric distillation	Distill Pentylol and Hexylol from Sabutol Bottoms	Continuous
	Solvents – Chemical Recovery (S500) Alcohol distillation	
Degassing	Dissolved gases are removed from chemical water	Continuous
Feed storage	Reaction water Storage to E501	Continuous
Atmospheric distillation	Removal of water and other light components from chemical water	Continuous
Scrubbing	Vapours are scrubbed of acids	Continuous
	Solvents – Blending plant	
Raw material	Feed for blends	Batch
Blending tanks	To blend formulations according to customer requirements	Batch
Storage	Final Products	Batch
	Solvents – Mining Chemicals plant	
Raw material	Feed for blends	Batch
Blending tanks	To blend formulations according to customer requirements	Batch
Storage	Final Products	Batch
Vapour combustion unit	Destruction of organic vapours from the loading racks	Batch
Various storage tanks	Storage of liquid products	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Poly 2		
Feed Streams:		
Knock-out drum	Knock out oil entrainment in supply ethylene	Continuous
Ethylene Compression	Compression of supply ethylene from supply pressure to reaction pressure	Continuous
Hydrogen Storage	Acceptance of supply high pressure hydrogen from air products line	Continuous
Raw material offloading	Offloading of rail cars / isocontainers into storage tanks before use in catalyst and LLDPE manufacturing	Batch
Catalyst Plant:		
Dehydration	Preparation of silica for use in the manufacture of catalyst	Batch
Catalyst Preparation	Manufacture of Ziegler Natta, silica based catalyst for the polyethylene manufacture process	Batch
Catalyst Storage	Storage of catalyst manufactured and transfer to reactor catalyst feeders	Batch
Catalyst Deactivation	Deactivation of out of specification catalyst	Batch
Purification	Purification of feed streams to remove trace poisons before use in the Catalyst and LLDPE manufacturing processes	Continuous and batch
Reaction	Produce polyethylene in the fluidized bed reactor	Continuous
Degassing:		
Degassing Bin	Degassing of reactor polymer to remove hydrocarbons from polymer and screen polymer to prevent conveying line blockages	Continuous
Monomer recovery	Knock out hydrocarbons from degassing bin vent via a compressor and fridge system – recycle liquid hydrocarbons to the reactor	Continuous
Flare	Flaring of hydrocarbons not recovered at the monomer recovery unit	Continuous
	Flaring of reactor inventory during reactor shutdown / purging	- Batch
Blending:		
Intermediate storage	Intermediate storage and feed of reactor polymer to the extruder	Batch
Extruder	Mixing of reactor polymer with additives and pelletising	Batch
Packline	Bagging of polymer into 25kg bags and 1.25ton semi bulk bags	Batch
Warehouse	Storage of polymer before being transported to customers	Batch
Poly 3		
Ethylene Feed		
Knock-out drum	Knock-out oils and wax formation in feed line	Continuous
Compressors	Compress Ethylene to required reaction pressure	Continuous
Reactor	Produce Polyethylene	Continuous
Separators	Separate Ethylene from Polyethylene	Continuous
Recycle unit		
Knock-out drums	Knock-out oils and wax formation	Continuous
Heat exchangers	Cool down ethylene	Continuous
Off-loading Area		

Unit Process	Function of Unit Process	Batch or Continuous Process
Buffer Tank	Isododecane used as flushing agent	Batch
Buffer Tank	Compressor Lubrication Oil (Polybutene & Polyglycol)	Batch
Storage tank (iso-tanker)	Contain Propionaldehyde used as modifier solvent	Batch
Extrusion	Pelletise polymer	Continuous
Pellet transfer and degassing	Transfer pellets and degas product	Continuous
Waste oil and initiator	Disposal of waste oil and initiator	Batch
Flare system	Flaring ethylene or propylene	Batch
VCM and PVC		
Reactor	VCM Plant Unit 1100 – manufacture of 1,2-dichloroethane (EDC) from ethylene and chlorine.	Continuous
Cracker	VCM Plant Unit 1400 – cracking of EDC to form vinyl chloride monomer (VCM) and hydrogen chloride (HCl)	Continuous
Reactor	VCM Plant Unit 1200 – manufacture of EDC by oxyhydrochlorination of ethylene	Continuous
Incinerator	VCM Plant Unit 1600 – by-product hydrochloric acid recovery from mixed gaseous and liquid plant streams from both the VCM and PVC Plants.	Continuous
Scrubber	VCM Plant Unit 1500 Safety Scrubber – removal of HCl from gaseous vent streams during incinerator off-line time.	Batch
Cold flare	VCM Plant Unit 1500 Cold Flare – vent gaseous streams of VCM and HCl diluted with steam and nitrogen during emergencies and gas clearing in preparation for maintenance shutdown.	Batch
Tanks – spheres	PVC Plant Storage Spheres – storage of VCM	Continuous / Batch
Reactors	PVC Plant Reaction Unit – manufacture of poly (vinyl chloride) (PVC) from VCM	Batch
Separation - recovery	PVC Plant Vinyl Chloride Recovery Unit – recovery of unreacted VCM from the manufacture of PVC	Continuous
Drying	PVC Plant Drying Unit – remove moisture from raw PVC polymer	Continuous
Separation - recovery	PVC Plant Multigrade Recovery Unit – recovers PVC polymer from effluent water streams	Batch
Monomers		
Ethylene unit 4600	Cracking of ethane and propane Separation of ethylene & ethane from C2 rich gas	Continuous
Ethylene storage tank	Storage of final product	Continuous
Ethane storage sphere	Storage of furnace feed material	Continuous
Propylene storage sphere and bullets	Storage of final product	Continuous
Cracker system	Cracking of ethane or propane to ethylene (This unit operation include boiler feed water, dilution steam, crack gas quench, MEA, Caustic and fuelgas)	Continuous
Cooling water system	Used as cooling medium	Continuous
Loading bay facility	Loading of ethylene road tanker	Batch
Feed gas preparation	Ethane saturator	Continuous
Compression	Crack gas compression as well as ethylene and propylene compression	Continuous
Flare system	Flaring of off-spec product during upset conditions as well as over-pressure protection (3 flares: Ground flare; elevated flare and tank flare)	Continuous
Cold separation	This unit operation include de-ethaniser, C3-recovery, secondary feed gas drying, cold	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
	separation, de-methaniser, ethylene cycle, C2-splitter and ethane system	
Liquefaction	This unit operation include propylene refrigeration, ethylene distribution and storage	Batch
Pre-cooling and drying	Propylene system, pre-cooling, acetylene removal, primary feed gas drying	Continuous
Utilities	Plant air, instrument air, LP nitrogen, de-oxo nitrogen, fire steam, 38bar HP steam, 4.5bar MP steam & 1.5bar LP steam, drinking water, condensate & fire water system	Continuous / Batch
DCS system	Digital Control System for plant operation	Continuous
	Cyanide	
Water	Process make up water	Batch
Nitrogen	Plant purging, bag house pulsing and coke feed	Continuous
Caustic	Diluted caustic for the production of sodium cyanide	Batch
Ammonia	For the production of hydrogen cyanide gas	Continuous
Sodium cyanide	Primary and secondary absorption	Batch
Sodium cyanide	Crude Tanks	Batch
Sodium cyanide	Final storage	Batch
Natural gas	Piped in for the production of hydrogen cyanide gas	Continuous
Bag house	Filtering of hydrogen cyanide gas	Continuous
Absorbers	Absorbing HCN gas into caustic	Continuous
Back up scrubbers	Final separation of HCN gas from waste gas stream	Continuous
Stack and seal pot	Exhausting waste gas mainly hydrogen into atmosphere	Continuous
Press filter	Filtration of crude sodium cyanide	Batch
Nash compressors	Recycle hydrogen system into process	When required
Loading facility	Dispatch of final product	Continuous
	Chlorine	
Chlorine production	To produce chlorine, hydrogen, sodium hydroxide	Continuous
Calcium Chloride	Produce calcium chloride	Batch
Hydrochloric Acid	Hydrochloric acid	Continuous
Tank farm	Storage and dispatch of caustic soda, hydrochloric acid and sulfuric acid.	Continuous
	Sasol Wax – Production	
Reactors	Production of hydrocarbons	Continuous
Distillation column	Separation of hydrocarbons	Continuous
Packaging	Solidification of wax to get required products	Continuous
Bagging	Packaging of products	Continuous
Mixing and blending	Production of catalyst	Batch
Hoppers	Storage of sodium carbonate	Batch
	Sasol Wax – Catalyst preparation	
Dissolving reactors	To produce a metal solution	Batch
Precipitation reactors	To precipitate the catalyst slurry from precursor solutions	Batch

Unit Process	Function of Unit Process	Batch or Continuous Process
Calcination	To strengthen the catalyst particles	Continuous
Driers	To dry the catalyst to the correct moisture content	Continuous
Evaporators	To concentrate the by-product solution from the precipitation area	Continuous
Crystallisers	To crystallise a salt slurry solution	Continuous
Drier	To dry the salt crystals	Continuous
Storage tanks	Storage for nitric acid, potassium silicate, and caustic soda.	Batch

3 TECHNICAL INFORMATION

Raw material consumption for the listed activities applying for MES postponement at SO is tabulated in Table 3-1. For completeness, the raw materials used by all process are included in Appendix C1 (Table C-1), unless the information is intellectual property (IP) or otherwise sensitive due to competition law. Pollution abatement technologies employed at SO for the listed activities applying for MES postponement are provided in Table 3-2 (all appliance and abatement equipment in use at SO is provided in Appendix C; Table C-2).

3.1 Raw Materials Used and Production Rates

Table 3-1: Raw materials used in the listed activities seeking MES postponement

Raw Material Type	Design Consumption Rate (Volume)	Units (quantity/period)
Thermal oxidation		
Spent Caustic	30 660	t/a
Organic Solvents	13 140	t/a
High Sulfur Pitch	21 900	t/a
Organic Solvents	17 520	t/a
Limestone	26 280	t/a
Organic waste water	17 520	t/a
Off- specification waxes	720	t/a
Sasol spent catalyst	2 448	t/a
Funda filter cake	2 640	t/a
Polyethylene wax	960	t/a
Other solid waste	1 800	t/a
High organic waste	4 800	t/a
Pitch/ tar waste Slops oils	1 800	t/a
Fuel Gas	8 760	kNm^3/a
Steam Station 1 and 2		
Water (Steam Station 1)	6 132	kt/a
Water (Steam Station 2)	9 070	kt/a
Coal (Steam Station 1)	2 148	kt/a
Coal (Steam Station 2)	2 000	kt/a

3.2 Appliances and Abatement Equipment Control Technology

Table 3-2: Appliances and abatement equipment control technology

Appliance name	Appliance type/description	Appliance function/purpose
Spent Caustic Incinerator B6993		
Scrubber	Venturi scrubber	Scrubbing of flue gasses to remove particulates and SO_2
New High Sulfur Pitch (HSP) Incinerator B6930		
Fluidized bed	Limestone fluidized bed	Removal of SO_2
Bag house	Bag house	Particulate removal
Steam Station 1 and 2		
Electrostatic Precipitators	Electrostatic precipitators	Reducing the quantity of particulate emissions from the boilers.

4 ATMOSPHERIC EMISSIONS

The establishment of a comprehensive emission inventory for the listed activities seeking postponement formed the basis for the assessment of the air quality impacts from SO on the receiving environment.

Point source parameters are provided in Table 4-1. A locality map indicating the position of SO in relation to surrounding residential and industrial areas is included as Figure 4-1. For completeness, the details for all point sources at SO are provided in Appendix C1; Table C-3 and Table C-4.

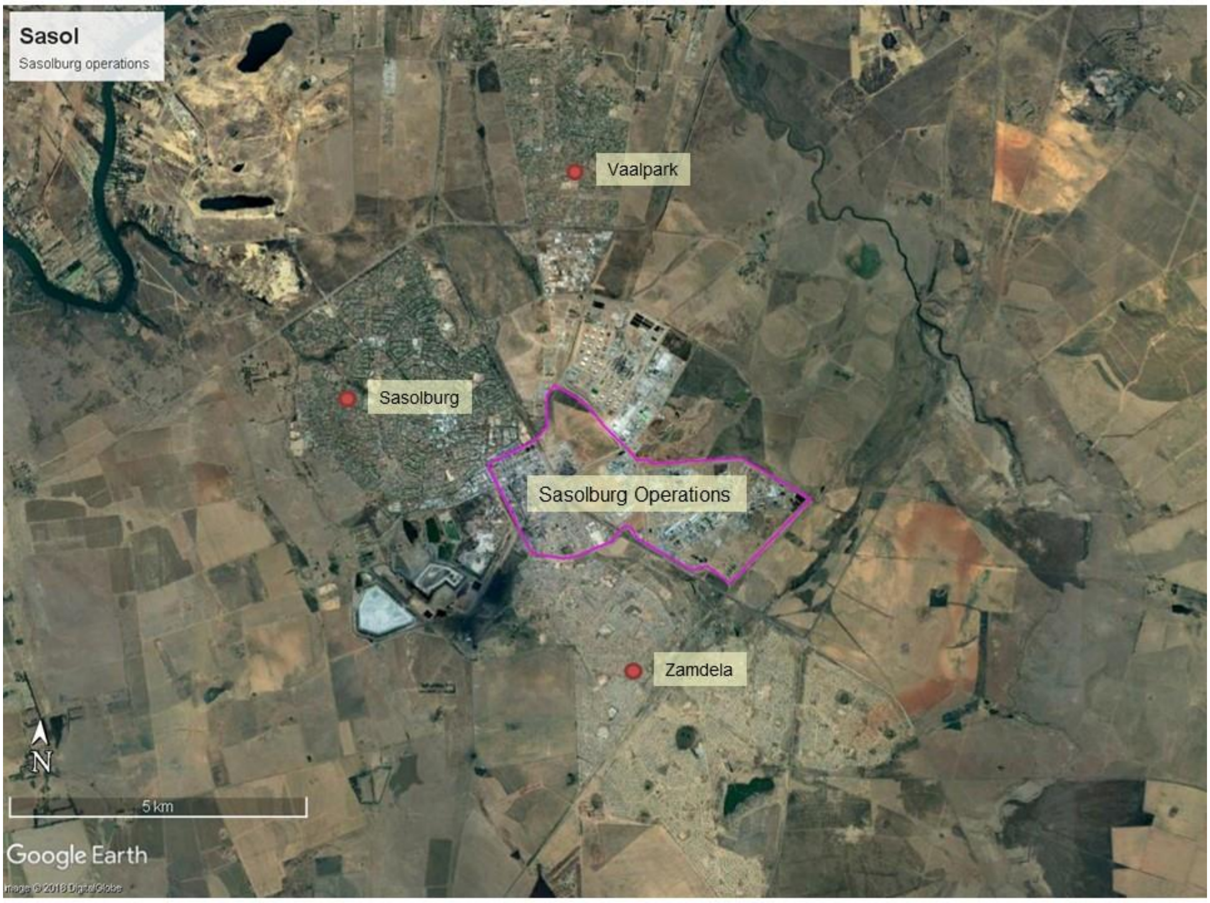

Figure 4-1: Locality map of SO in relation to surrounding residential and industrial areas

4.1 Point Source Parameters

Table 4-1: Point source parameters

Point Source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m) (a)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m^3/hr)	Actual Gas Exit Velocity (m/s)	Continuous or batch
Baseline point sources										
I1	AAA: ST6010	-26.8230	27.8680	20		0.95	846	36 923.95	14.47	Continuous
I2	Butanol ST1040	-26.8233	27.8668	25		1.5	123	68 515.78	10.77	Continuous
I60	F501 + F 502 vent	26.7762	27.8447	15		0.16	35	50.67	0.70	Continuous
I61	F 505 vent	26.7762	27.8447	15		0.1	176	57.11	2.02	Continuous
I62	E1204	26.7759	27.8447	15		0.1	24	12.44	0.44	Continuous
I63	B 1102	26.7759	27.8447	10		0.4	59	452.39	1.00	Continuous
I64	F1133 A+B	26.7759	27.8447	15		0.1	27	36.76	1.30	Continuous
I3	Fired Heater ATR A Train	-26.8263	27.8406	65	52	3.32	190	460 932	14.79	Continuous
I4	Fired Heater ATR B Train	-26.8267	27.8408	65	52	3.32	226	488 669	15.68	Continuous
I65 – I67	Rectisol	26.8227	27.8401	75	5	Combined with Steam Station 1				
I5	J 4062 A Dust scrubber	-26.8290	27.8410	22	9	1	29	56 181	19.87	Continuous
I6	J 4062 B Dust scrubber	-26.8290	27.8410	22		1	28	56 436	19.96	Continuous
I7	J4063 A	-26.8290	27.8410	85		1.5	21	232 712	36.58	Continuous
I8	J4063 B	-26.8290	27.8410	85		1.5	23	94 599	14.87	Continuous
I9	J4063 C	-26.8290	27.8410	85		1.5	23	66 607	10.47	Continuous
I10	Steam cracker furnaces, B002a,b	-26.8320	27.8440	20	10	1.8	527	106 175	11.59	Continuous
I11	Steam cracker furnaces, B003 and MEA	-26.8319	27.8440	26	16	1.2	200	34 608	8.5	Continuous
I12	Fuel gas furnace	-26.8302	27.8474	40		1.3	384	30 629	6.41	Continuous
I68	Phenol Plant	-26.8239	27.8406	30		0.2	29	26	0.23	Continuous
I69	SOx scrubber on N-base units	-26.8300	27.8470	12		0.11	101	1 984	58.00	Continuous
I13	Oven B 4701	-26.8308	27.8463	26		1	409	7 804	2.76	Continuous
I14	Oven B 4702	-26.8308	27.8463	26		1	320	7 408	2.62	Continuous
I15	Oven B 4801	-26.8308	27.8464	26		1.25	165	13 960	3.16	Continuous

Point Source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m) (a)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Continuous or batch
I16	Oven B 4802	-26.8308	27.8465	26		1.25	285	7 289	1.65	Continuous
I17	Cat prep SBR	-26.8313	27.8426	15		0.5	100	7 166	10.14	Continuous
I18	SCR outlet	-26.8294	27.8408	40	On top of roof	1.00	40	16 116	5.70	Continuous
I19	Furnace B2801	-26.8262	27.8429	20	None in the vicinity	0.7	356	3 879	2.80	Continuous
I20	Furnace B1521	-26.8258	27.8426	20	None in the vicinity	0.77	336	4 694	2.80	Continuous
I21	Furnace B2471	-26.8316	27.8499	45	None in the vicinity	0.97	324	6 997	2.63	Continuous
I22	Fired Heater (B2601)	26.4924	27.5031	39.1	n/a	1.40	35	3 547	0.64	Continuous
I27	VCM incinerator	-26.8300	27.8730	30		0.36	45	4 104	11.20	Continuous
I28	VCM Cracker	-26.8300	27.8730	40		1.71	390	101 693	12.30	Continuous
I29	PVC Dryer stack North (A)	-26.8279	27.8733	35		1.8	57	131 917	14.40	Continuous
I30	PVC Dryer stack South (B)	-26.8279	27.8734	35		1.8	61	141 352	15.43	Continuous
	PVC Multigrade (sludge plant) vent Stack	-26.8276	27.8741	6		0.05	100	89.06	12.60	Continuous
	PVC Slurry Stock Tank Stack	-26.8272	27.8744	35		1.2	45	61 073	15.00	Continuous
	PVC Reaction Stack North	-26.8276	27.8741	24		0.60	30	7 736	7.60	Continuous
	PVC Reaction Stack South	-26.8272	27.8735	24		0.60	30	7 736	7.60	Continuous
I54	DeNOx unit	-26.8255	27.8387	30	21.5	0.6	450	12 215	12	Continuous
I55	DeNOx unit	-26.8255	27.8387	30	21.5	0.6	450	12 215	12	Continuous
I56	Step 4 burner flue gas	-26.8258	27.8385	30	19	0.15	330	636.17	10	Continuous
I57	Step 6 burner flue gas	-26.8259	27.8385	30	19	0.15	330	636.17	10	Continuous
I58	Hot oil system fuel gas burner	-26.8257	27.8385	27	19	0.3	330	279.92	1.1	Continuous
I59	Step 7 burner flue gas	-26.8259	27.8385	29	19	0.3	550	865.19	3.4	Continuous
I35	Bay 1 (stack 1 - 6)	-26.8196	27.8477	27		1.2	200	89 166	21.90	Continuous
I36		-26.8196	27.8477	27		1.2	200	105 981	26.03	Continuous
I37		-26.8196	27.8477	27		1.2	200	121 168	29.76	Continuous
I38		-26.8196	27.8477	27		1.2	200	102 724	25.23	Continuous

Point Source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m) (a)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Continuous or batch
I39		-26.8196	27.8477	27		1.2	200	114 613	28.15	Continuous
I40		-26.8196	27.8477	27		1.2	200	110 378	27.11	Continuous
I41	Bay 2 (stack 7-12)	-26.8194	27.8482	27		1.2	200	111 600	27.41	Continuous
I42		-26.8194	27.8482	27		1.2	200	113 514	27.88	Continuous
I43		-26.8194	27.8482	27		1.2	200	119 539	29.36	Continuous
I44		-26.8194	27.8482	27		1.2	200	118 888	29.20	Continuous
I45		-26.8194	27.8482	27		1.2	200	116 404	28.59	Continuous
I46		-26.8194	27.8482	27		1.2	200	108 383	26.62	Continuous
I47	Bay 3 (stack 13-18)	-26.8192	27.8486	27		1.2	200	66 569	16.35	Continuous
I48		-26.8192	27.8486	27		1.2	200	105 778	25.98	Continuous
I49		-26.8192	27.8486	27		1.2	200	123 122	30.24	Continuous
I50		-26.8192	27.8486	27		1.2	200	65 266	16.03	Continuous
I51		-26.8192	27.8486	27		1.2	200	73 694	18.10	Continuous
I52		-26.8192	27.8486	27		1.2	200	54 232	13.32	Continuous
I53	NAP Bunsen Street	-26.8252	27.8602	75		1.5	215	39 634	6.23	Continuous
Point sources applying for postponement										
I31	Heavy Ends B incinerator (B6990)	-26.8255	27.8404	40		1.5	650	69 979	11.00	Continuous
I32	High sulfur pitch incinerator (B6930)	-26.8254	27.8402	40		1.5	180	159 043	25.00	Continuous
I33	Spent caustic incinerator (B6993)	-26.8255	27.8404	40		1.2	83	60 258	14.80	Continuous
I23	SS1 Boiler 4	-26.8222	27.8407	75		2.5	160	235 030	13.3	Continuous
I24	SS1 Boiler 5&6	-26.8224	27.8404	75		2.5	160	458 751	25.96	Continuous
I25	SS1 Boiler 7&8	-26.8225	27.8401	75		2.5	160	478 543	27.08	Continuous
I26	SS2 Boiler 9-15	-26.8222	27.8488	145		7.8	160	1 746 014	10.15	Continuous

Notes:

(a) "Height above nearby building" is given as the minimum difference between the release height and the height of nearby buildings, where the point source is located equidistant from more than one building. Building height differences only included for sources affected by building downwash effects.

(b) Height of release lower than nearby building.

4.2 Point Source Maximum Emission Rates during Normal Operating Conditions

In cases where periodic compliance measurements are conducted, these are measured in accordance with the methods prescribed in Schedule A of the MES and aligned with what is prescribed in the Atmospheric Emission Licence (AEL). These reflect the average of measurements conducted over a 3-hour period during normal operating conditions.

Table 4-2: Point source emission rates during normal operating conditions (units: g/s)

Point Source number	Industry name	Source name	SO_2	NO_X as NO_2	PM	CO	HF	Sum of heavy metals	Hg	Cd+Tl	TOCs	VOCs
I1	Solvents	AAA: ST6010	0.31	0.04	0.11						9.51E-6	
I2		Butanol ST1040	0.05	0.08	0.18						4.44E-1	
I60		F501 + F 502 vent									3.90E-1	
I61		F 505 vent									5.89E-1	
I62		E1204									5.89E-1	
I63		B 1102									1.34	
I64		F1133 A+B									3.69E-1	
I3	ATR Phenosolvan	Fired Heater ATR A Train	0.13	4.19	0.02							
I4		Fired Heater ATR B Train	0.19	1.89	0.12							
I65 – I67		Rectisol									292.94	0.097
I5	Prillan Plant	J 4062 A Dust scrubber			0.03							
I6		J 4062 B Dust scrubber			0.02							
I7		J4063 A			0.12							
I8		J4063 B			0.06							
I9		J4063 C			0.03							
I10	Sasol Polymers - Monomers (excluding flares)	Steam cracker furnaces, B002a,b	0.14	0.4306	0.11							
I11		Steam cracker furnaces, B003 and MEA	5.71E-3	1.82	8.24E-3							
I12	Merisol (excluding flares)	Fuel gas furnace	2.85E-2	0.19	8.24E-3							
I68		Phenol Plant									2.03	2.54E-3
I69		SOx scrubber on N-base units	5.93E-3								5.98E-1	6.34E-4
I13	Sasol Wax	Oven B 4701	3.49E-3	1.27E-2	1.90E-2							

Point Source number	Industry name	Source name	SO_2	NO_x as NO_2	PM	CO	HF	Sum of heavy metals	Hg	Cd+Tl	TOCs	VOCs
I14		Oven B 4702	2.85E-3		9.51E-4							
I15		Oven B 4801	4.12E-3	5.96E-2	4.03E-1							
I16		Oven B 4802	2.38E-2	4.03E-1	9.51E-4							
I17		Cat prep SBR			1.59E-3							
I18		SCR outlet	9.51E-4	1.788								
I19		Furnace B2801	1.59E-3	2.54E-2	1.27E-2							
I20		Furnace B1521	1.33E-2	1.58E-1	1.27E-2							
I21		Furnace B2471		4.15E-1	9.83E-3							
I22		Fired Heater (B2601)		1.99E-1	2.31E-2							
I27	Vinyl business - VCM (excluding autoclaves)	VCM incinerator	4.1E-3	3.49E-3	7.229E-3	1.59E-2	9.99E-5	2.92E-5	6.34E-07	1.27E-06		
I28		VCM Cracker	4.98E-2	1.78E-2	4.44E-3							
I29		PVC Dryer stack North (A)	1.98E-1		2.97E-1	1.61E-1	0.38					
I30		PVC Dryer stack South (B)	1.12E-1		4.08E-1	3.01E-1	0.60					
		PVC Multigrade (sludge plant) vent Stack	0.00	0.00	0.00						6.31E-04	0.00
		PVC Slurry Stock Tank Stack	0.00	0.00	0.00						6.31E-04	0.00
		PVC Reaction Stack North	0.00	0.00	0.00						6.31E-04	0.00
		PVC Reaction Stack South	0.00	0.00	0.00						3.15E-04	0.00
I54	SCCM	DeNOx unit		5.11E-2								
I55		DeNOx unit		7.01E-2								
I56		Step 4 burner flue gas		1.26E-1								
I57		Step 6 burner flue gas		1.26E-1								
I58		Hot oil system fuel gas burner		5.61E-2								
I59		Step 7 burner flue gas		1.68E-1								
I35	SGEPP – Engines	Bay 1 (stack 1 - 6)	2.85E-3	2.17E-1	1.40E-2							
I36			1.68E-02	3.92E-01	4.15E-02							
I37			2.51E-02	7.16	6.61E-01							
I38			7.77E-02	8.72	5.26E-02							

Point Source number	Industry name	Source name	SO_2	NO_x as NO_2	PM	CO	HF	Sum of heavy metals	Hg	Cd+Tl	TOCs	VOCs
I39			9.73E-02	6.40	1.33E-01							
I40			2.79E-02	7.42E-01	1.42E-01							
I41		Bay 2 (stack 7-12)	2.79E-02	4.34	5.55E-02							
I42			1.11E-02	3.94E-01	4.15E-02							
I43			1.68E-02	3.47E-01	4.15E-02							
I44			1.40E-02	3.64E-01	9.16E-02							
I45			3.04E-02	1.64E-01	3.04E-02							
I46			7.52E-02	3.50E-01	5.83E-02							
I47		Bay 3 (stack 13-18)	5.71E-03	6.22	4.39E-01							
I48			1.40E-02	3.17	3.90E-02							
I49			5.83E-02	1.88	5.83E-02							
I50			1.93E-02	3.41	2.22E-02							
I51			1.68E-02	2.94	2.79E-02							
I52			1.93E-02	1.53	2.51E-02							
I53	NAP Bunsen Street	NAP Bunsen Street		3.63								
I31	Section 6900	Heavy Ends B incinerator (B6990)	2.47	1.34	1.40	0.05	7.77E-03	1.41E-01	3.17E-05	3.17E-05	3.53E-2	1.90E-3
I32		High sulfur pitch incinerator (B6930)	40.68	9.04	1.14	0.11	1.36E-02	6.78E-02	5.07E-04	5.71E-04	1.69E-1	
I33		Spent caustic incinerator (B6993)	2.83	4.57	3.27	12.07	6.53E-03	2.2E-01	9.51E-05	3.17E-05	2.17E-01	
I23	Steam station	SS1 Boiler 4	30.49	55.27	6.28							
I24		SS1 Boiler 5&6	59.51	107.88	12.27							
I25		SS1 Boiler 7&8	62.08	112.51	12.81							
I26		SS2 Boiler 9-15	226.51	353.91	28.32							

4.3 Point Source Maximum Emission Rates during Start-up, Maintenance and/or Shut-down

Unplanned downtime events such as upset conditions are undesirable from a production perspective as well as an environmental perspective and Sasol endeavours to minimise unplanned downtime by conducting regular and pro-active maintenance and ensuring control of the process within their designed operating parameters. While unplanned downtime cannot be completely eliminated, it is minimised as far as practicably possible, and rectified with high priority.

The MES prescribes that start-up, shut-down, upset and maintenance events should not exceed 48-hours – and if they do, a Section 30 National Environmental Management Act (NEMA) incident is incurred (as also indicated in the Air Emission Licence (AEL)). SO can confirm that, in the preceding two years, its facility has not exceeded the 48-hour window during start up, maintenance, upset and shutdown conditions, which has ensured that ambient impacts are limited in duration.

Sasol owns and operates accredited ambient air quality monitoring stations in the vicinity of its Sasolburg plant. The real-time ambient air quality monitoring data is closely followed during upset conditions at the plant, to ensure that air quality does not exceed the national ambient air quality standards as a consequence of Sasol's activities.

SO has an annual phase shut down on both the Sasol One and Midland sites with a total shut-down once every four years for statutory maintenance and inspections. These shut-downs are planned well in advance. Visible emissions are normally associated with cold start-up from the Nitric acid plant and boilers as well as the reformers, which results in the flaring of gas.

The Atmospheric Impact Report (AIR) Regulations require that the maximum emissions during start-up, shut down and upset conditions must be included within the AIR for the processes. This information is unfortunately not available for two practical reasons, explained below.

1. Since Sasol operates predominantly gaseous plants, operating the plant under start-up, shut down and upset condition is a period of high instability and for safety reasons, as few people as possible are allowed on the plant. Therefore ad hoc sampling under these conditions is a safety risk and therefore the sampling cannot be conducted. It should further be emphasised that the aim of the plant personnel is to get the plant back into operation as soon as possible and therefore the support required by sampling teams cannot be provided as the focus is on returning the plant to stable operation.

   Another practical limitation is identification of the precise process conditions that will result in a maximum emission concentration. Since these conditions are unstable, large variations in plant conditions occur dynamically and pin pointing the exact combination of conditions at which to take the sample indicative of a maximum concentration is virtually impossible. Additional to the last mentioned, a maximum concentration may hypothetically exist for only a couple of minutes, however the prescribed legislation requires certain sampling techniques to be done over a period of at least an hour and then to be repeated for two times. Doing this under start-up, shut down and upset conditions are almost impossible due to the dynamics of a plant.

2. In the event where online monitoring is available, Sasol can attempt to make concentrations available for start-up, shut down and upset conditions; however, in investigating this Sasol has realised that the maximum concentrations are higher than the calibration range of the instrument, meaning that the online instrument is yielding only its maximum value. Since the actual true maximum concentration is higher than the instrument maximum, the true actual concentration cannot be provided and therefore an accurate maximum concentration under start-up, shut-down and upset conditions cannot be included.

In mentioning the above, cognisance should be taken that Sasol's ambient air quality monitoring stations monitor ambient air quality over a 24-hour period and any upset, start-up or shut down events will reflect in the ambient air quality measurements and results. Therefore, maximum measured concentrations, although not quantified on site, is included in measured values for ambient air quality.

4.4 Fugitive Emissions

Fugitive emissions on the Sasolburg sites are managed and quantified through two fugitive emissions monitoring programs.

4.4.1 Fallout Dust

Fallout dust is governed by the National Dust Control Regulations (NDCR) (Government Gazette No. 36974, No. R. 827; 1 November 2013). SO has 13 dustfall monitoring stations measuring the dust fallout on and around the site. The dust fallout buckets are placed in locations where the likely fallout of dust from coal stockpiles, fine ash dams and construction activities will occur, to ensure adequate control of most probable dust sources is in place. The Safety, Health and Environment function at the Sasolburg site is responsible for the measurement and management of dust in accordance with the NDCR and an accredited third party is responsible for replacing and analysing the buckets on a monthly basis.

The results for an annual sampling campaign for fallout dust are included in Appendix C3 (Figure C-1 to Figure C-12). These figures indicate that the fallout dust is predominantly within the lower range considered acceptable for residential areas, despite being an industrial site. Sasol inherently does not operate a process with large quantities of dust or large stock piles of possible fugitive dust emissions, with the exception of some coal stock piles and fine ash dams. The operational fine ash dam is wet and therefore wind-blown dust is limited. Non-operational fine ash dams are vegetated as soon as possible to reduce windblown dust.

The monitoring plan philosophy is that Sasol conduct monitoring and investigate spikes in the monitoring results. In the event that a spike is due to possible long-term effect, the problem will be addressed to ensure low levels of fugitive fallout dust.

4.4.2 Fugitive VOCs

The second monitoring program is associated with fugitive VOC emissions. These emissions originate from various basins and ponds, as well as from process equipment such as storage tanks. The on-site monitoring of fugitive process emissions is associated with Leak Detection and Repair. A third party contractor is contracted to conduct leak detection, with the help of a "sniffer" device and an infrared camera, to identify and quantify the leaks associated with various process emissions. The report results are then included in the maintenance plan and the leaking process units are repaired per schedule. This process has been in operation for a period exceeding five years. Subsequent to the changeover from coal to gas in 2004, the presence of harmful VOCs such as benzene, toluene and xylene is limited.

4.5 Emergency Incidents

There was one reportable incident that occurred at SO during 2016 and 2017 on the Sasol One site on 29 June 2017. The incident was as a result of a power failure outside of Sasol's control that resulted in the loss of steam throughout the site which caused a flare to emit black smoke for a period of 6 hours. The incident was reported as a NEMA Section 30 reportable incident, reference SO-env-237.

Emergency incidents on the site are handled through standard operating procedures governing the actions that need to take place as well as defining the responsibilities of the parties involved in managing the incident. Part of any environmental incident/emergency response, the environmental respondent will evaluate the incident and then classify it according to an internal ranking as well as against relevant legislative requirements which will then trigger the necessary reporting requirements.

5 IMPACT OF ENTERPRISE ON THE RECEIVING ENVIRONMENT

5.1 Analysis of Emissions' Impact on Human Health

The report includes the results for three emission scenarios per pollutant, in order to establish the delta impacts against air quality limit values. The scenarios are as follows:

- *Baseline Emissions* – modelling conducted based on the current routine inventory and impacts
- *Minimum Emissions Standards* – modelling conducted based on plants theoretically complying with New Plant Standards
- *Alternative Emission Limits* – the emission reductions as proposed by SO, where applicable and different from the scenarios above.

5.1.1 Study Methodology

5.1.1.1 Study Plan

The study methodology may conveniently be divided into a "preparatory phase" and an "execution phase". The basic methodology followed in this assessment is provided in Figure 5-1.

The preparatory phase included the flowing basic steps prior to performing the actual dispersion modelling and analyses:

1. Understand Scope of Work
2. Assign Appropriate Specialists
3. Review of legal requirements (e.g. dispersion modelling guideline)
4. Prepare a Plan of Study for Peer Review
5. Decide on Dispersion Model

The Regulations Regarding Air Dispersion Modelling (Gazette No 37804 published 11 July 2014) was referenced for the dispersion model selection (Appendix B).

Three Levels of Assessment are defined in the Regulations Regarding Air Dispersion Modelling:

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50km)
- Level 3: require more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situation:
  - where a detailed understanding of air quality impacts, in time and space, is required;
  - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types & chemical transformations;
  - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
  - when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an airshed; or,
  - when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level O_3, particulate formation, visibility)

The models recommended for Level 3 assessments are CALPUFF or SCIPUFF. In this study, CALPUFF was selected for the following reasons (as referenced in Figure 5-1 - Model Aspects to Consider and Dispersion Models):

- This Lagrangian Gaussian Puff model is also well suited to simulate low or calm wind speed conditions. Alternative regulatory models such as the US EPA AERMOD model treats all plumes as straight-line trajectories, which under calm wind conditions over-estimates the plume travel distance (Busini *et al.*, 2012; Gulia *et al.* 2015; Lakes Environmental, 2017).
- CALPUFF is able to perform chemical transformations. In this study the conversion of NO to NO_2 and the secondary formation of particulate matter was a concern.

The execution phase (i.e. dispersion modelling and analyses) firstly involves gathering specific information in relation to the emission source(s) and site(s) to be assessed. This includes:

- Source information: Emission rate, exit temperature, volume flow, exit velocity, etc.;
- Site information: Site building layout, terrain information, land use data;
- Meteorological data: Wind speed, wind direction, temperature, cloud cover, mixing height;
- Receptor information: Locations using discrete receptors and/or gridded receptors.

The model uses this specific input data to run various algorithms to estimate the dispersion of pollutants between the source and receptor. The model output is in the form of a predicted time-averaged concentration at the receptor. These predicted concentrations are compared with the relevant ambient air quality standard or guideline. Post-processing can be carried out to produce percentile concentrations or contour plots that can be prepared for reporting purposes.

The following steps were followed for the execution phase of the assessment:

- Decide on meteorological data input (Figure 5-1 - CALMET). A summary of the model control options for CALMET is provided in Appendix D. Refer to Section 5.1.4.6.
- Prepare all meteorological model input files (Figure 5-1 - CALMET)
    - Surface meteorological files
    - WRF meteorological files
    - Topography
    - Land Use
- Select control options in meteorological model (Figure 5-1 - CALMET)
    - Dispersion coefficients
    - Vertical levels
    - Receptor grid
- *Feedback to Project Team and revise where necessary*
- Review emissions inventory and ambient measurements
- *Feedback to Project Team and revise where necessary*
- Decide on dispersion model controls and module options (Figure 5-1 - CALPUFF). A summary of the model control options for CALPUFF is provided in Appendix E. Refer to Section 5.1.4.6
- Decide on dispersion module options (Figure 5-1 - CALPUFF).
    - Sulfate and nitrate formation module (MESOPUFF or RiVAD)
    - NO_2 formation (MESOPUFF or RiVAD)
    - Model resolution
- *Feedback to Project Team and revise where necessary*
- Decide on modelling domain and receptor locations (Figure 5-1 – CALPUFF and Simulations)
- *Feedback to Project Team and revise where necessary*

- Prepare all dispersion model input files (Figure 5-1 - CALPUFF)
    - Control options
    - Measured ambient O_3 and NH_3 for chemical transformation module
    - Meteorology
    - Source data
    - Receptor grid and discrete receptors
- Review all modelling input data files and fix where necessary
- Simulate source groups per pollutant and calculate air concentration levels for regular and discrete grid locations for the following scenarios (Figure 5-1 – Simulations):
    - Baseline (current) air emissions
    - Change Baseline sources to reflect theoretical compliance with “New Plant” standards
    - Change Baseline sources to reflect “Alternative Emission Limits”, where applicable
- Compare against National Ambient Air Quality Standards (NAAQS)
- Preparation of draft AIR
- Preparation of final AIR.

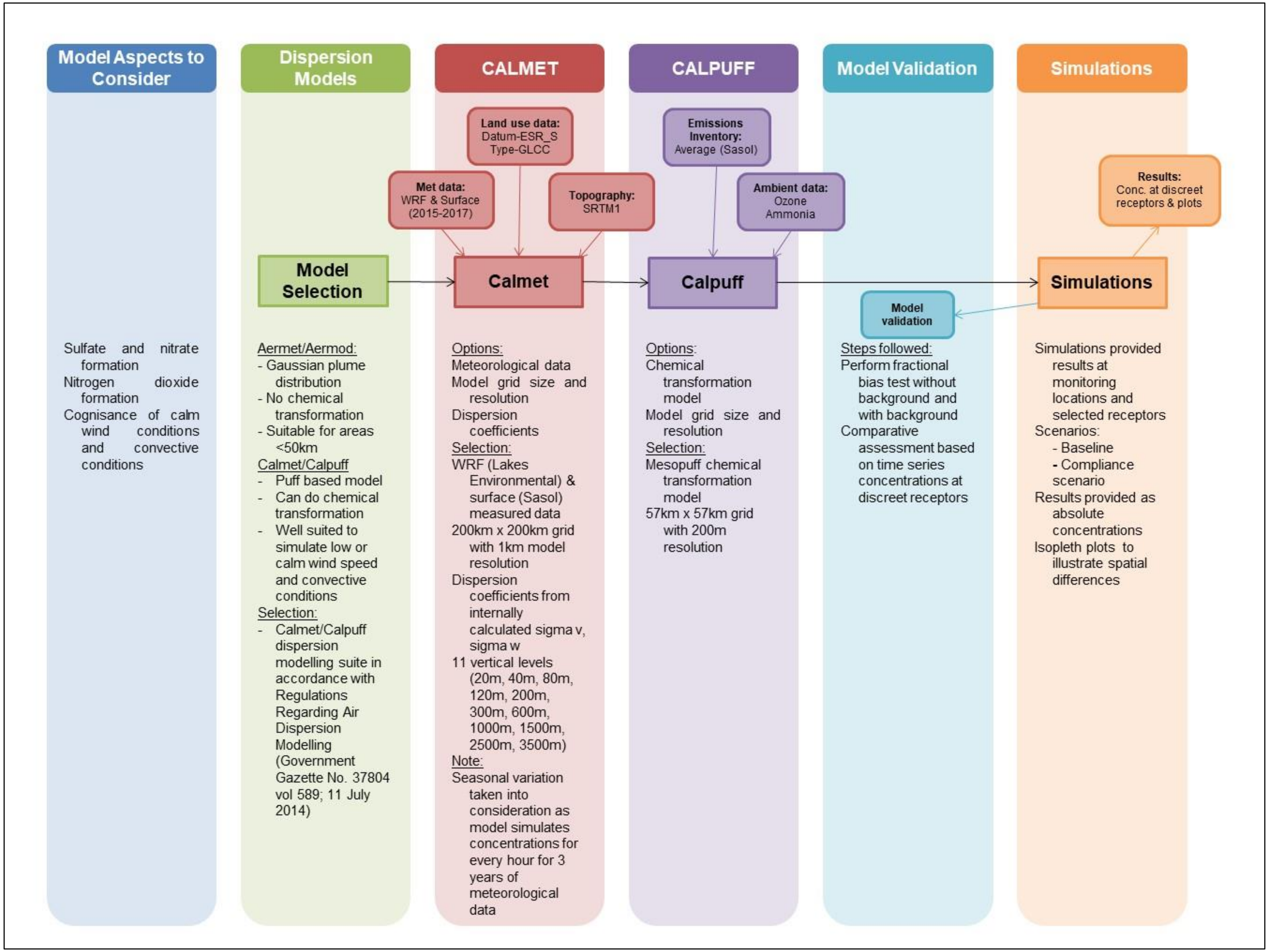

Figure 5-1: The basic study methodology followed for the assessment

5.1.1.2 Emission Scenarios

In order to assess the impact of the postponements for which SO is applying, three emissions scenarios were modelled, with the results throughout the AIR presented as illustrated in Figure 5-2.

1. **Current baseline emissions**, reflective of the impacts of present operations, which are modelled as *averages* of measurements taken from periodic emission monitoring. This scenario is represented by the first column in the presentation of all AIR graphs (shown in blue in Figure 5-2). Baseline emissions were derived from 3rd parties and accredited (ISO/IEC17025) laboratories. Emissions measurements follow the requirements prescribed in Schedule A of GN 893. For Steam Stations and Thermal Oxidation however the current maximum allowable emission limits were modelled to accommodate uncertainties in the representativeness of some measurements at Steam Stations and since no alternative information is available for Thermal Oxidation since the plant is still offline. Although this approach over-predicts ambient impacts, it will accommodate the impact of the emissions of the site whilst all concentrations are confirmed.

The following two scenarios are modelled to reflect the administrative basis of the MES, being ceiling emission levels. These scenarios are therefore theoretical cases where the point source is constantly emitting at the highest expected emission level possible under normal operating conditions, for the given scenario (i.e. the 100th percentile emission concentration).

2. **Compliance with the 2020 new plant standards.** This is modelled as a ceiling emissions limit (i.e. maximum emission concentration) aligned with the prescribed standard and reflects a scenario where abatement equipment is introduced to theoretically reduce emissions to conform to the standards. This scenario is then represented by the second column in the presentation of all AIR graphs (shown in green in Figure 5-2).
3. **A worst-case scenario of operating constantly at the requested alternative emissions limits**, which have been specified as ceiling emissions limits (i.e. maximum emission concentrations). This scenario is represented by the third column in the presentation of all AIR graphs (shown in purple in Figure 5-2). It is re-emphasised that SO will not physically increase its current baseline emissions (expressed as an average). SO seeks alternative emissions limits which are aligned with the performance of the new technology which is currently being installed. Since the technology's performance can only be confirmed after the submission of the Postponement Application, the actual alternative limit that will be requested will be confirmed at the end of 2019. It is expected that this limit will be lower than the current AEL limit which is modelled for Steam Stations during this scenario.

In Figure 5-2, the black arrows above the green bar reflects the predicted delta (change) in ambient impacts of SO's baseline emissions versus the given compliance scenario. The orange dot in Figure 5-2 represents physically measured ambient air quality, reflective of the total impact of all sources in the vicinity, as the 99th percentile recorded value over the averaging period. On a given day, there is a 99% chance that the actual measured ambient air quality would be lower than this value, but this value is reflected for the purpose of aligning with modelling requirements. The orange line represents the applicable NAAQS.

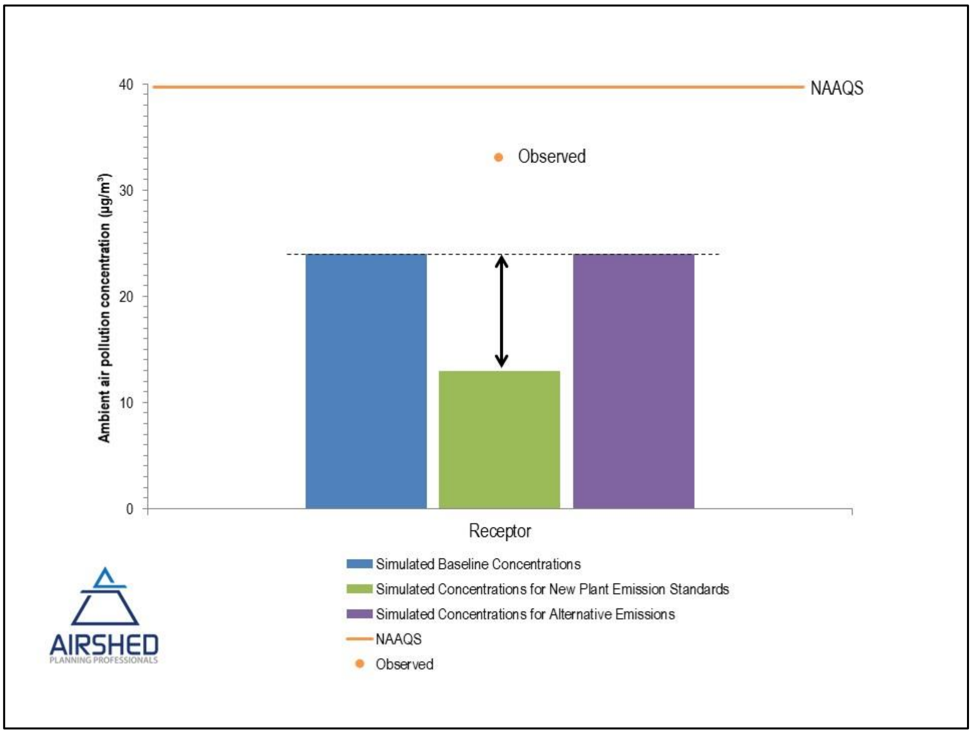

Figure 5-2: Schematic displaying how the dispersion modelling scenarios are presented, for each monitoring station receptor in the modelling domain

5.1.1.3 CALPUFF/CALMET Modelling Suite

As discussed in the previous section, the CALPUFF model was selected for use in the current investigation to predict maximum short-term (1 and 24-hour) and annual average ground-level concentrations at various receptor locations within the computational domain. CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal (Scire *et al.*, 2000a). It can accommodate arbitrarily varying point source, area source, volume source, and line source emissions. The CALPUFF code includes algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub grid scale terrain interactions as well as longer range effects such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, vertical wind shear, overwater transport and coastal interaction effects.

The model is intended for use on scales from tens of metres to hundreds of kilometres from a source (US EPA 1998). The CALPUFF model allows the user to select from a number of calculation options, including a choice of dispersion coefficient and chemical transformation formulations. The different dispersion coefficient approaches accommodated in the CALPUFF model include:

- stability-based empirical relationships such as the Pasquill-Gifford or McElroy-Pooler dispersion coefficients;
- turbulence-based dispersion coefficients (based on measured standard deviations of the vertical and crosswind horizontal components of the wind); and
- similarity theory to estimate the turbulent quantities using the micrometeorological variables calculated by CALMET

The most desirable approach is to use turbulence-based dispersion coefficients using measured turbulent velocity variances or intensity components, if such data are readily available and they are of good quality. However, since reliable turbulent measurements are generally not available, the next best recommendation is to use the similarity approach.

CALPUFF includes parameterized chemistry modules for the formation of secondary sulfate and nitrate from the oxidation of the emitted primary pollutants, SO_2 and NO_x. The conversion processes are assumed to be linearly dependent (first-order) on the relevant primary species concentrations. Two options are included, namely the MESOPUFF II and RIVAD/ARM3 chemistry options. In both options, a fairly simple stoichiometric thermodynamic model is used to estimate the partitioning of total inorganic nitrate between gas-phase nitric acid and particle-phase ammonium nitrate. Ammonia and O_3 concentrations are required as background values to the model.

CALPUFF uses dry deposition velocities to calculate the dry deposition of gaseous and particulate pollutants to the surface. These dry deposition velocities can either be user-specified or calculated internally in CALPUFF. A resistance-based model is used for the latter option. For gaseous pollutants, the resistances that are considered are the atmospheric resistance, the deposition layer resistance, and the canopy resistance. For particles, a gravitational settling term is included, and the canopy resistance is assumed to be negligible. CALPUFF uses the scavenging coefficient approach to parameterize wet deposition of gases and particles. The scavenging coefficient depends on pollutant characteristics (e.g., solubility and reactivity), as well as the precipitation rate and type of precipitation. The model provides default values for the scavenging coefficient for various species and two types of precipitation (liquid and frozen). These values may be overridden by the user.

CALPUFF also has the capability to model the effects of vertical wind shear by explicitly allowing different puffs to be independently advected by their local average wind speed and direction, as well as by optionally allowing well-mixed puffs to split into two or more puffs when across-puff shear becomes important. Another refinement is an option to use a probability density function (pdf) model to simulate vertical dispersion during convective conditions.

The CALPUFF modelling system consists of a number of software components, as summarised in Table 5-1, however only CALMET and CALPUFF contain the simulation engines to calculate the three-dimensional atmospheric boundary layer conditions and the dispersion and removal mechanisms of pollutants released into this boundary layer. The other components are mainly used to assist with the preparation of input and output data. Table 5-1 also includes the development versions of each of the codes used in this investigation.

Table 5-1: Summary description of CALPUFF/CALMET model suite with versions used in the investigation

Module	Version	Description
CALMET	V6.5.0	Three-dimensional, diagnostic meteorological model
CALPUFF	V7.2.1	Non-steady-state Gaussian puff dispersion model with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation and other effects.
CALPOST	V7.1.0	A post-processing program for the output fields of meteorological data, concentrations and deposition fluxes.
CALSUM	V7.0.0	Sums and scales concentrations or wet/dry fluxes from two or more source groups from different CALPUFF runs
PRTMET	V4.495	Lists selected meteorological data from CALMET and creates plot files
POSTUTIL	V7.0.0	Processes CALPUFF concentration and wet/dry flux files. Creates new species as weighted combinations of modelled species; merges species from different runs into a single output file; sums and scales results from different runs; repartitions nitric acid/nitrate based on total available sulfate and ammonia.

Module	Version	Description
TERREL	V7.0.0	Combines and grids terrain data
CTGPROC	V7.0.0	Processes and grids land use data
MAKEGEO	V3.2	Merges land use and terrain data to produce the geophysical data file for CALMET

A summary of the main CALMET and CALPUFF control options are given in Appendices D and E, respectively.

5.1.2 Legal Requirements

5.1.2.1 Atmospheric Impact Report

In the event where an application for postponement is being made, Section 21 of NEM: Air Quality Act (AQA), Regulations 11 and 12 state:

1. An application for postponement may be made to the National Air Quality Officer
2. The application contemplated in Regulation 11 must include, amongst others, an Atmospheric Impact Report.

The format of the Atmospheric Impact Report is stipulated in the Regulations Prescribing the Format of the AIR, Government Gazette No. 36904, Notice Number 747 of 2013 (11 October 2013) (Appendix B; Table B-1).

Sasol appointed Airshed to compile this AIR to meet the requirements of Regulation 12 (Postponement of compliance time frames) of the Listed Activities and Associated MES (Government Gazette No. 37054, 22 November 2013) (Appendix B; Table B-1).

5.1.2.2 National Ambient Air Quality Standards

Modelled concentrations will be assessed against NAAQS (Table 5-2), where they are prescribed by South African legislation. Where no NAAQS exists for a relevant non-criteria pollutant, health screening effect levels based on international guidelines are used. These are discussed with the results of dispersion modelling in Section 5.1.8.

Table 5-2: National Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Frequency of Exceedance	Compliance Date
Benzene (C_6H_6)	1 year	5	0	1 January 2015
Carbon Monoxide (CO)	1 hour	30000	88	Immediate
	8 hour[(a)]	10000	11	Immediate
Lead (Pb)	1 year	0.5	0	Immediate
Nitrogen Dioxide (NO_2)	1 hour	200	88	Immediate
	1 year	40	0	Immediate
Ozone (O_3)	8 hour[(b)]	120	11	Immediate
Inhalable particulate matter less than	24 hour	40	4	Immediate until 31 December 2029
	24 hour	25	4	1 January 2030

Pollutant	Averaging Period	Concentration (µg/m³)	Frequency of Exceedance	Compliance Date
2.5 µm in diameter ($PM_{2.5}$)	1 year	20	0	Immediate until 31 December 2029
	1 year	15	0	1 January 2030
Inhalable particulate matter less than 10 µm in diameter (PM_{10})	24 hour	75	4	Immediate
	1 year	40	0	Immediate
Sulfur Dioxide (SO_2)	10 minutes	500	526	Immediate
	1 hour	350	88	Immediate
	24 hour	125	4	Immediate
	1 year	50	0	Immediate

Notes:
(a) Calculated on 1 hour averages.
(b) Running average.

5.1.2.3 National Dust Control Regulations

South Africa's Draft National Dust Control Regulations were published on 27 May 2011 with the dust fallout standards passed and subsequently published on 1 November 2013 (Government Gazette No. 36974). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Acceptable dustfall rates according to the regulations are summarised in Table 5-3.

Table 5-3: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m²-day over a 30 day average	Permitted frequency of exceedance
Residential areas	D < 600	Two within a year, not sequential months.
Non-residential areas	600 < D < 1 200	Two within a year, not sequential months.

The regulations also specify that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

A revised Draft National Dust Control Regulations were published on 25 March 2018 (Government Gazette No. 41650) which references the same acceptable dustfall rates but refers to the latest version of the ASTM D1739 method to be used for sampling.

5.1.3 Regulations Regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Regulations regarding Air Dispersion Modelling were promulgated in Government Gazette No. 37804 vol. 589; 11 July 2014, and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations Regarding Air Dispersion Modelling are applicable:

(a) in the development of an air quality management plan, as contemplated in Chapter 3 of the AQA;
(b) in the development of a priority area air quality management plan, as contemplated in Section 19 of the AQA;
(c) in the development of an atmospheric impact report, as contemplated in Section 30 of the AQA; and,
(d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the AQA.

The Regulations have been applied to the development of this report. The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Chapter 2 of the Regulations present the typical levels of assessments, technical summaries of the prescribed models (SCREEN3, AERSCREEN, AERMOD, SCIPUFF, and CALPUFF) and good practice steps to be taken for modelling applications.

Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Chapter 3 of the Regulations prescribe the source data input to be used in the models.

Dispersion modelling can typically be used in the:

- Apportionment of individual sources for installations with multiple sources. In this way, the individual contribution of each source to the maximum ambient predicted concentration can be determined. This may be extended to the study of cumulative impact assessments where modelling can be used to model numerous installations and to investigate the impact of individual installations and sources on the maximum ambient pollutant concentrations.
- Analysis of ground level concentration changes as a result of different release conditions (e.g. by changing stack heights, diameters and operating conditions such as exit gas velocity and temperatures).
- Assessment of variable emissions as a result of process variations, start-up, shut-down or abnormal operations.
- Specification and planning of ambient air monitoring programmes which, in addition to the location of sensitive receptors, are often based on the prediction of air quality hotspots.

The above options can be used to determine the most cost-effective strategy for compliance with the NAAQS. Dispersion models are particularly useful under circumstances where the maximum ambient concentration approaches the ambient air quality limit value and provide a means for establishing the preferred combination of mitigation measures that may be required including:

- Stack height increases;
- Reduction in pollutant emissions through the use of air pollution control systems (APCS) or process variations;
- Switching from continuous to non-continuous process operations or from full to partial load.

Chapter 4 of the Regulations prescribe meteorological data input from onsite observations to simulated meteorological data. The chapter also gives information on how missing data and calm conditions are to be treated in modelling applications. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the diluting effect of the atmosphere. Therefore, it is important that meteorology is carefully considered when modelling.

New generation dispersion models, including models such as AERMOD and CALPUFF[1], simulate the dispersion process using planetary boundary layer (PBL) scaling theory. PBL depth and the dispersion of pollutants within this layer are influenced by specific surface characteristics such as surface roughness, albedo and the availability of surface moisture:

- Roughness length (z_o) is a measure of the aerodynamic roughness of a surface and is related to the height, shape and density of the surface as well as the wind speed.
- Albedo is a measure of the reflectivity of the Earth's surface. This parameter provides a measure of the amount of incident solar radiation that is absorbed by the Earth/atmosphere system. It is an important parameter since absorbed solar radiation is one of the driving forces for local, regional, and global atmospheric dynamics.
- The Bowen ratio provides measures of the availability of surface moisture injected into the atmosphere and is defined as the ratio of the vertical flux of sensible heat to latent heat, where sensible heat is the transfer of heat from the surface to the atmosphere via convection and latent heat is the transfer of heat required to evaporate liquid water from the surface to the atmosphere.

Topography is also an important geophysical parameter. The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result. Thus the accurate determination of terrain elevations in air dispersion models is very important.

The modelling domain would normally be decided on the expected zone of influence; the latter extent being defined by the predicted ground level concentrations from initial model runs. The modelling domain must include all areas where the ground level concentration is significant when compared to the air quality limit value (or other guideline). Air dispersion models require a receptor grid at which ground-level concentrations can be calculated. The receptor grid size should include the entire modelling domain to ensure that the maximum ground-level concentration is captured and the grid resolution (distance between grid points) sufficiently small to ensure that areas of maximum impact adequately covered. No receptors however should be located within the property line as health and safety legislation (rather than ambient air quality standards) is applicable within the site.

Chapter 5 provides general guidance on geophysical data, model domain and coordinates system required in dispersion modelling, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air concentration data. The chapter also provides guidance on the treatment of NO_2 formation from NO_x emissions, chemical transformation of sulfur dioxide into sulfates and deposition processes.

Chapter 7 of the Regulations outline how the plan of study and modelling assessment reports are to be presented to authorities. A comparison of how this study met the requirements of the Regulations is provided in Appendix B.

5.1.4 Atmospheric Dispersion Processes

CALPUFF initiates the simulation of point source plumes with a calculation of buoyant plume rise as discussed below in Section 5.1.4.1. Transport winds are extracted from the meteorological data file at the location of the stack and at the effective plume height (stack height plus plume rise). For near-field effects, the height of the plume in transition to the final plume height is taken into account. The puff release rate is calculated internally, based on the transport speed and the distance to the closest receptor.

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[1] The CALMET modelling system require further geophysical parameters including surface heat flux, anthropogenic heat flux and leaf area index (LAI).

As the puff is transported downwind, it grows due to dispersion and wind shear, and the trajectory is determined by advection winds at the puff location and height at each time step. The pollutant mass within each puff is initially a function of the emission rate from the original source. The pollutant mass is also subject to chemical transformation, washout by rain and dry deposition, when these options are selected, as is the case in this application. Chemical transformation and removal are calculated based on a one-hour time step.

Both wet and dry deposition fluxes are calculated by CALPUFF, based on a full resistance model for dry deposition and the use of precipitation rate-dependent scavenging coefficients for wet deposition. Pollutant mass is removed from the puff due to deposition at each time step. For the present modelling analyses, most options were set at "default" values, including the MESOPUFF II transformation scheme[2] and the treatment of terrain.

5.1.4.1 Plume Buoyancy

Gases leaving a stack mix with ambient air and undergo three phases namely the initial phase, the transition phase and the diffusion phase (Figure 5-3). The initial phase is greatly determined by the physical properties of the emitted gases. These gases may have momentum as they enter the atmosphere and are often heated and therefore warmer than the ambient air. Warmer gases are less dense than the ambient air and are therefore buoyant. A combination of the gases' momentum and buoyancy causes the gases to rise (vertical jet section, in Figure 5-3). In the Bent-Over Jet Section, entrainment of the cross flow is rapid because, by this time, appreciable growth of vortices has taken place. The self-generated turbulence causes mixing and determines the growth of plume in the thermal section. This is referred to as plume rise and allows air pollutants emitted in this gas stream to be lifted higher in the atmosphere. Since the plume is higher in the atmosphere and at a further distance from the ground, the plume will disperse more before it reaches ground level. With greater volumetric flow and increased exit gas temperatures, the plume centreline would be higher than if either the volumetric flow or the exit gas temperature is reduced. The subsequent ground level concentrations would therefore be lower.

[2] A sensitivity study was carried out with the RIVAD II transformation scheme to examine the performance of the different approaches to calculating the SO_2 to SO_4 and NO_x to NO_3 transformation rates. The concentrations from the RIVAD II and the MESOPUFF II transformation schemes showed no real bias with the secondary particulate formation varying by -41% to 31% for the two schemes.

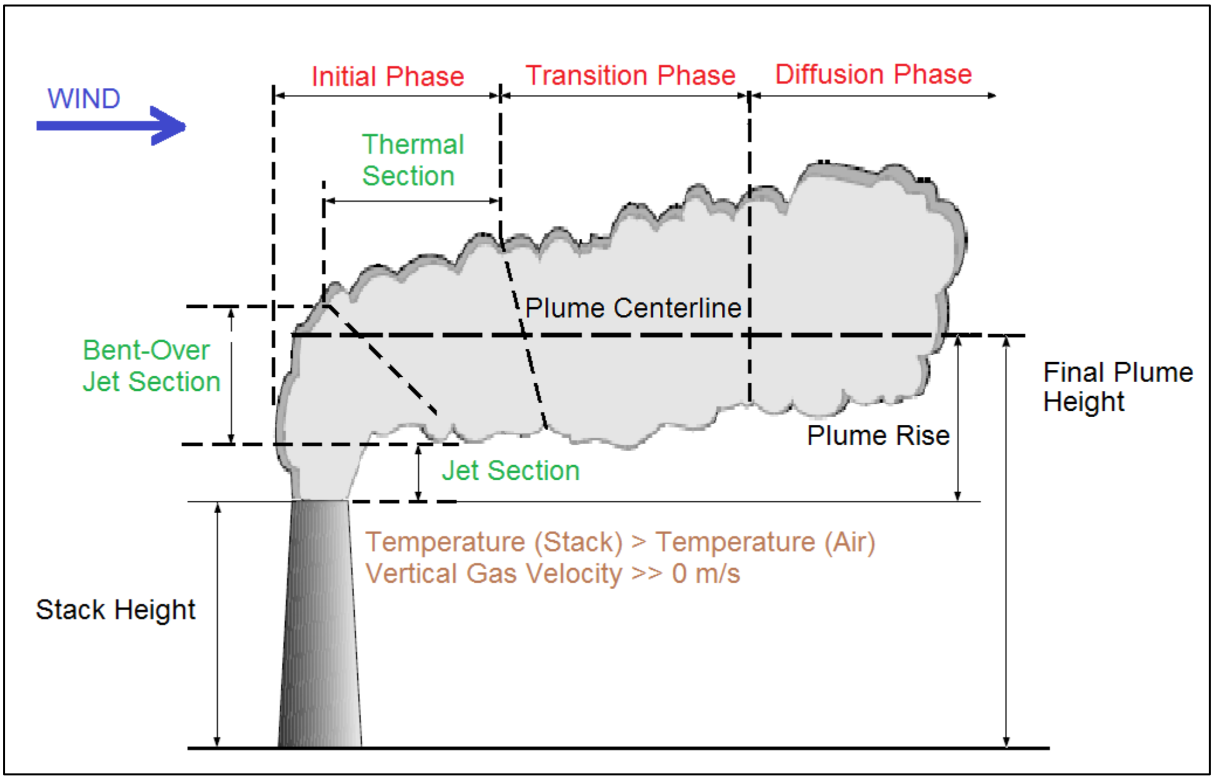

Figure 5-3: Plume buoyancy

This is particularly important in understanding some of the dispersion model results in Section 5.1.8.

5.1.4.2 Urban & Rural Conditions

Land use information is important to air dispersion modelling, firstly to ensure that the appropriate dispersion coefficients and wind profiles (specified as surface roughness) are used, and secondly, that the most appropriate chemical transformation models are employed. Urban conditions result in different dispersion conditions than in rural areas, as well as changing the vertical wind profiles. Urban conditions are also generally associated with increased levels of VOCs, thereby influencing chemical equilibriums between the photochemical reactions of NO_x, CO and O_3.

It can be appreciated that the definition of urban and rural conditions for the dispersion coefficients and wind profiles, on the one hand, and chemical reactions on the other, may not be the same. Nonetheless, it was decided to use the US Environmental Protection Agency's (US EPAs) guideline on air dispersion models (US EPA 2005), to classify the surrounding land-use as rural or urban based on the Auer method, which is strictly recommended for selecting dispersion coefficients.

The classification scheme is based on the activities within a 3 km radius of the emitting stack. Areas typically defined as rural include residences with grass lawns and trees, large estates, metropolitan parks and golf courses, agricultural areas, undeveloped land and water surfaces. An area is defined as urban if it has less than 35% vegetation coverage or the area falls into one of the use types in Table 5-4.

Table 5-4: Definition of vegetation cover for different developments (US EPA 2005)

Urban Land-Use		
Type	**Development Type**	**Vegetation Cover**
I1	Heavy industrial	Less than 5%

Urban Land-Use		
Type	Development Type	Vegetation Cover
I2	Light/moderate industrial	Less than 10%
C1	Commercial	Less than 15%
R2	Dense/multi-family	Less than 30%
R3	Multi-family, two storeys	Less than 35%

According to this classification scheme, the study area is classified as urban.

5.1.4.3 Nitrogen Dioxide Formation

Of the several species of nitrogen oxides, only NO_2 is specified in the NAAQS. Since most sources emit uncertain ratios of these species and these ratios change further in the atmosphere due to chemical reactions, a method for determining the amount of NO_2 in the plume must be selected.

Estimation of this conversion normally follows a tiered approach, as discussed in the Regulations Regarding Air Dispersion Modelling (Government Gazette No. 37804, published 11 July 2014), which presents a scheme for annual averages:

> *Tier 1: Total Conversion Method*
> *Use any of the appropriate models recommended to estimate the maximum annual average NO_2 concentrations by assuming a total conversion of NO to NO_2. If the maximum NO_x concentrations are less than the NAAQS for NO_2, then no further refinement of the conversion factor is required. If the maximum NO_x concentrations are greater than the NAAQS for NO_2, or if a more "realistic" estimate of NO_2 is desired, proceed to the second tier level.*
>
> *Tier 2: Ambient Ratio Method (ARM) - Multiply NO_x by a national ratio of NO_2/NO. = 0.80*
> *Assume a wide area quasi-equilibrium state and multiply the Tier 1 empirical estimate NO_x by a ratio of NO_2/NO_x = 0.80. The ratio is recommended for South Africa as the conservative ratio based on a review of ambient air quality monitoring data from the country. If representative ambient NO and NO_2 monitoring data is available (for at least one year of monitoring), and the data is considered to represent a quasi-equilibrium condition where further significant changes of the NO/NO_2 ratio is not expected, then the NO/NO_2 ratio based on the monitoring data can be applied to derive NO_2 as an alternative to the national ratio of 0.80.*

In the Total Conversion Method, the emission rate of all NO_x species is used in the dispersion model to predict ground-level concentrations of total NO_x. These levels of NO_x are assumed to exist as 100% NO_2 and are directly compared to the NAAQS for NO_2. If the NAAQS are met, the Tier 2 methods are not necessary.

Although not provided in the Regulations (Section 5.1.3), the conversion of NO to NO_2 may also be based on the amount of ozone available within the volume of the plume. The NO_2/NO_x conversion ratio is therefore coupled with the dispersion of the plume. This is known as the Ozone Limiting Method (OLM). Use of onsite ozone data is always preferred for the OLM method.

Ideally, the NO_2 formation should be dealt with in the dispersion model. CALPUFF has one such a module, known as the RIVAD / ARM3 chemical formulations. The RIVAD / ARM3 chemical formulations option in the CALPUFF model can be used to calculate NO_2 concentrations directly in rural (non-urban) areas (Morris et al., 1988). The RIVAD / ARM3 option incorporates the effect of chemical and photochemical reactions on the formation of nitrates and other deposition chemicals.

However, since the study area could be classified as urban (Section 5.1.4.2), the RIVAD / ARM3 chemical formulations should not be used.

Whilst the MESOPUFF II chemical transformation scheme, which is also included in the CALPUFF model accommodates NO_x reactions, these are only considering the formation of nitrates and not the NO /NO_2 reactions.

Given all of the above limitations, it was decided to employ the Ambient Ratio Method (ARM), i.e. the second version of the DEA Tier 2 option. The ARM ambient ratio method is based upon the premise that the NO_2/NO_x ratio in a plume changes as it is transported but attains an equilibrium value some distance away from the source (Scire and Borissova, 2011). In their study, Scire and Borissova analysed hourly monitored NO_2 and NO_x data for 2006 at 325 monitoring sites throughout USA, which amounted to approximately 2.8 million data points for each species. These observations were grouped into a number of concentration ranges (bins), and the binned data were used to compute bin maximums and bin average curves. Short-term (1-hr) NO_2/NO_x ratios were subsequently developed based on bin-maximum data. Similarly, long-term (annual average) NO_2/NO_x ratios were based on bin-averaged data. The method was tested using the NO_2/NO_x ratios applied to the observed NO_x at selected stations to predict NO_2, and then compared to observed NO_2 concentrations at that station. The comparison of NO_2 derived from observed NO_x using these empirical curves was shown to be a conservative estimate of observed NO_2, whilst at the same time arriving at a more realistic approximation than if simply assuming a 100% conversion rate. More details of the adopted conversion factors are given in Appendix F.

5.1.4.4 Particulate Formation

CALPUFF includes two chemical transformation schemes for the calculation of sulfate and nitrate formation from SO_2 and NO_x emissions. These are the MESOPUFF II and the RIVAD / ARM3 chemical formulations. Whist the former scheme is not specifically restricted to urban or rural conditions; the latter was developed for use in rural conditions. Since the study area could be classified as urban (Section 5.1.5), the RIVAD / ARM3 chemical formulations should not be used. The chemical transformation scheme chosen for this analysis was therefore the MESOPUFF II scheme. As described in the CALPUFF User Guide it is a "pseudo first-order chemical reaction mechanism" and involves five pollutant species namely SO_2, sulfates (SO_4), NO_x, nitric acid (HNO_3) and particulate nitrate. CALPUFF calculates the rate of transformation of SO_2 to SO_4, and the rate of transformation of NO_x to NO_3, based on environmental conditions including the ozone concentration, atmospheric stability, solar radiation, relative humidity, and the plume NO_x concentration. The daytime reaction formulation depends on solar radiation and the transformation increases non-linearly with the solar radiation (see the SO_2 to SO_4 transformation rate equation (equation 2-253 in the CALPUFF User Guide). At night, the transformation rate defaults to a constant value of 0.2% per hour. Calculations based on these formulas show that the transformation rate can reach about 3 per cent per hour at noon on a cloudless day with 100 ppb of ozone.

With the MESOPUFF-II mechanism, NO_x transformation rates depend on the concentration levels of NO_x and O_3 (equations 2-254 and 2-255 in the CALPUFF User Guide) and both organic nitrates (RNO_3) and HNO_3 are formed. According to the scheme, the formation of RNO_3 is irreversible and is not subject to wet or dry deposition. The formation of HNO_3, however, is reversible and is a function of temperature and relative humidity. The formation of particulate nitrate is further determined through the reaction of HNO_3 and NH_3. Background NH_3 concentrations are therefore required as input to calculate the equilibrium between HNO_3 and particulate nitrate. At night, the NO_x transformation rate defaults to a constant value of 2.0% per hour. Hourly average ozone and ammonia concentrations were included as input in the CALPUFF model to facilitate these sulfate and nitrate formation calculations.

The limitation of the CALPUFF model is that each puff is treated in isolation, i.e. any interaction between puffs from the same or different points of emission is not accounted for in these transformation schemes. CALPUFF first assumes that ammonia reacts preferentially with sulfate, and that there is always sufficient ammonia to react with the entire sulfate present within a single puff. The CALPUFF model performs a calculation to determine how much NH_3 remains after the particulate sulfate has been formed and the balance would then be available for reaction with NO_3 within the puff. The formation of particulate nitrate is subsequently limited by the amount of available NH_3. Although this may be regarded a limitation, in this application the particulate formation is considered as a group and not necessarily per species.

5.1.4.5 Ozone Formation

Similar to sulphate, nitrate and nitrogen dioxide, O_3 can also be formed through chemical reactions between pollutants released into the atmosphere. As a secondary pollutant, O_3 is formed in the lower part of the atmosphere, from complex photochemical reactions following emissions of precursor gases such as NOx and VOCs (Seinfeld and Pandis, 1998). O_3 is produced during the oxidation of CO and hydrocarbons by hydroxyls (OH) in the presence of NO_x and sunlight (Seinfeld and Pandis, 1998). The rate of ozone production can therefore be limited by CO, VOCs or NO_x. In densely populated regions with high emissions of NOx and hydrocarbons, rapid O_3 production can take place and result in a surface air pollution problem. In these urban areas O_3 formation is often VOC-limited. O_3 is generally NO_x-limited in rural areas and downwind suburban areas.

O_3 concentration levels have the potential to become particularly high in areas where considerable O_3 precursor emissions combine with stagnant wind conditions during the summer, when high insolation and temperatures occur (Seinfeld and Pandis, 1998). The effects of sunlight on O_3 formation depend on its intensity and its spectral distribution.

The main sectors that emit ozone precursors are road transport, power and heat generation plants, household (heating), industry, and petrol storage and distribution. In many urban areas, O_3 nonattainment is not caused by emissions from the local area alone. Due to atmospheric transport, contributions of precursors from the surrounding region can also be important. The transport of O_3 is determined by meteorological and chemical processes which typically extend over spatial scales of several hundred kilometres. Thus, in an attempt to study O_3 concentrations in a local area, it is necessary to include regional emissions and transport. This requires a significantly larger study domain with the inclusion of a significantly more comprehensive emissions inventory of NO_x and VOCs sources (e.g. vehicle emissions in Gauteng). Such a collaborative study was not within the scope of this report.

5.1.4.6 Model Input

5.1.4.6.1 Meteorological Input Data

The option of Partial Observations was selected for the CALMET wind field model which used both simulated and observed meteorological data (refer to Appendix D for all CALMET control options). For simulated data, the Weather Research and Forecasting mesoscale model (known as WRF) was used.

The WRF Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. It features two dynamical cores, a data assimilation system, and a software architecture facilitating parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres. WRF can generate atmospheric simulations using real data (observations, analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally-efficient platform, while providing recent advances in physics, numeric, and data assimilation contributed by developers across the very broad research community.

WRF data for the period 2015 to 2017 on a 4 km horizontal resolution for a 200 km by 200 km was used. An evaluation of the WRF data is provided in Table 5-6 with the benchmark for the WRF data provided in Table 5-5. This evaluation was undertaken for a point extracted at OR Tambo (see Figure 5-8). OR Tambo was selected for the evaluation as it is expected that the data quality at this weather station is of high standard. From the evaluation, the daily average WRF results for the period 2015 to 2017 were within the benchmarks for model evaluation, with the exception of wind direction (WRF providing value of 36 degrees for the gross error where benchmark is at ≤30 degrees) and temperature (WRF providing value of 2.22 K for the gross error where the benchmark is at ≤2 K and -1.27 K for the mean bias where benchmark is at ≤± 0.5 K).

Table 5-5: Benchmarks for WRF Model Evaluation

	Wind Speed	Wind Direction	Temperature	Humidity
IOA	≥ 0.6		≥ 0.8	≥ 0.6
RMSE	≤ 2 m/s			
Mean Bias	≤ ± 0.5 m/s	≤ ± 10 deg	≤ ± 0.5 K	≤ ± 1 g/kg
Gross Error		≤ 30 deg	≤ 2 K	≤ 2 g/kg

Table 5-6: Daily evaluation results for the WRF simulations for the 2015-2017 extracted at OR Tambo[(a)]

	Wind Speed	Wind Direction	Temperature	Humidity
IOA	0.60		0.84	0.6
RMSE	1.55			
Mean Bias	0.05	0.39	**-1.27**	-0.54
Gross Error		**36.26**	**2.22**	1.11

(a) Values that do not meet the benchmark is provided in bold

A comparison of wind roses from measured meteorological data at OR Tambo (Figure 5-4) to WRF data (extracted at OR Tambo) (Figure 5-5) is provided below. The measured wind direction at OR Tambo has a higher frequency of winds from the north and lower frequency of winds from the north-northeast to east than the WRF data. The gross error for wind direction could influence the CALPUFF simulated pollutant concentrations by up to 36 degrees. This is limited by the inclusion of measured wind speed and direction at surface stations near SO.

A comparison of monthly temperature profiles from measured meteorological data at OR Tambo to WRF data (extracted at OR Tambo) is provided in Figure 5-6. The measured temperature data is higher than the WRF data. This could result in the CALPUFF model underpredicting concentrations as the plume is not exposed to as much buoyancy in the atmosphere. From a sensitivity analysis, the plum rise may be overpredicted by less than 2% with the exception of the VCM group which overpredicts by as much as 6% due to their relatively low exit temperatures.

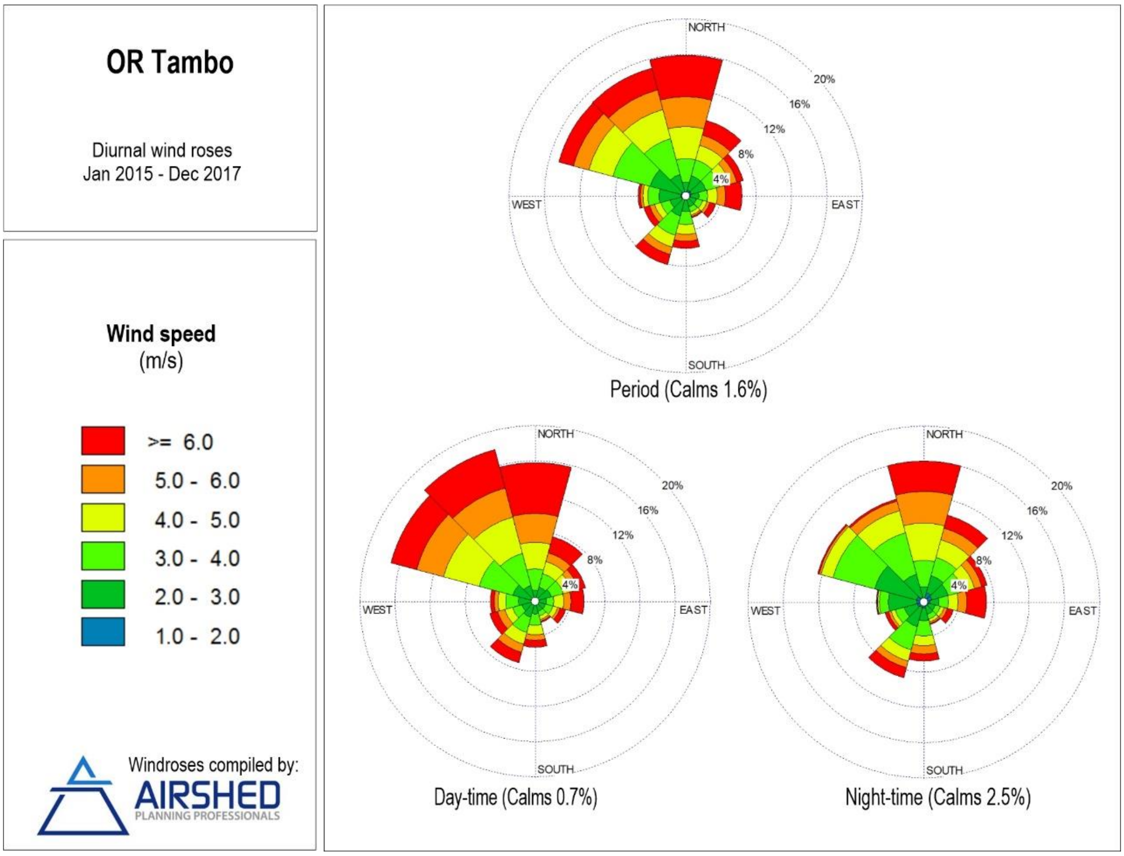

Figure 5-4: Period, day- and night-time wind rose for OR Tambo for the period 2015 - 2017

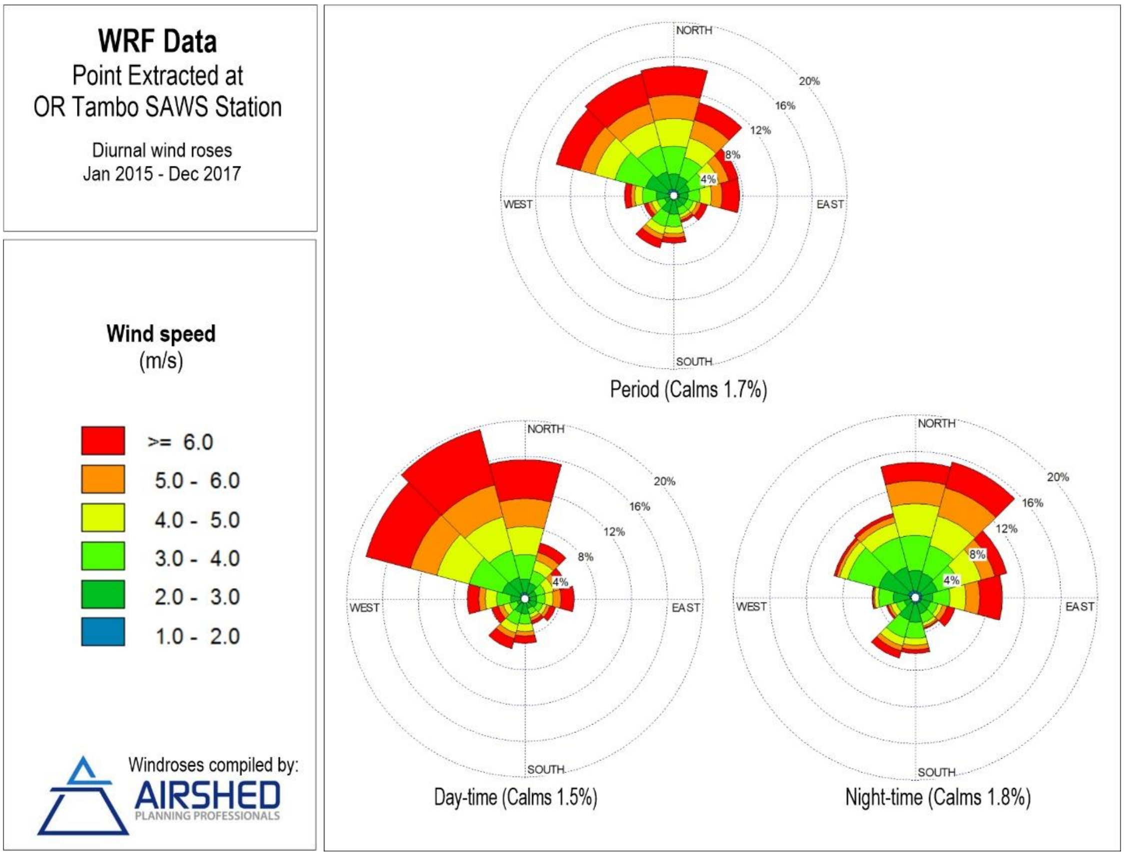

Figure 5-5: Period, day- and night-time wind rose for WRF data as extracted at OR Tambo for the period 2015 - 2017

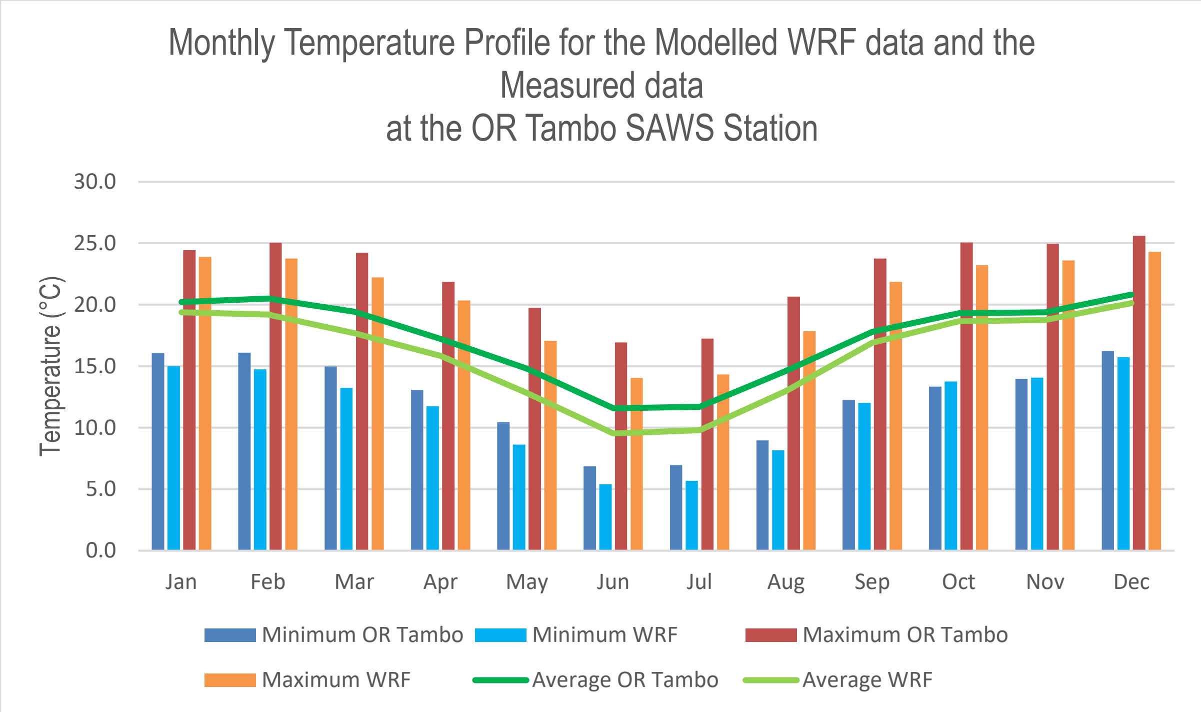

Figure 5-6: Monthly temperature profile for WRF data as extracted at OR Tambo and measured data from OR Tambo SAWS station data for the period 2015 – 2017

WRF data was supplemented with surface field observations from three monitoring stations operated by Sasol in the Sasolburg area and three monitoring stations operated by Sasol in the Secunda area. Meteorological parameters provided for the Sasol monitoring stations in the Sasolburg area are provided in Table 5-7.

Table 5-7: Meteorological parameters provided for the Sasol monitoring stations in the Sasolburg area

Monitoring Station	Latitude	Longitude	Closest Residential Area	Meteorology						
				WD	WS	Temp	RH	Press	SR	Rain
Eco Park	-26.778	27.837	Vaalpark	✓	✓	✓	✓	✓	✓	✓
AJ Jacobs	-26.822778	27.826111	Sasolburg	✓	✓					
Leitrim	-26.850278	27.874167	Sasolburg	✓	✓	✓	✓	✓		

WD: Wind direction
WS: Wind speed
Temp: Temperature
RH: Relative humidity
Press: Surface pressure
SR: Solar radiation

An evaluation of the WRF data at the Eco Park monitoring station location is provided in Table 5-8. From the evaluation, the daily average WRF results for the period 2015 to 2017 were within the benchmarks for model evaluation, with the exception of wind direction (WRF providing value of -18 degrees mean bias where the benchmark is ≤±10 degrees and 46 degrees for the gross error where benchmark is at ≤30 degrees) and temperature (WRF providing value of 2.27 K for the gross error where the benchmark is at ≤2 K and -0.81 K for the mean bias where benchmark is at ≤± 0.5 K). The gross error and mean bias for wind direction is limited by the inclusion of measures wind direction near SO.

Table 5-8: Daily evaluation results for the WRF simulations for the 2015-2017 extracted at Eco Park[a]

	Wind Speed	Wind Direction	Temperature	Humidity
IOA	0.64		0.88	**0.56**
RMSE	1.72			
Mean Bias	0.41	**-18.48**	**-0.81**	0.47
Gross Error		**46.76**	**2.27**	1.20

(a) Values that do not meet the benchmark is provided in bold

Figure 5-7 and Figure 5-8 provides examples of the CALMET layer 1 (up to 20 m above surface) wind vector plots from the CALMET data for 15 May 2015 at 05:00 and 2 February 2015 at 05:00 respectively. The spatial variations in the wind field over parts of the domain are due to terrain effects which are to be expected during this part of the diurnal cycle.

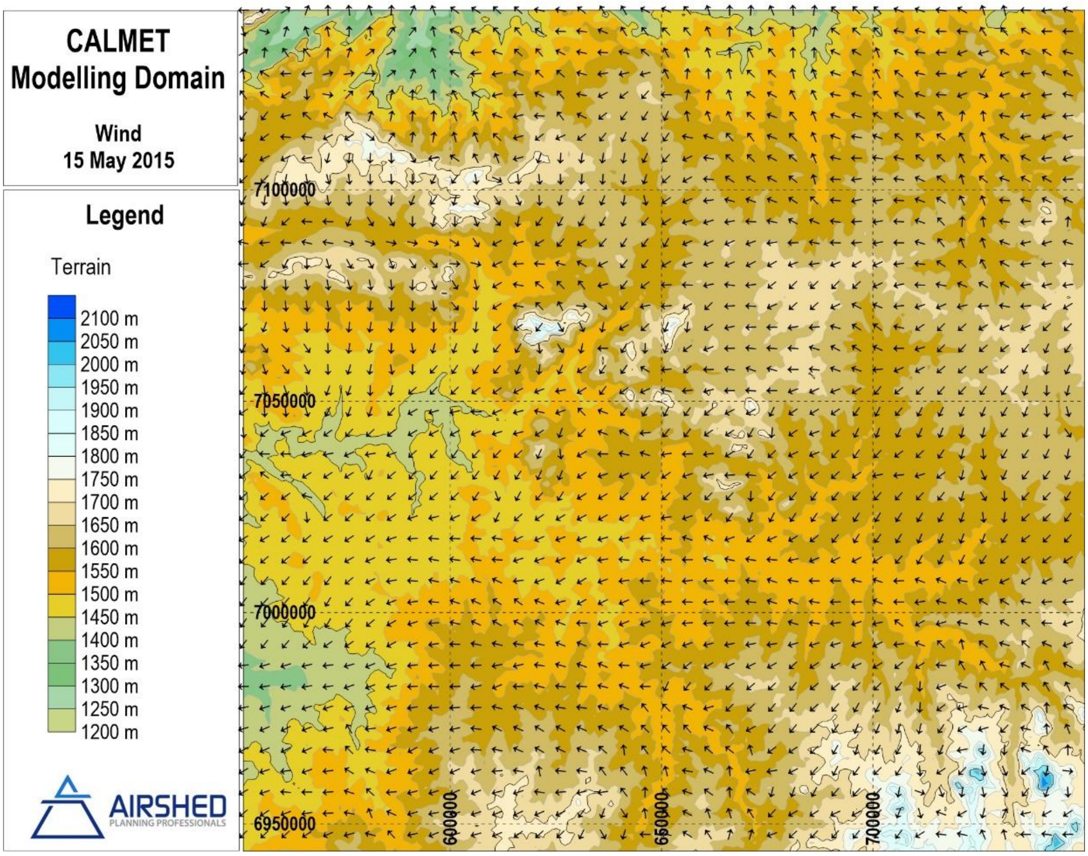

Figure 5-7: CALMET Layer 1 wind vector plot for 15 May 2015 at 05:00

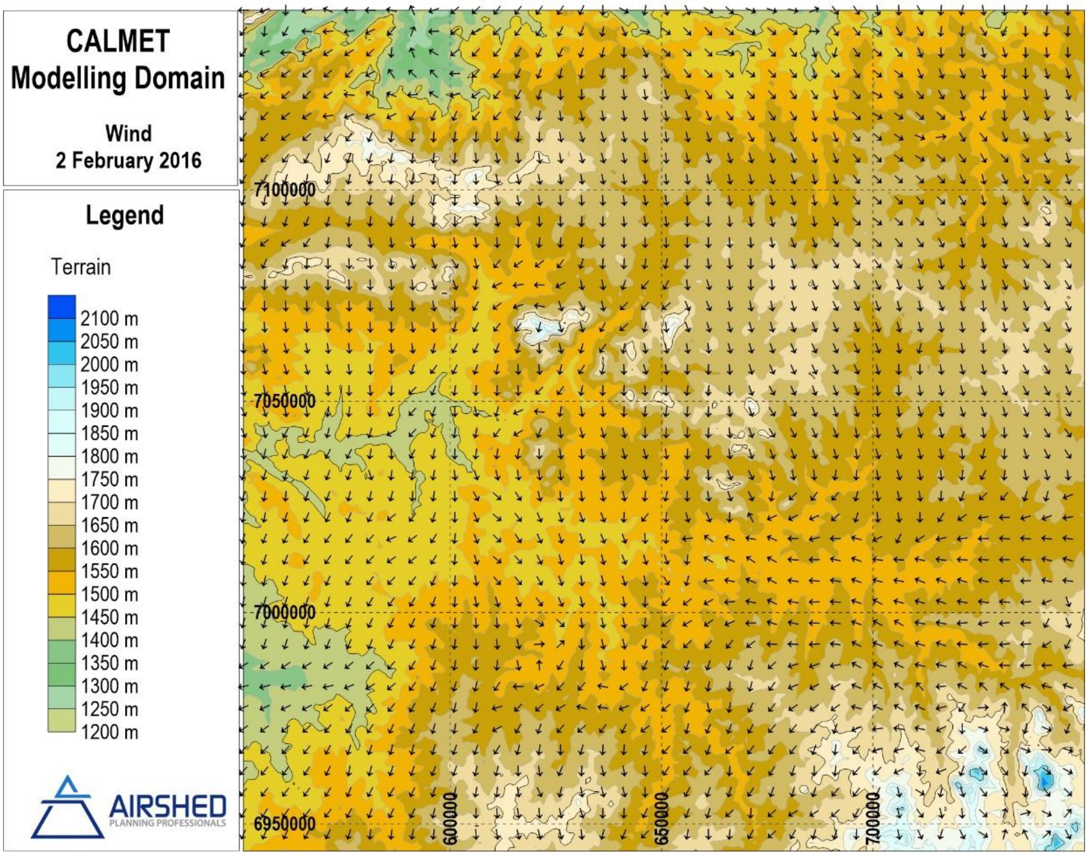

Figure 5-8: CALMET Layer 1 wind vector plot for 2 February 2016 at 05:00

5.1.4.6.2 Land Use and Topographical Data

Readily available terrain and land cover data for use in CALMET was obtained via the Lakes Environmental CALPUFF View interface. Use was made of Shuttle Radar Topography Mission (SRTM) (30 m, 1 arc-sec) terrain data and Global Land Cover Characterization (GLCC) land use data for Africa.

Figure 5-9 provides the terrain contours and landuse categories over the entire CALMET domain and the location of the CALPUFF computational domain.

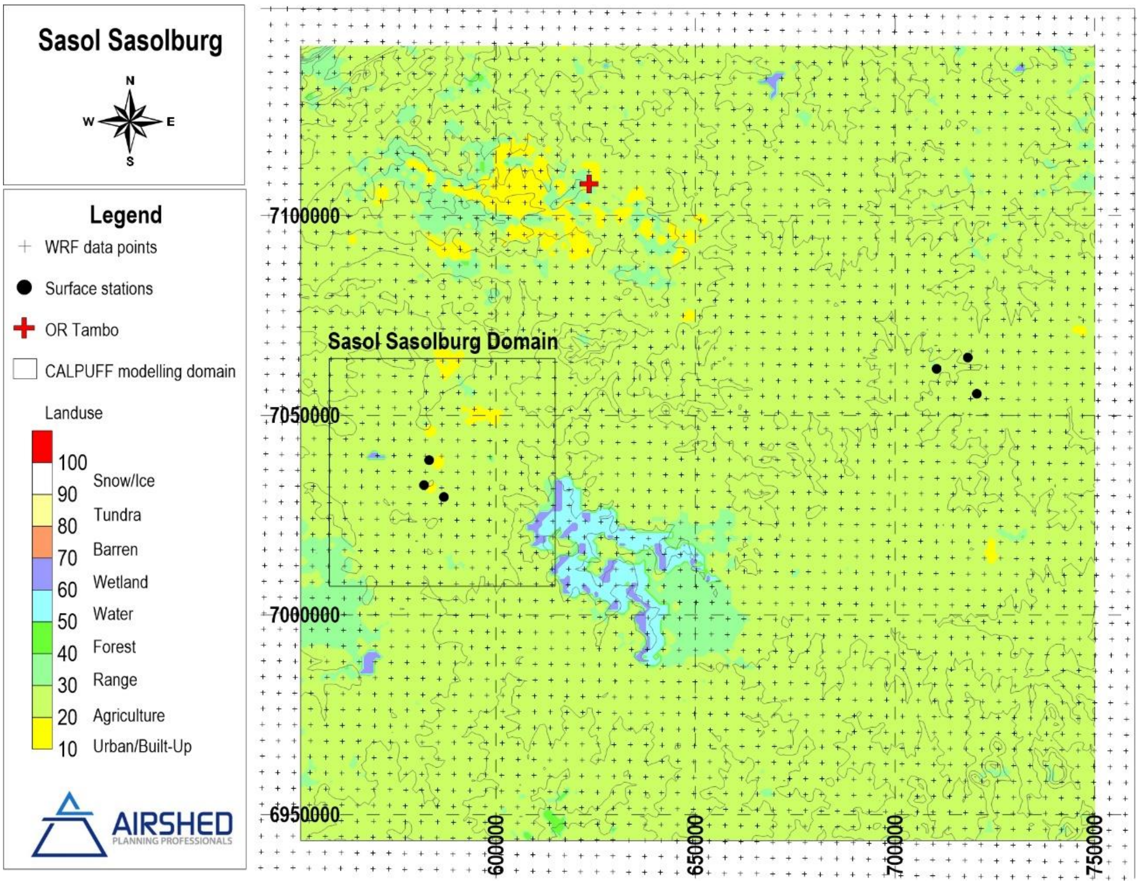

Figure 5-9: Land use categories, terrain contours, meteorological WRF grid points and surface station locations displayed on 200 x 200 km CALMET domain (1 km resolution)

5.1.4.6.3 Dispersion Coefficients

The option of dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.) was selected (refer to Appendix E for all CALPUFF control options).

5.1.4.6.4 Grid Resolution and Model Domain

The CALMET modelling domain included an area of 200 km by 200 km with a grid resolution of 1 km. The vertical profile included 11 vertical levels up to a height of 3 500 m. The CALPUFF model domain selected for the sources at the Sasol Sasolburg facility included an area of 57 km by 57 km with a grid resolution of 200 m. This area was selected based on the area of impact around Sasolburg simulated during an assessment undertaken for the Vaal Triangle Airshed Priority Area.

5.1.4.6.5 Building Downwash

The impact of building downwash on ground-level pollutant concentrations was evaluated using “ScreenView" - a Tier 1 screening model which includes the same building downwash scheme as CALPUFF. For the most conservative simulation of downwind concentrations “ScreenView” was used with a full meteorological set. The SO site was selected for evaluation due to the relatively short distances between sources and receptors. The screening exercise assessed the individual impact of three sources selected based on location; stack height; proximity to nearby buildings (excluding complex pipework structures); and, proximity to receptors. The baseline emission parameters (temperature, release height, exit velocities, etc.) were used in combination with three theoretical building heights (10, 15, and 20 m). A single emission rate (1 m/s) was used to simulated the ground-level concentrations at automated distances between 1 m and 5 000 m from the sources, at 100 m intervals.

The screening assessment indicated that building downwash did not affect downwind concentration as a result of the boilers, due to height of release (75 m for Steam Station 1). Sources with lower release heights (15 m and 20 m) were found to increase ground-level concentrations downwind of the source where the scale of increase was dependent on the height of the near-by building. The distance after which simulate ground-level concentrations matched levels for comparative simulations where building downwash was not included was a minimum of 1 800 m.

Due to the close proximity between sources, buildings and receptors at the SO facility, building downwash was accounted for in the dispersion modelling, specifically buildings and sources along the western boundary of the facility, which is within 100 m of a residential area (Table 5-9). The AERMOD Building Profile Input Program (BPIP) module was used to generate a building downwash input file for CALPUFF where building dimensions were provided by Sasol.

Table 5-9: Parameters of buildings on the SO facility included in the dispersion modelling

Building ID	Latitude	Longitude	Height (m)	X length (m)	Y length (m)	Angle from North
1	-26.83214	27.84326	10.0	15.0	24.0	332°
2	-26.83169	27.84446	10.1	30.5	50.5	332°
3	-26.83192	27.84290	8.5	30.0	30.0	332°
4	-26.83164	27.84270	37.0	11.2	24.0	332°
5A	-26.83199	27.84266	6.0	18.0	19.0	332°
5B	-26.83206	27.84254	6.0	12.0	30.0	332°
5C	-26.83182	27.84256	9.0	5.0	14.0	332°
6A	-26.83197	27.84236	8.0	9.0	14.0	332°
6B	-26.83170	27.84233	6.0	7.0	7.0	332°
6C	-26.83172	27.84251	6.0	9.0	10.0	332°
7	-26.83188	27.84188	12.0	12.0	3.5	332°
8A	-26.83207	27.84156	7.0	6.0	11.0	332°
8B	-26.83197	27.84149	4.0	6.0	30.0	332°
9	-26.83156	27.84206	2.0	5.0	12.0	332°
11	-26.83135	27.84253	37.0	40.0	40.0	332°
13	-26.83249	27.84264	5.0	11.0	35.0	332°
16	-26.82605	27.84036	13.0	20.0	32.6	63°
17	-26.82843	27.84057	13.6	32.0	55.0	332°
19	-26.82878	27.84025	13.6	40.0	90.0	332°
20	-26.82874	27.84082	13.0	22.0	25.0	332°
21	-26.82951	27.84067	9.0	16.0	22.0	332°
22	-26.82994	27.84130	10.0	16.8	42.2	22.5°
23	-26.82524	27.83835	10.0	19.9	43.8	332°
24	-26.82574	27.83844	26.6	18.0	20.0	332°
25	-26.82623	27.83830	10.0	17.5	79.2	63°

5.1.5 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. The horizontal dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. A summary of the measured meteorological data is given in Appendix G.

Sasol currently operates four meteorological stations in the Sasolburg area (viz. Sasol 1 Fence Line, Eco Park, AJ Jacobs and Leitrim). For this assessment, data from the Sasol operated meteorological stations at Eco Park, AJ Jacobs and Leitrim was provided for the period 2015 to 2017. Parameters useful in describing the dispersion and dilution potential of the site (i.e. wind speed, wind direction, temperature and atmospheric stability) are subsequently discussed.

5.1.5.1 Surface Wind Field

Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the red area, for example, representing winds >6m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind field and diurnal variability (2015 to 2017) for the three Sasol operated meteorological stations in the Sasolburg area is provided in Figure 5-10 to Figure 5-12.

The predominant flow field at Eco Park is from the east-southeast (~12% frequency of occurrence). During day-time conditions winds from the north-western sector increases while winds from the east-southeast are more frequent during night-time conditions (Figure 5-10).

The predominant wind direction at AJ Jacobs is from the north-northeast (~11% frequency of occurrence) (Figure 5-11). Very little wind is measured from the south-eastern sector. During day-time conditions winds from the western sector increase while winds from the north-northeast are more frequent during night-time conditions. A higher frequency of low-speed winds (1-2 m/s) and calm conditions (less than 1 m/s) was measured at this monitoring station.

The predominant wind direction at Leitrim is from the north-northeast and east (~10% frequency of occurrence). During day-time conditions winds from the western sector increase while winds from the east, south-southeast and north-northeast are more frequent during night-time conditions (Figure 5-12).

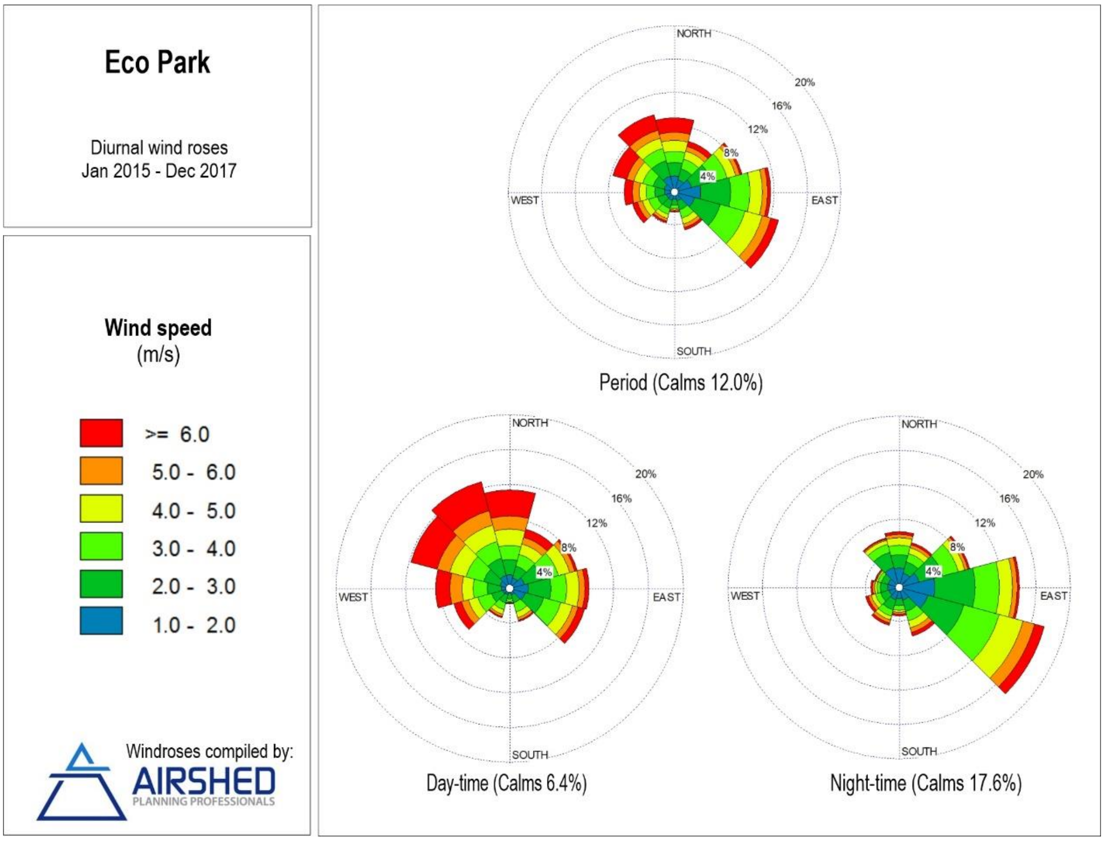

Figure 5-10: Period, day- and night-time wind rose for Eco Park for the period 2015 - 2017

Figure 5-11: Period, day- and night-time wind rose for AJ Jacobs for the period 2015 - 2017

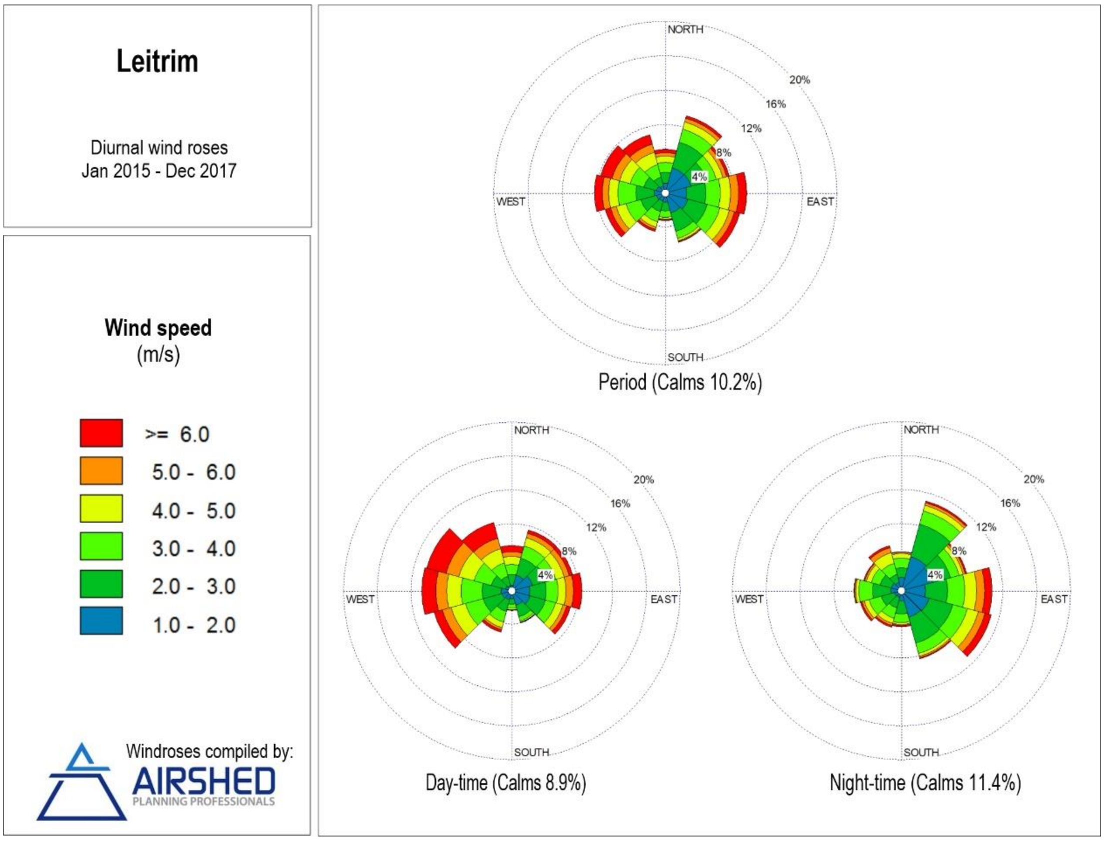

Figure 5-12: Period, day- and night-time wind rose for Leitrim for the period 2015 - 2017

5.1.5.2 Temperature

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

The average monthly temperature trends are presented in Figure 5-13 and Figure 5-14 for Eco Park and Leitrim respectively. Monthly mean and hourly maximum and minimum temperatures are given in Table 5-9.

Table 5-10: Monthly temperature summary (2015 - 2017)

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C) (2015 - 2017)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eco Park												
Minimum	17.2	16.7	14.7	11.6	6.8	4.0	3.9	5.7	11.4	13.2	14.3	17.1
Maximum	27.1	27.6	26.3	24.2	21.8	19.1	19.3	22.8	25.8	27.3	27.1	28.1
Average	22.1	21.9	20.3	17.5	14.0	11.0	11.2	14.2	18.4	20.3	20.8	22.4
Leitrim												
Minimum	17.3	16.7	14.6	11.6	7.1	4.6	4.0	5.6	10.8	13.4	14.1	17.0
Maximum	27.4	28.4	26.6	24.4	22.2	19.2	19.7	23.2	25.8	27.7	27.3	28.4
Average	22.2	22.3	20.3	17.8	14.2	11.4	11.4	14.3	18.1	20.6	20.7	22.5

Average temperatures ranged between 11 °C and 22.5 °C. The highest temperatures occurred in December and the lowest in July. During the day, temperatures increase to reach maximum at around 15:00 in the afternoon. Ambient air temperature decreases to reach a minimum at around 07:00 i.e. just before sunrise.

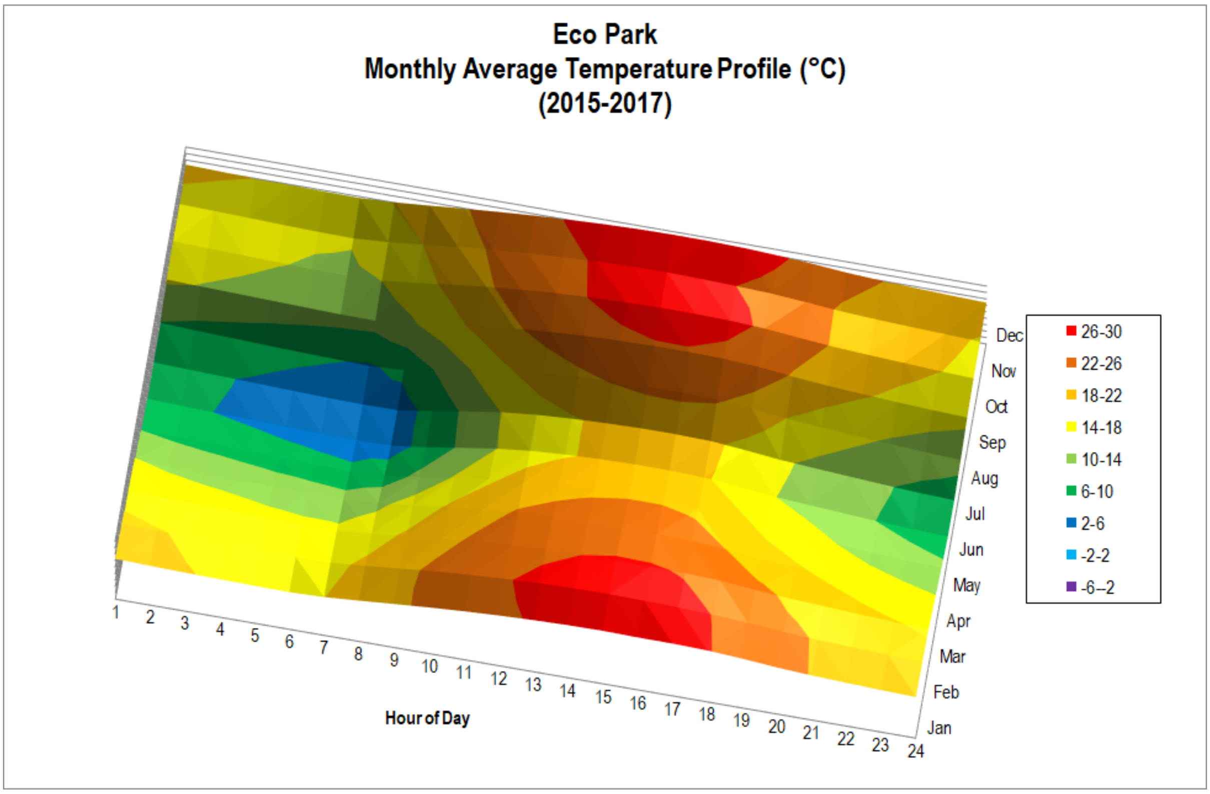

Figure 5-13: Monthly average temperature profile for Eco Park (2015 – 2017)

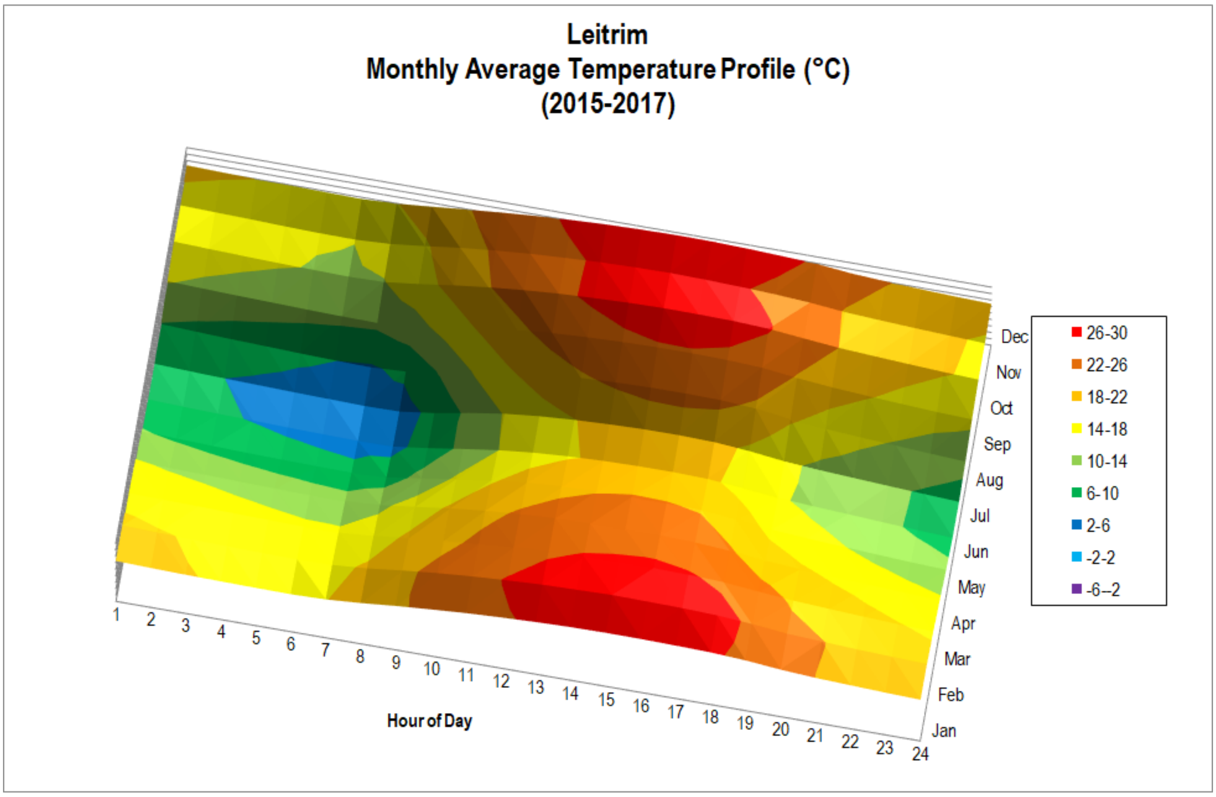

Figure 5-14: Monthly average temperature profile for Leitrim (2015 – 2017)

5.1.5.3 Atmospheric Stability

The atmospheric boundary layer properties are described by two parameters; the boundary layer depth and the Monin-Obukhov length.

The Monin-Obukhov length (LMo) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

Diurnal variation in atmospheric stability, as calculated from on-site data (Tiwary and Colls, 2010), and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 5-15. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions.

For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called looping (Figure 5-15 (c)) and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as coning (Figure 5-15 (b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called fanning (Figure 5-14 (a)) (Tiwary & Colls, 2010).

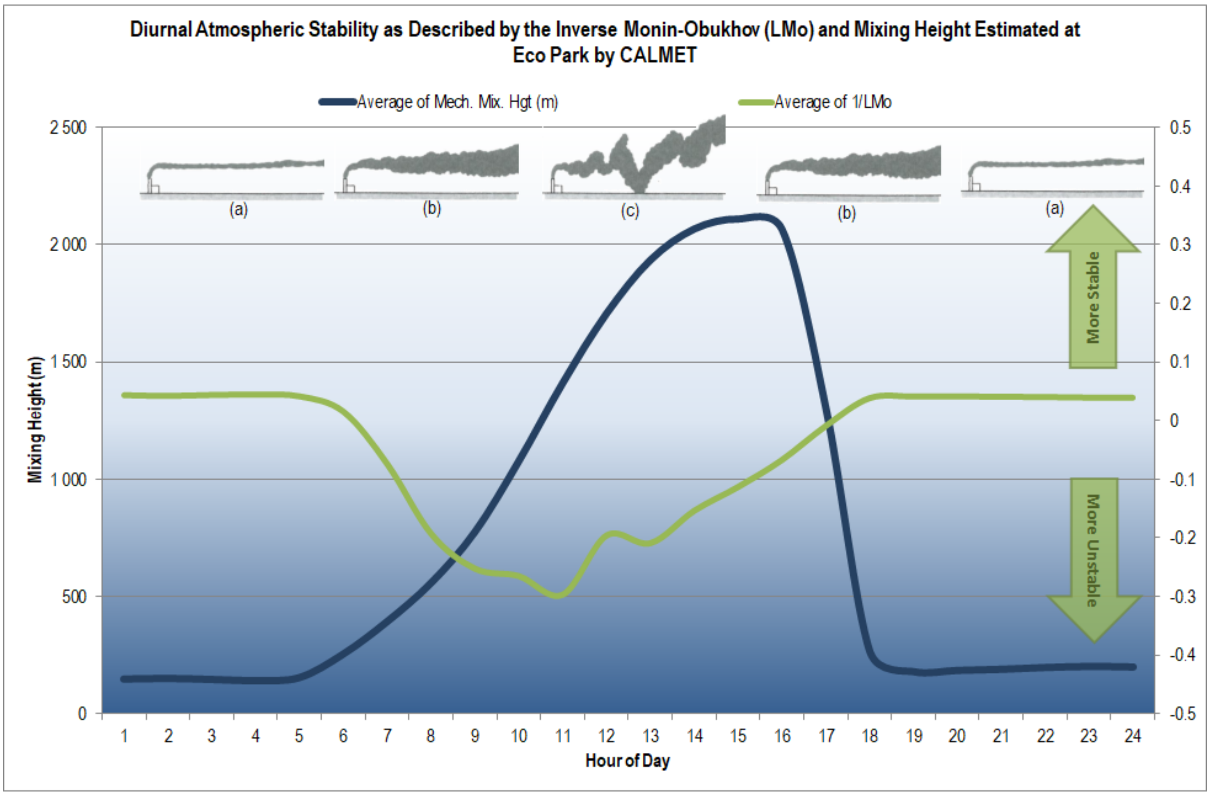

Figure 5-15: Diurnal atmospheric stability (extracted from CALMET at the Eco Park monitoring point)

5.1.5.4 Air Quality Monitoring data

A summary of ambient data measured at Leitrim, AJ Jacobs and Eco Park for the period 2015 – 2017 is provided in Table 5-12, Table 5-13 and Table 5-14 respectively. A summary of ambient air quality data recorded at the DEA stations - Three Rivers, Sharpeville, and Zamdela - is provided in Table 5-15, Table 5-16, and Table 5-17. Time series of the measured ambient air quality data is provided in Appendix G.

Table 5-11: Summary of the ambient NH_3 measurements at Fence Line for the period 2010-2012 (units: µg/m³)

Period	Hourly				Annual Average
	Max	99th Percentile	90th Percentile	50th Percentile	
			NH_3		
2010	231.34	65.19	6.59	0.59	4.74
2011	270.11	82.68	15.98	1.10	6.60
2012	236.77	88.22	23.29	5.18	10.11
Average	*246.07*	*78.69*	*15.28*	*2.29*	*7.15*
NOTE: * Ammonia is no longer monitored at the Sasol monitoring stations and therefore data for the most recent available period was used.					

Table 5-12: Summary of the ambient measurements at Leitrim for the period 2015-2017 (units: µg/m³)

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
				NO_2			
2015	21%	178.4	64.9	39.0	17.3	21.2	1
2016	91%	140.7	87.2	47.8	17.6	22.8	-
2017	90%	117.4	77.9	42.9	15.4	19.2	-
Average			*76.7*	*43.2*	*16.8*	*21.1*	
				SO_2			
2015	85%	1007.4	185.0	82.3	20.0	33.3	4
2016	94%	515.9	205.8	78.5	28.4	39.4	15
2017	90%	425.8	172.6	70.3	24.6	33.5	2
Average			*187.8*	*77.0*	*24.3*	*35.4*	
Period	**Availability**	**Daily**				**Annual Average**	**No of recorded daily exceedances**
		Max	**99th Percentile**	**90th Percentile**	**50th Percentile**		
				SO_2			
2015	85%	46.1	40.5	26.9	11.2	33.3	-
2016	94%	45.7	38.2	23.7	14.4	39.4	-
2017	90%	37.1	30.6	22.2	11.8	33.5	-
Average			*36.4*	*24.2*	*12.4*	*35.4*	
				PM_{10}			
2015	81%	192.1	153.4	106.0	37.7	49.2	57
2016	24%	129.9	121.6	100.9	12.7	38.5	21
2017	52%	193.5	142.4	80.4	29.4	38.0	22
Average			*139.1*	*95.8*	*26.6*	*41.9*	
				$PM_{2.5}$			
2015	65%	117.0	75.2	50.0	19.3	24.2	5
2016	26%	59.8	58.5	37.2	2.9	12.6	8
2017	52%	49.7	39.1	22.3	8.1	10.5	2
Average			*57.6*	*36.5*	*10.1*	*15.8*	

Table 5-13: Summary of the ambient measurements at AJ Jacobs for the period 2015-2017 (units: µg/m³)

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
				NO_2			
2015	86%	127.4	79.6	46.3	15.3	21.0	-
2016	95%	125.4	73.5	42.9	16.1	20.3	-
2017	92%	164.7	81.4	52.1	25.1	26.6	-
Average			*78.1*	*47.1*	*18.8*	*22.7*	
				SO_2			
2015	98%	603.6	284.1	111.1	46.3	56.3	34
2016	96%	676.0	307.7	121.1	41.0	57.2	54
2017	88%	718.5	320.6	173.4	78.0	89.7	56
Average			*304.1*	*135.2*	*55.1*	*67.7*	
Period	**Availability**	**Daily**				**Annual Average**	**No of recorded daily exceedances**
		Max	**99th Percentile**	**90th Percentile**	**50th Percentile**		
				SO_2			
2015	98%	224.6	152.9	104.5	53.5	56.3	14
2016	96%	188.0	162.1	103.0	49.1	57.2	23
2017	88%	220.6	194.5	160.0	80.5	89.7	91
Average			*169.9*	*122.5*	*61.0*	*67.7*	
				PM_{10}			
2015	96%	124.6	119.9	81.1	39.5	46.4	48
2016	99%	154.9	105.1	76.1	37.7	43.1	39
2017	98%	107.3	94.6	74.0	33.4	38.9	32
Average			*106.5*	*77.1*	*36.9*	*42.8*	
				$PM_{2.5}$			
2015	93%	51.0	48.2	30.9	16.1	18.3	-
2016	82%	73.7	54.2	33.4	15.2	17.9	14
2017	93%	75.8	69.9	49.7	19.9	24.8	66
Average			*57.5*	*38.0*	*17.1*	*20.4*	

Table 5-14: Summary of the ambient measurements at Eco Park for the period 2015-2017 (units: µg/m³)

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
				NO_2			
2015	84%	782.9	85.1	52.9	15.9	22.3	2
2016	98%	373.1	85.9	51.1	15.0	21.5	6
2017	98%	439.8	84.2	49.2	14.4	20.5	3
Average			*85.1*	*51.1*	*15.1*	*21.5*	
				SO_2			
2015	96%	881.5	239.4	89.9	42.8	51.5	31
2016	98%	842.4	261.8	82.6	28.3	41.9	41
2017	98%	891.5	230.4	65.5	21.2	33.4	35
Average			*243.8*	*79.3*	*30.8*	*42.2*	
Period	**Availability**	**Daily**				**Annual Average**	**No of recorded daily exceedances**
		Max	**99th Percentile**	**90th Percentile**	**50th Percentile**		
				SO_2			
2015	96%	131.0	117.6	86.1	48.8	51.5	1
2016	98%	144.3	128.1	81.5	36.3	41.9	5
2017	98%	145.6	100.9	60.4	30.0	33.4	2
Average			*115.5*	*76.0*	*38.3*	*42.2*	
				PM_{10}			
2015	93%	150.4	126.1	83.0	27.5	37.2	45
2016	98%	131.1	117.9	69.5	27.2	33.1	29

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
2017	96%	145.5	98.3	68.5	23.3	31.4	29
Average			*112.6*	*71.9*	*26.5*	*34.0*	
$PM_{2.5}$							
2015	95%	61.7	52.6	35.2	14.7	18.2	-
2016	98%	312.9	308.8	32.9	13.3	20.6	23
2017	97%	331.9	69.8	46.1	16.3	22.0	50
Average			*143.7*	*38.1*	*14.7*	*20.3*	
O_3							
2015	98%	124.1	109.7	85.5	58.7	58.3	
2016	99%	1567.4	728.0	91.3	58.0	79.5	
2017	99%	112.3	108.0	85.3	60.0	61.2	
Average			*315.2*	*87.4*	*58.9*	*67.0*	

Table 5-15: Summary of the ambient measurements at Three Rivers for the period 2015-2017 (units: µg/m³)

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
NO_2							
2015	80%	178.6	104.6	64.5	24.8	31.5	-
2016	91%	148.4	92.1	53.0	21.8	26.4	-
2017	91%	178.2	95.1	54.3	20.8	26.3	-
Average			*97.3*	*57.3*	*22.5*	*28.1*	
SO_2							
2015	53%	592.0	110.1	30.3	8.0	14.5	5
2016	91%	474.8	163.1	30.4	7.6	15.5	7
2017	91%	539.3	141.5	36.2	10.1	17.9	9
Average			*138.3*	*32.3*	*8.6*	*16.0*	
Benzene							
2015	37%	17.3	6.7	3.7	0.4	1.2	
2016	83%	11.6	3.0	1.2	0.1	0.4	
2017	79%	13.2	2.8	0.8	0.1	0.3	
Average			*4.2*	*1.9*	*0.2*	*0.7*	
CO							
2015	83%	5710	1808	715	260	352	-
2016	91%	5250	1482	896	496	587	-
2017	44%	3769	1632	979	549	658	-
Average			*1641*	*863*	*435*	*532*	
Period	**Availability**	**Daily**				**Annual Average**	**No of recorded daily exceedances**
		Max	**99th Percentile**	**90th Percentile**	**50th Percentile**		
SO_2							
2015	53%	105.2	55.4	26.9	10.8	14.5	-
2016	91%	117.7	67.3	32.7	11.0	15.5	-
2017	91%	114.2	72.4	33.0	14.3	17.9	-
Average			*65.0*	*30.9*	*12.0*	*16.0*	
PM_{10}							
2015	82%	144.2	119.3	84.3	46.2	51.4	54
2016	90%	174.2	130.1	101.8	53.7	61.1	87
2017	90%	248.4	177.6	63.5	32.0	38.6	24
Average			*142.3*	*83.3*	*43.9*	*50.4*	
$PM_{2.5}$							
2015	87%	76.6	69.7	45.7	25.6	27.7	5
2016	82%	96.5	61.8	45.8	26.0	28.7	58
2017	78%	83.0	60.1	34.7	21.0	22.1	18
Average			*63.8*	*42.0*	*24.2*	*26.2*	

			O_3				
2015	80%	127.8	105.2	85.0	55.9	55.6	
2016	89%	122.8	104.0	83.9	55.5	56.4	
2017	45%	107.5	76.3	64.4	43.7	44.0	
Average			*95.2*	*77.8*	*51.7*	*52.0*	

Table 5-16: Summary of the ambient measurements at Sharpeville for the period 2015-2017 (units: µg/m³)

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
			NO_2				
2015	86%	344.0	156.7	96.3	31.3	43.9	15
2016	86%	176.8	104.7	62.7	22.6	29.7	-
2017	82%	195.5	105.2	64.1	21.8	29.6	-
Average			*122.2*	*74.4*	*25.2*	*34.4*	
			SO_2				
2015	87%	950.4	135.8	38.2	10.9	19.1	16
2016	80%	512.3	127.1	34.0	7.0	15.2	3
2017	69%	462.8	180.7	49.0	8.8	20.8	6
Average			*147.9*	*40.4*	*8.9*	*18.4*	
			Benzene				
2015	32%	25.9	12.2	3.1	0.5	1.3	
2016	0%						
2017	35%	56.1	16.8	5.4	0.8	2.1	
Average			*14.5*	*4.3*	*0.6*	*1.7*	
			CO				
2015	87%	6420	3492	1516	512	712	-
2016	88%	7684	3724	1903	739	968	-
2017	44%	5736	3317	1647	701	893	-
Average			*3511*	*1688*	*651*	*858*	
Period	**Availability**	**Daily**				**Annual Average**	**No of recorded daily exceedances**
		Max	**99th Percentile**	**90th Percentile**	**50th Percentile**		
			SO_2				
2015	87%	135.0	94.0	36.5	13.4	19.1	2
2016	80%	97.6	74.5	33.5	9.7	15.2	-
2017	69%	147.1	106.6	46.5	12.4	20.8	1
Average			*91.7*	*38.8*	*11.8*	*18.4*	
			PM_{10}				
2015	89%	178.0	153.6	110.3	53.8	62.8	83
2016	86%	251.0	234.8	166.9	84.6	95.9	185
2017	56%	188.5	130.5	84.1	41.8	46.7	36
Average			*173.0*	*120.4*	*60.1*	*68.5*	
			$PM_{2.5}$				
2015	88%	138.4	97.9	60.6	31.8	36.5	27
2016	53%	81.7	77.2	47.1	29.7	31.6	43
2017	90%	322.4	151.1	68.3	34.6	39.4	131
Average			*108.7*	*58.7*	*32.0*	*35.8*	
			O_3				
2015	88%	127.8	107.3	83.5	52.1	51.3	
2016	91%	107.9	103.8	72.9	45.9	48.3	
2017	50%	99.3	96.5	81.5	49.6	52.5	
Average			*102.5*	*79.3*	*49.2*	*50.7*	

Table 5-17: Summary of the ambient measurements at Zamdela for the period 2015-2017 (units: µg/m³)

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99th Percentile	90th Percentile	50th Percentile		
NO_2							
2015	87%	168.1	100.4	62.4	24.6	30.1	-
2016	88%	199.8	123.7	73.7	24.3	32.7	-
2017	50%	141.7	91.3	55.8	21.3	26.4	-
Average			*105.2*	*64.0*	*23.4*	*29.7*	
SO_2							
2015	87%	414.5	172.7	52.4	9.2	21.4	5
2016	87%	647.7	187.1	52.9	9.9	22.2	5
2017	75%	356.1	165.5	44.3	8.2	18.7	2
Average			*175.1*	*49.8*	*9.1*	*20.7*	
Benzene							
2015	63%	16.3	11.6	4.2	1.0	1.8	
2016	67%	2752.4	638.8	220.8	0.9	59.5	
2017	49%	31.5	25.9	7.7	1.3	3.1	
Average			*225.4*	*77.6*	*1.1*	*21.4*	
CO							
2015	73%	7187	3889	1267	491	652	-
2016	84%	12691	4860	1491	645	858	-
2017	38%	7690	3965	1432	703	845	-
Average			*4238*	*1397*	*613*	*785*	
Period	**Availability**	**Daily**				**Annual Average**	**No of recorded daily exceedances**
		Max	**99th Percentile**	**90th Percentile**	**50th Percentile**		
SO_2							
2015	87%	105.1	68.2	43.6	17.9	21.4	-
2016	87%	180.7	81.1	44.9	17.2	22.2	2
2017	75%	171.8	68.9	41.9	13.0	18.7	1
Average			*75.3*	*44.5*	*17.8*	*22.3*	
PM_{10}							
2015	57%	221.9	125.2	88.7	40.3	46.0	35
2016	92%	175.3	165.2	106.5	57.2	64.7	106
2017	76%	245.2	133.1	74.7	46.5	49.4	26
Average			*141.1*	*90.0*	*48.0*	*53.3*	
$PM_{2.5}$							
2015	80%	93.6	73.2	54.2	26.0	30.0	11
2016	82%	138.4	95.8	58.7	30.9	35.0	92
2017	83%	105.9	89.8	45.9	26.9	29.7	64
Average			*86.3*	*52.9*	*27.9*	*31.6*	
O_3							
2015	94%	95.7	88.0	71.3	49.1	50.4	
2016	95%	91.8	83.3	67.4	43.9	45.9	
2017	41%	77.4	71.8	53.0	35.0	35.7	
Average			*81.0*	*63.9*	*42.7*	*44.0*	

The following graphs summarise the observed concentrations of SO_2, NO_2 and PM_{10} at the six monitoring sites (Leitrim, AJ Jacobs, Eco Park, Three Rivers, Sharpeville, and Zamdela) monitoring stations for the years 2015, 2016 and 2017. The NAAQS have been included in the graphs for:

- SO_2 hourly (88 hourly exceedances of 350 µg/m³) and daily average (4 daily exceedances of 125 µg/m³)
- NO_2 hourly average (88 hourly exceedances of 200 µg/m³); and,
- PM_{10} daily average (4 daily exceedances of 75 µg/m³; 2015 standards).

The hourly 99th percentiles for SO_2 were below the limit value of 350 µg/m³ at all stations for all three years (Figure 5-16 to Figure 5-21). The daily 99th percentiles for SO_2 were exceeded at AJ Jacobs for 2015, 2016 and 2017 (Figure 5-23) and at Eco Park in 2016 (Figure 5-24) but were below the limit value (125 µg/m³) at Leitrim, Three Rivers, Sharpeville and Zamdela stations for all three years (Figure 5-22 and Figure 5-25 to Figure 5-27).

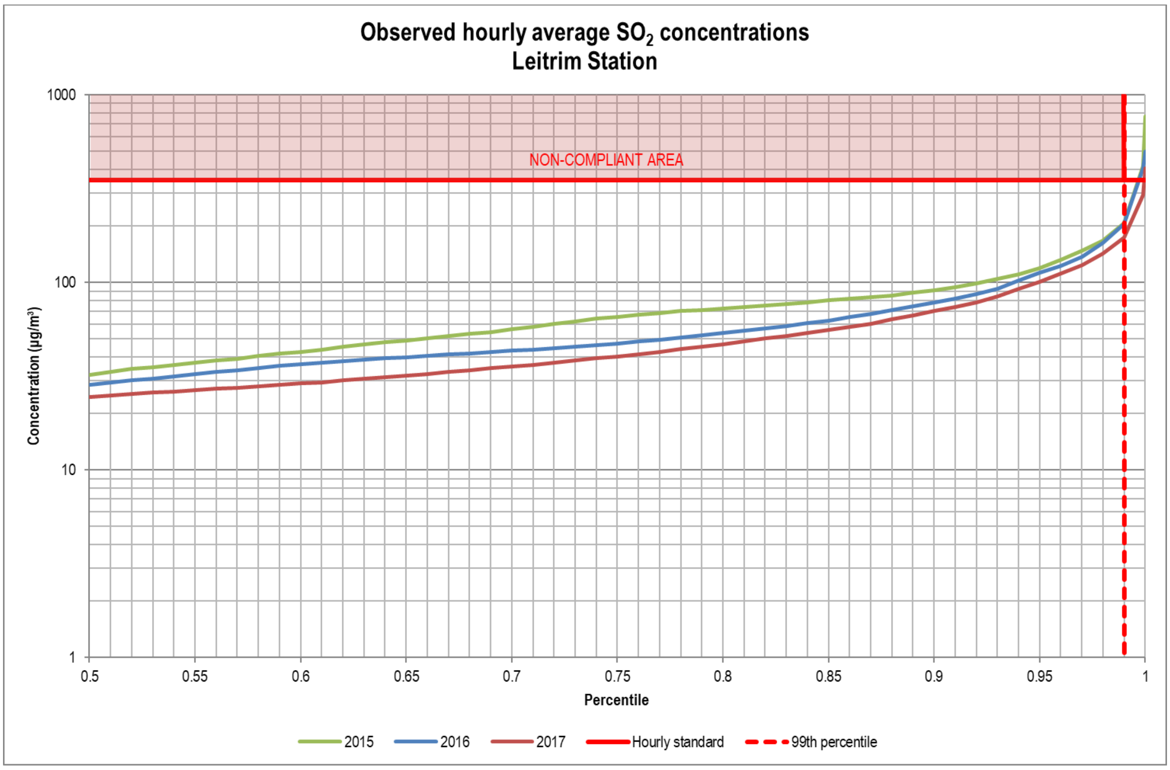

Figure 5-16: Observed hourly average SO_2 concentrations at Leitrim

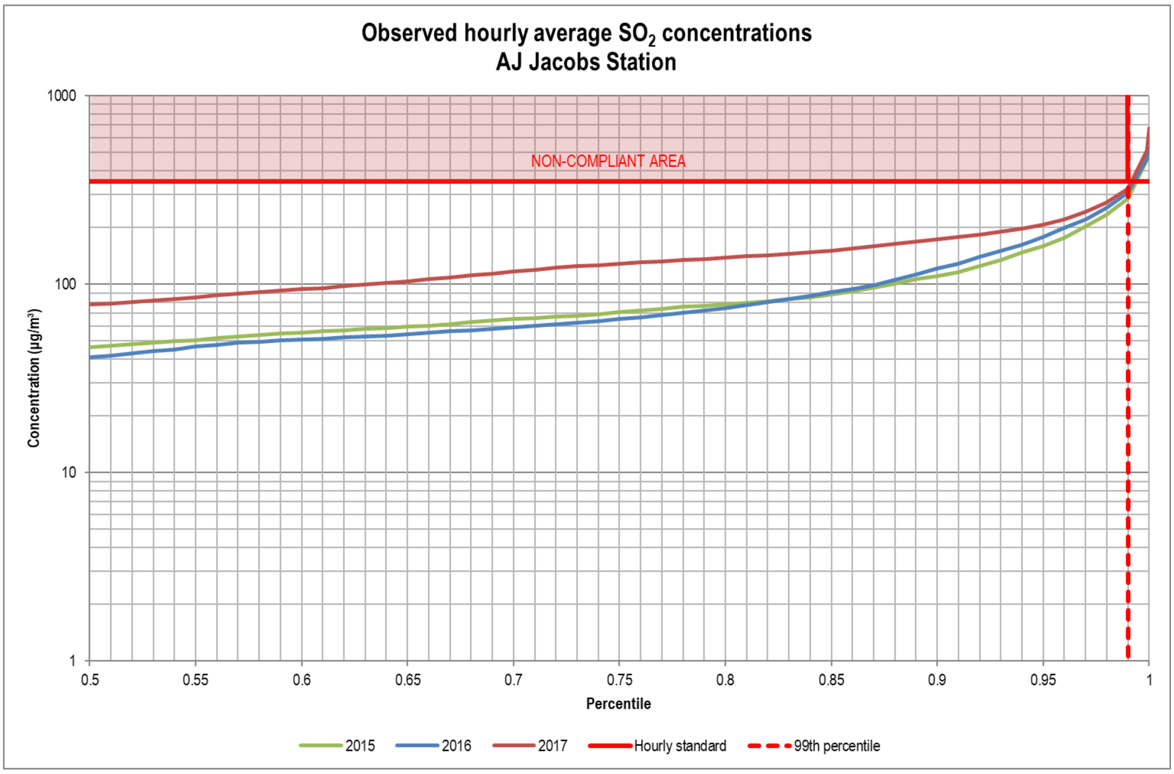

Figure 5-17: Observed hourly average SO_2 concentrations at AJ Jacobs

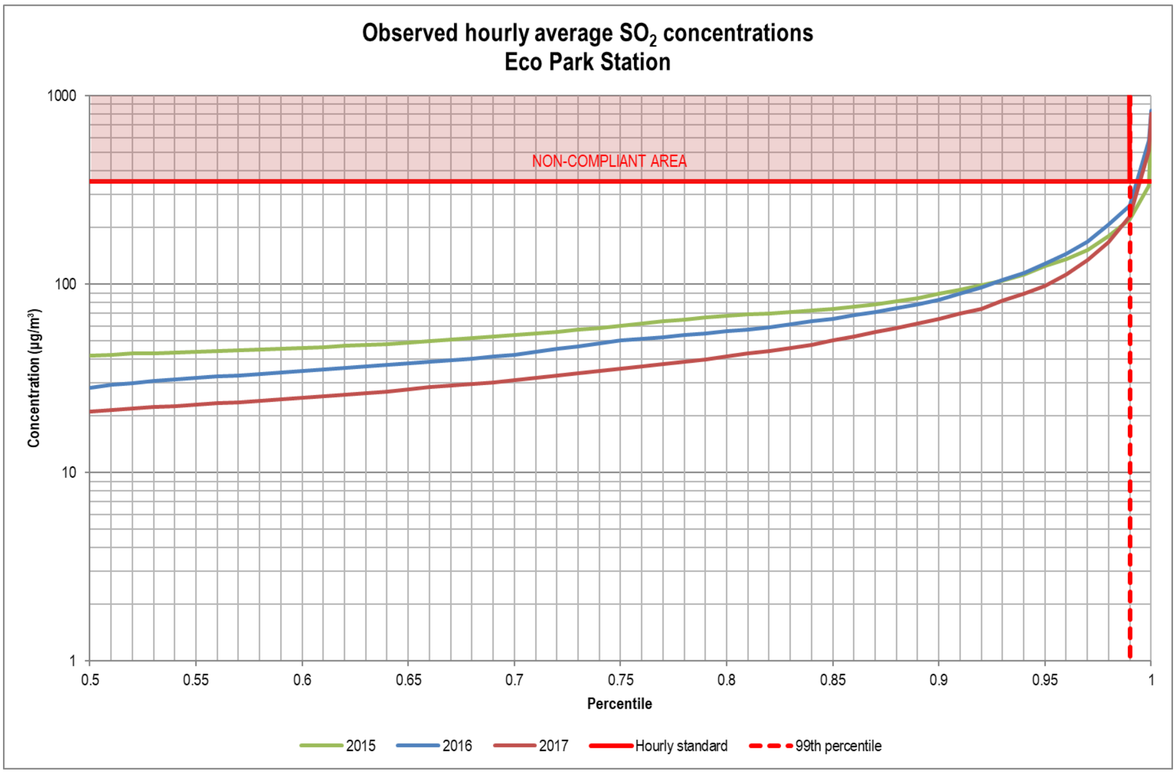

Figure 5-18: Observed hourly average SO_2 concentrations at Eco Park

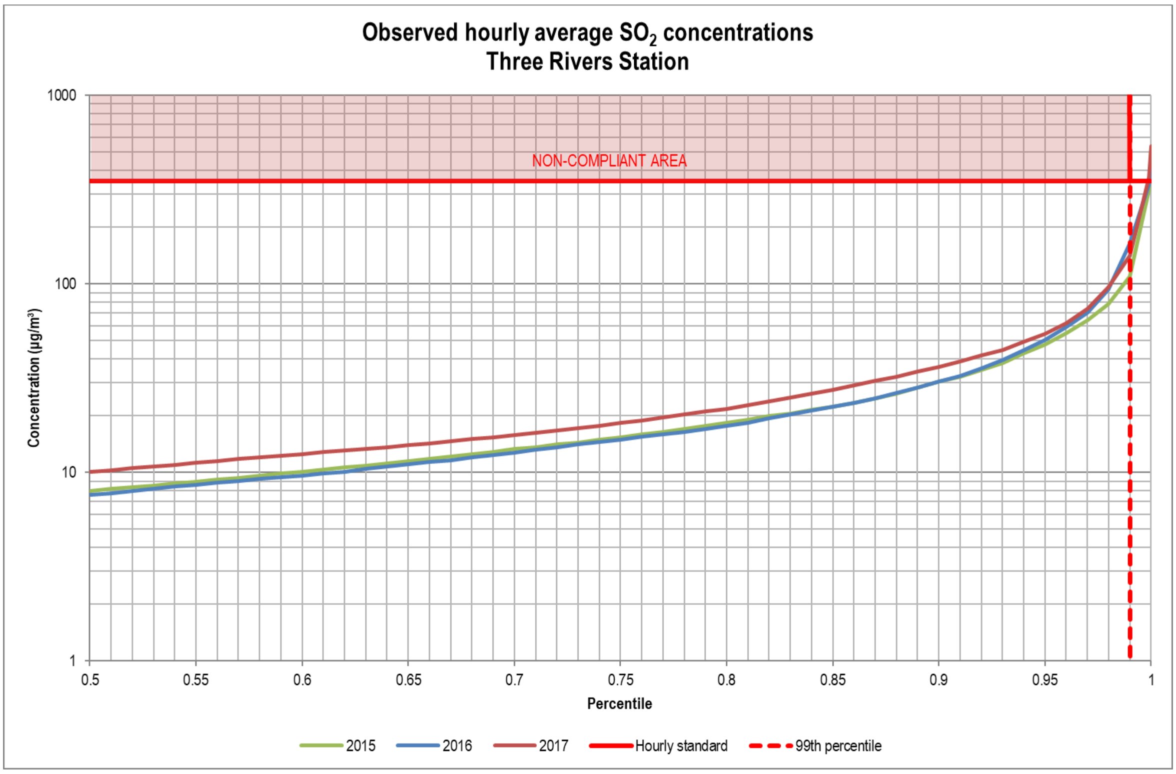

Figure 5-19: Observed hourly average SO_2 concentrations at Three Rivers

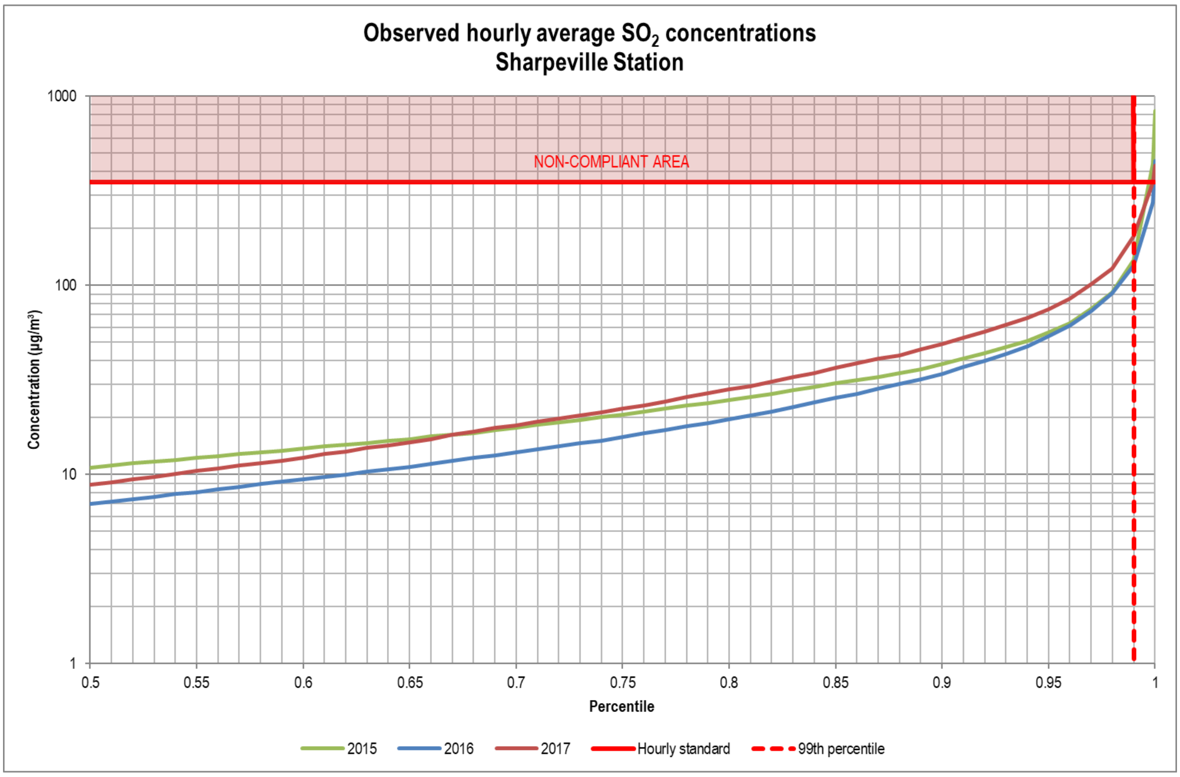

Figure 5-20: Observed hourly average SO_2 concentrations at Sharpeville

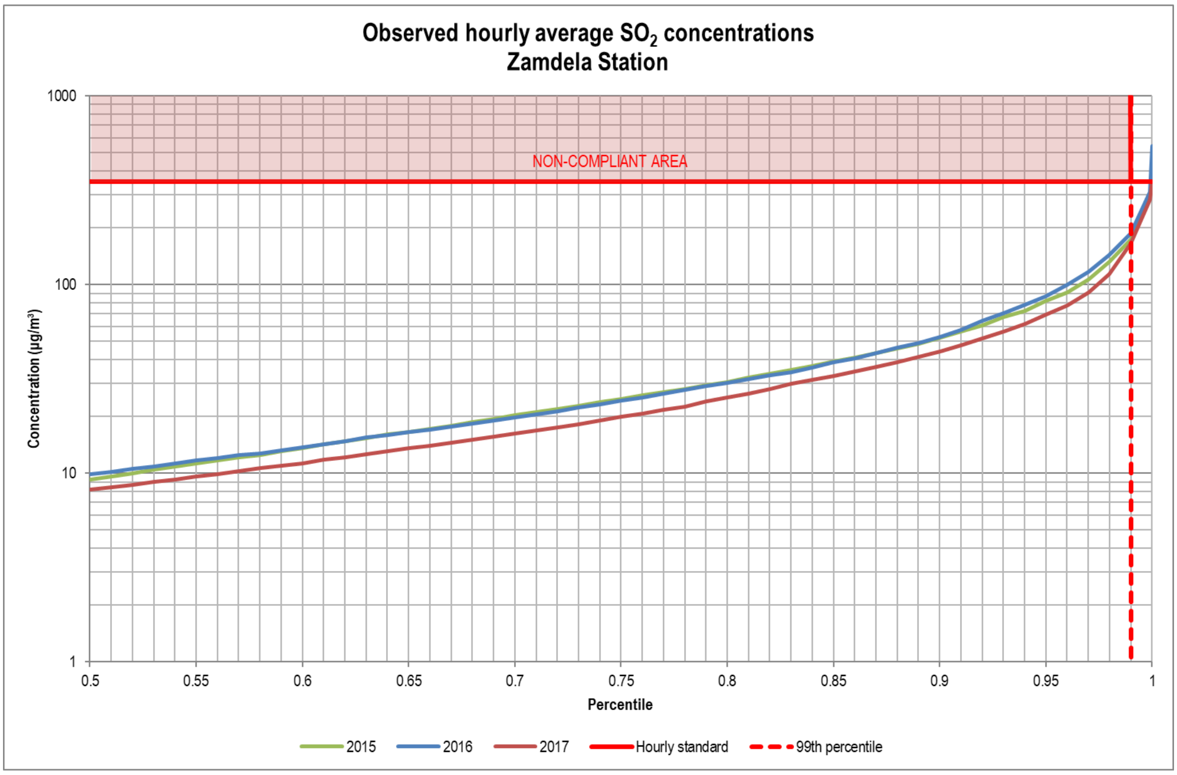

Figure 5-21: Observed hourly average SO_2 concentrations at Zamdela

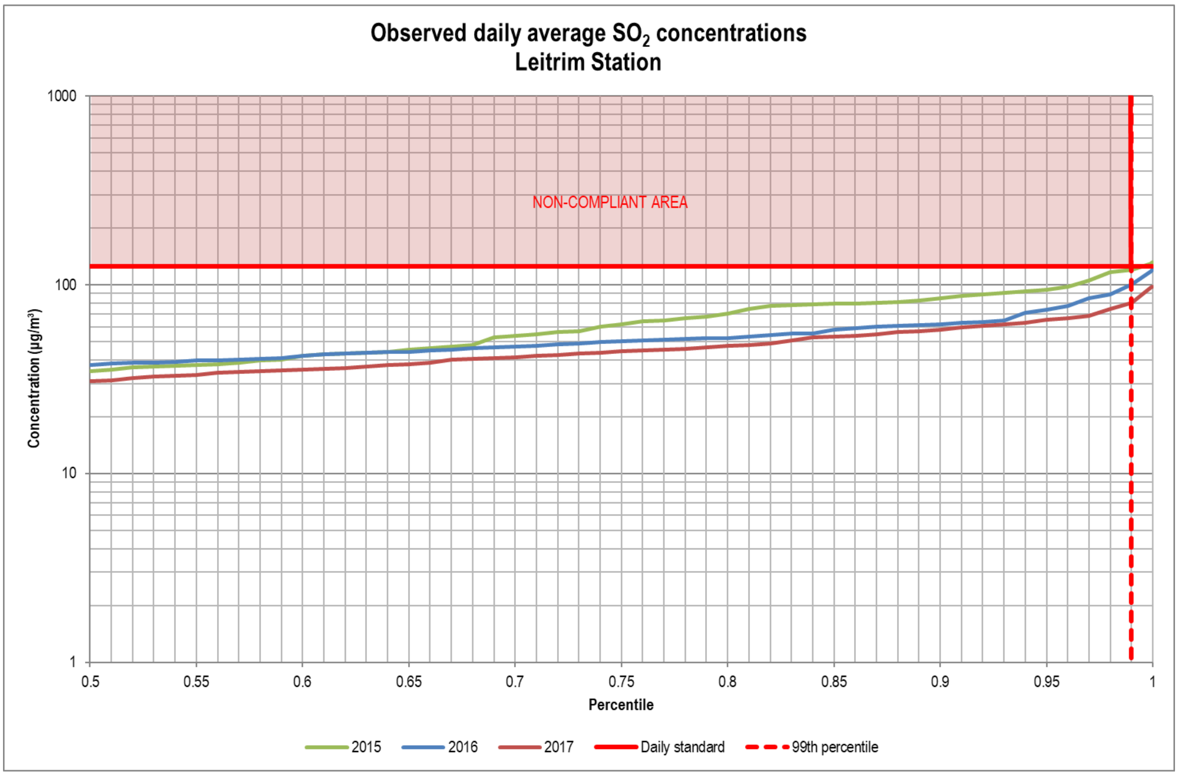

Figure 5-22: Observed daily average SO_2 concentrations at Leitrim

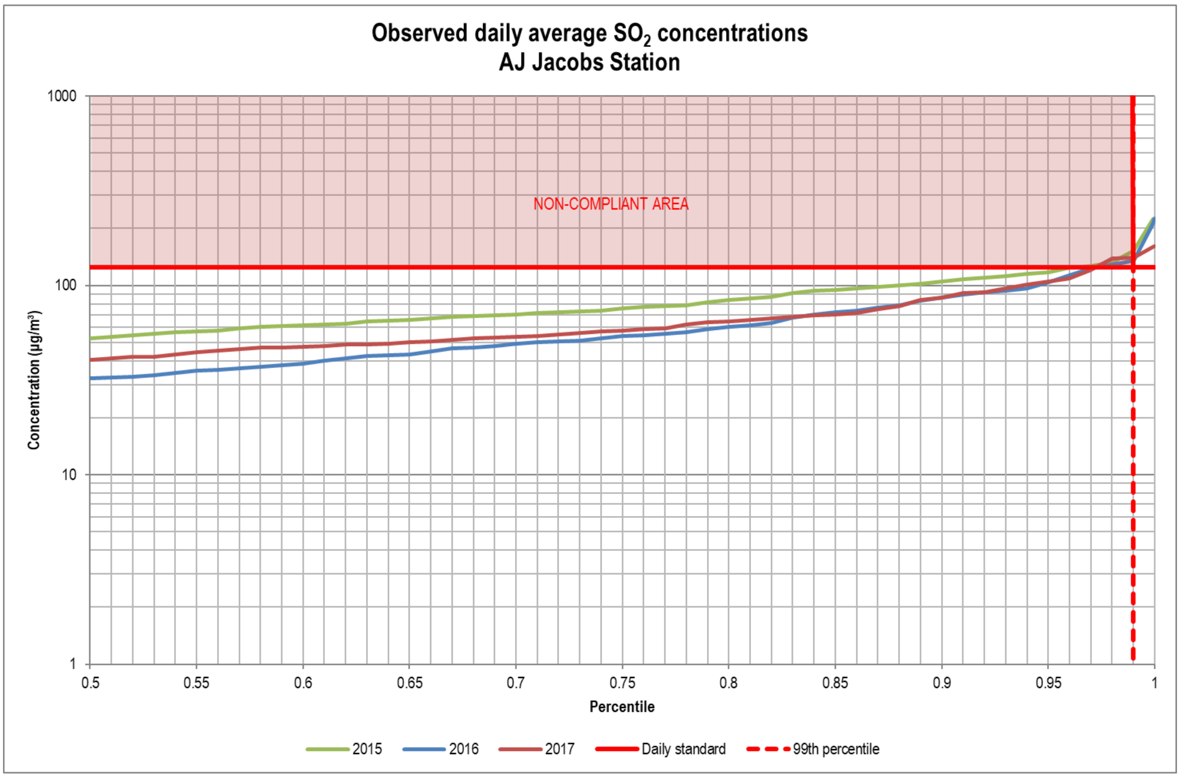

Figure 5-23: Observed daily average SO_2 concentrations at AJ Jacobs

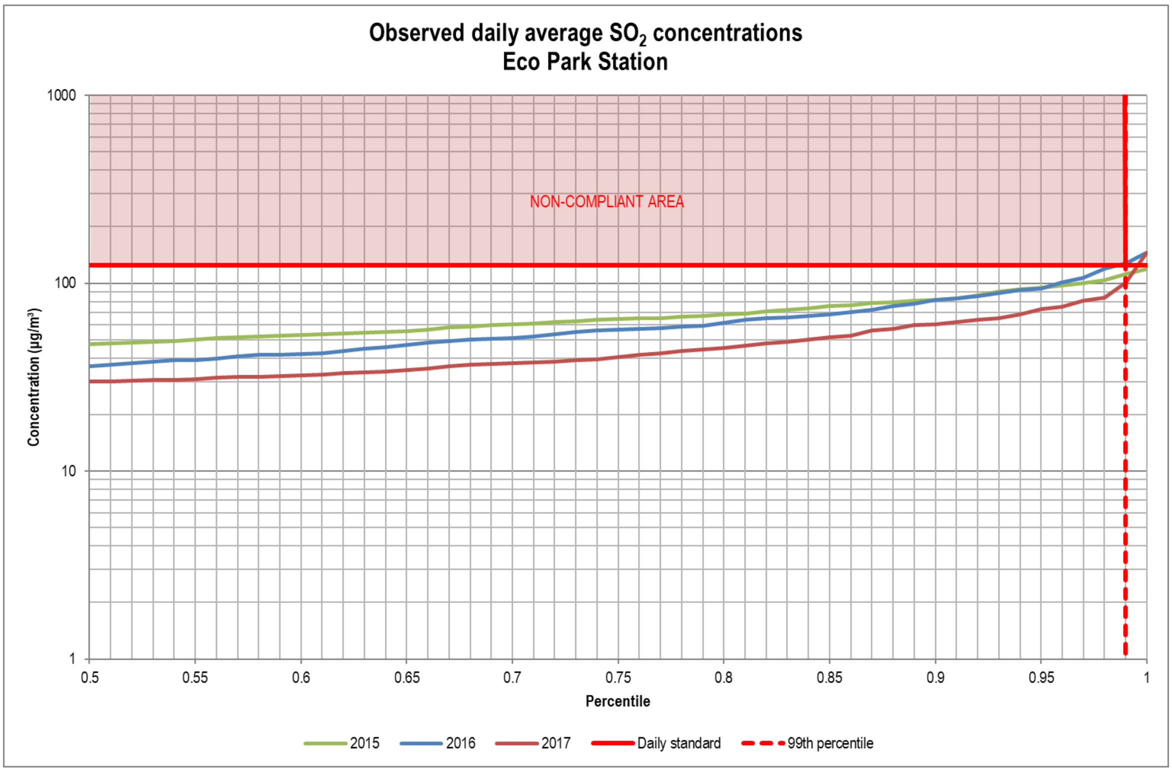

Figure 5-24: Observed daily average SO_2 concentrations at Eco Park

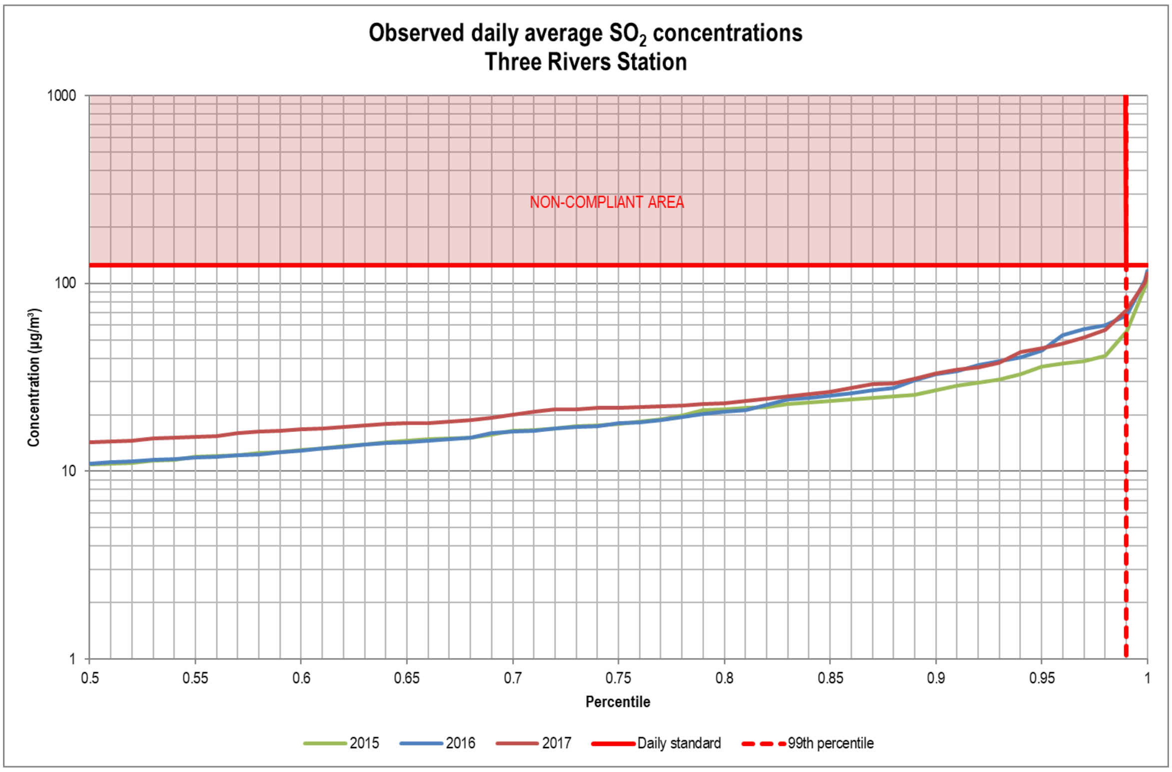

Figure 5-25: Observed daily average SO_2 concentrations at Three Rivers

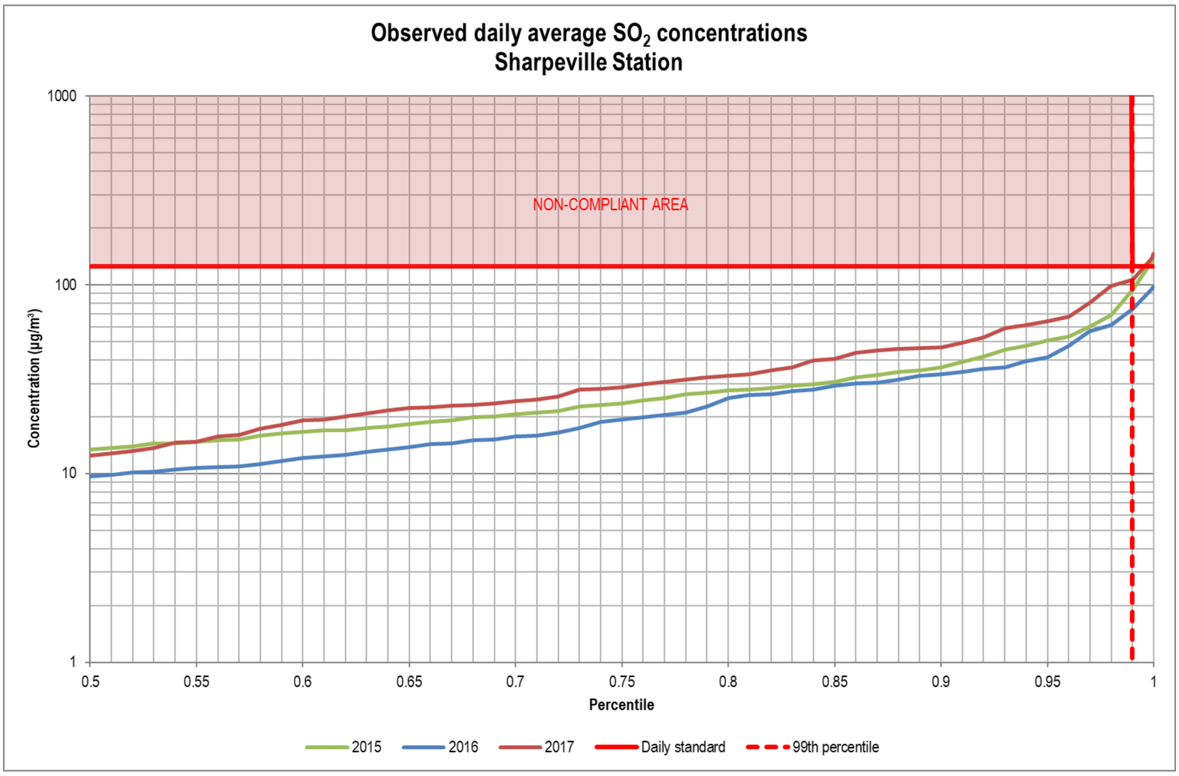

Figure 5-26: Observed daily average SO_2 concentrations at Sharpeville

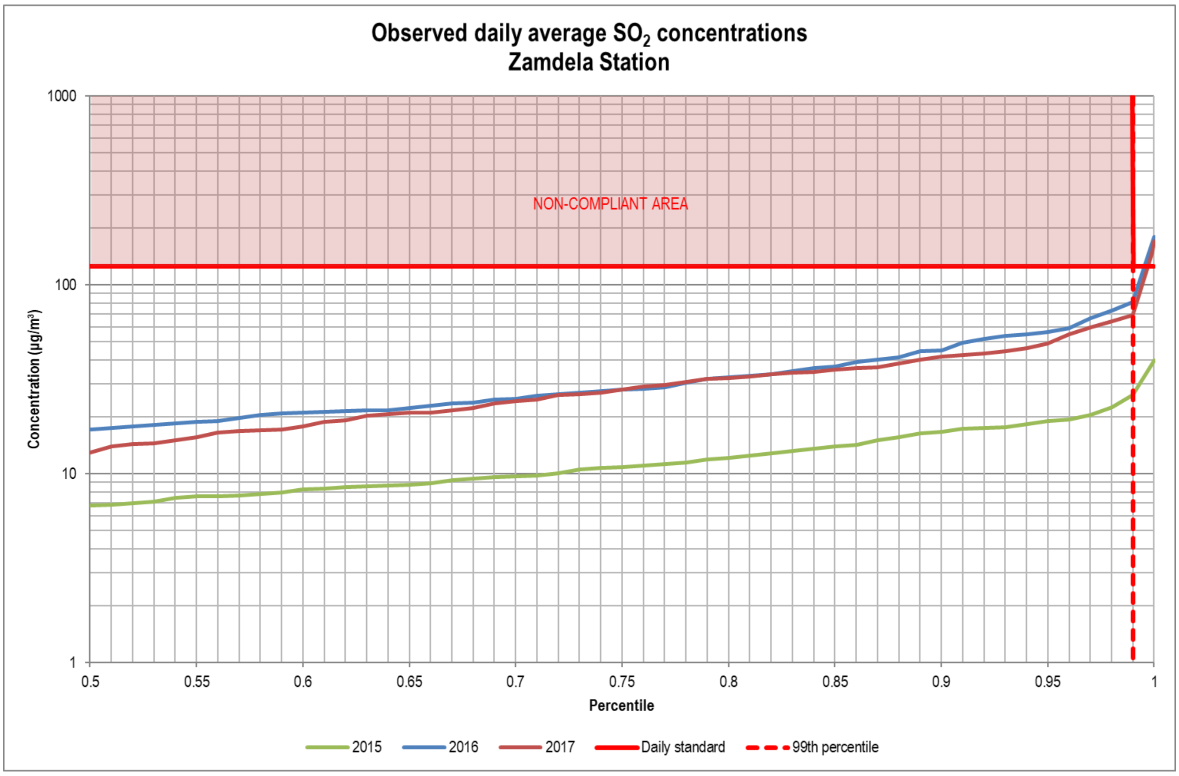

Figure 5-27: Observed daily average SO_2 concentrations at Zamdela

The hourly 99th percentiles for NO_2 were below the limit value (200 µg/m³) at all stations and for all three years (Figure 5-28 to Figure 5-33).

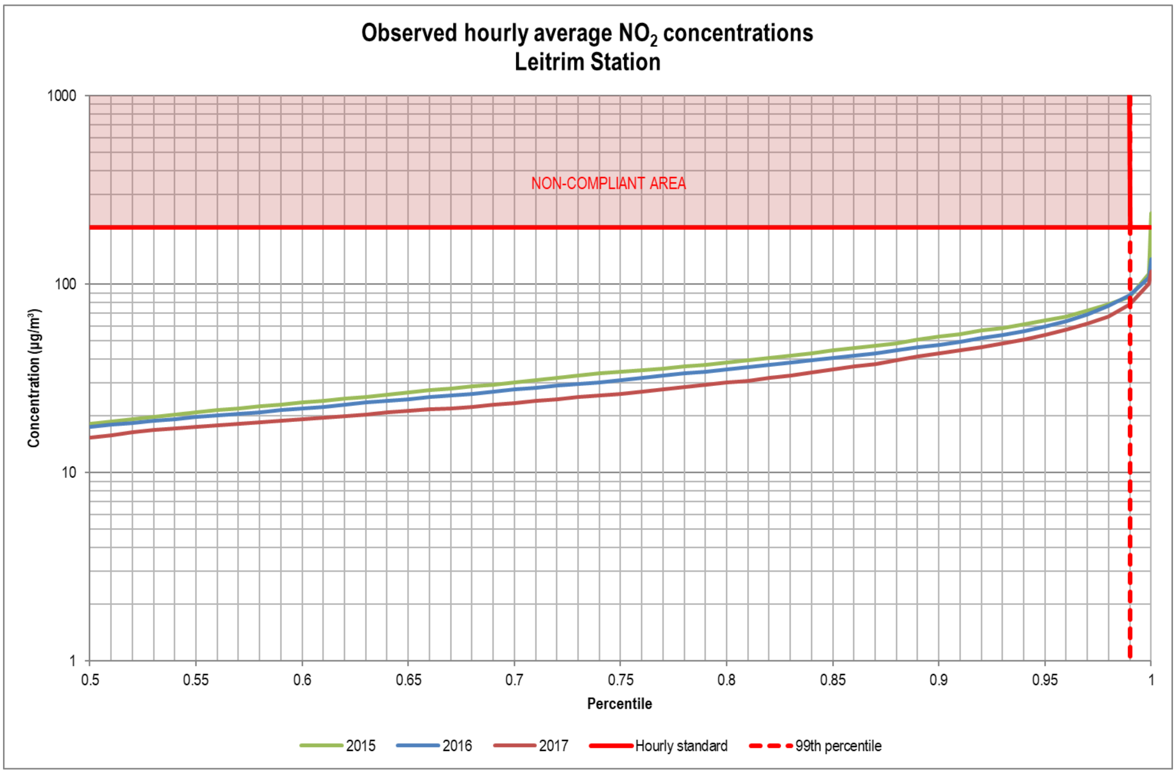

Figure 5-28: Observed hourly average NO_2 concentrations at Leitrim

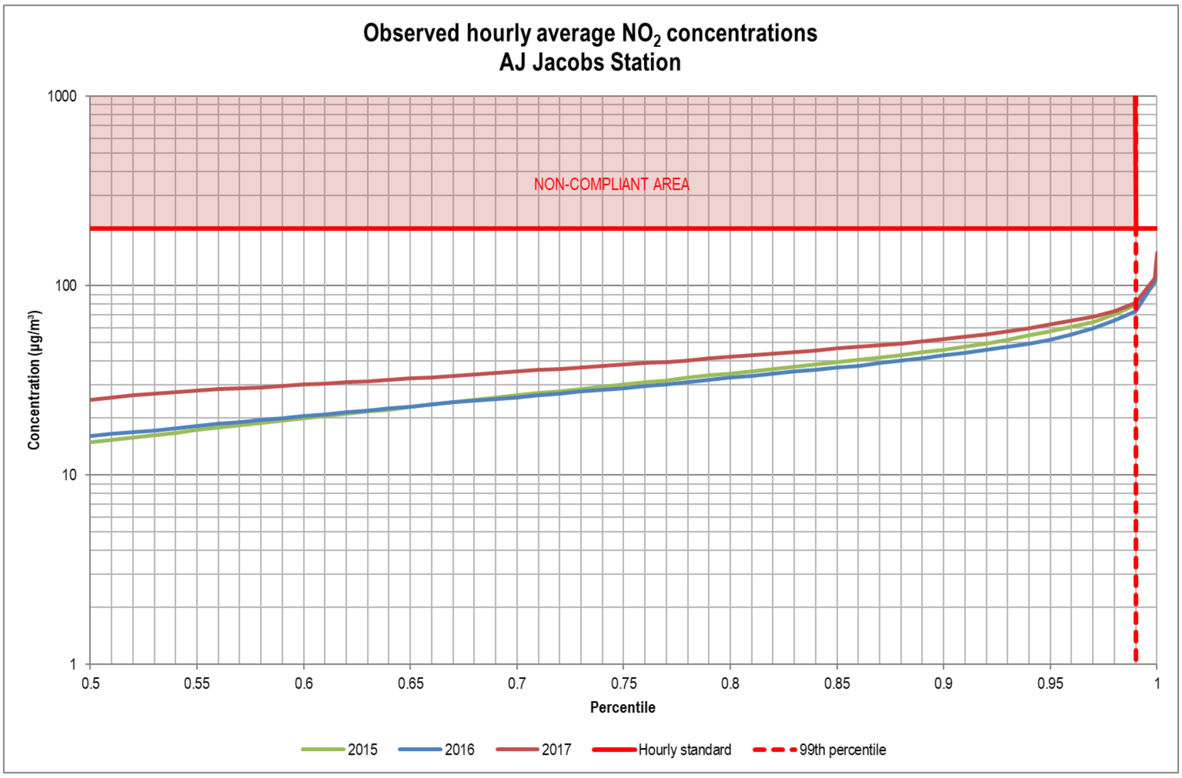

Figure 5-29: Observed hourly average NO_2 concentrations at AJ Jacobs

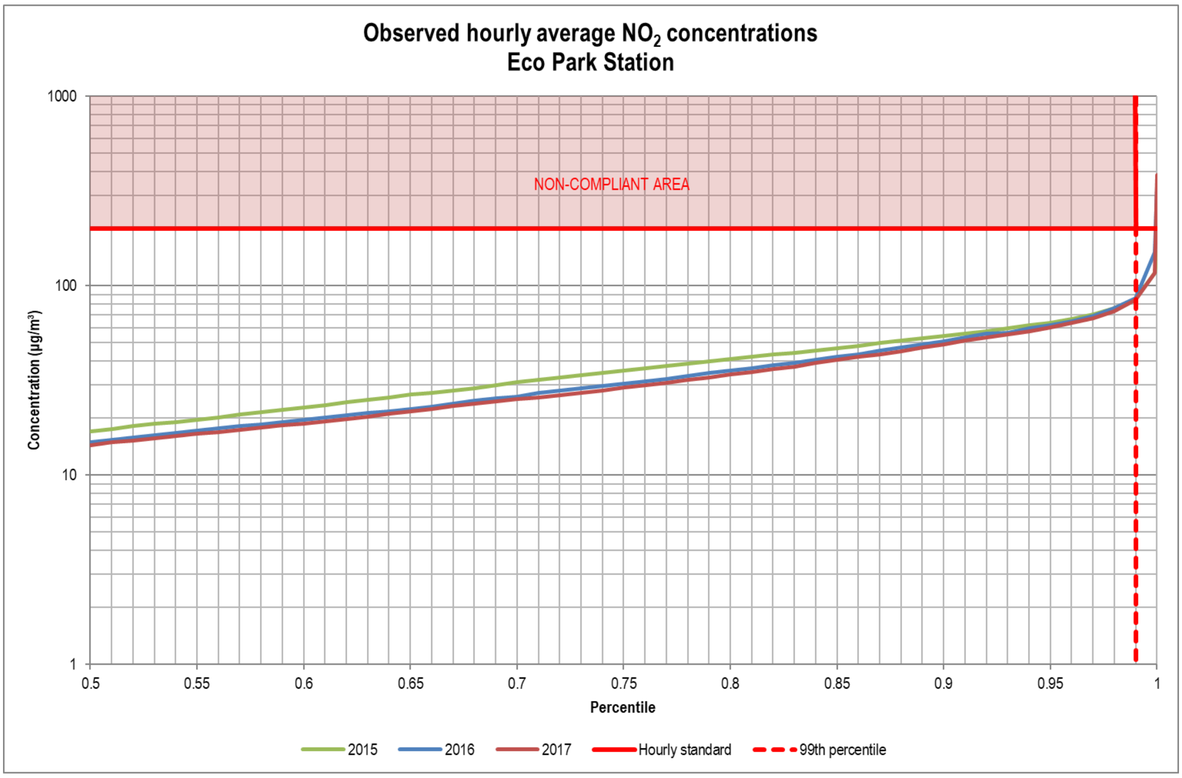

Figure 5-30: Observed hourly average NO_2 concentrations at Eco Park

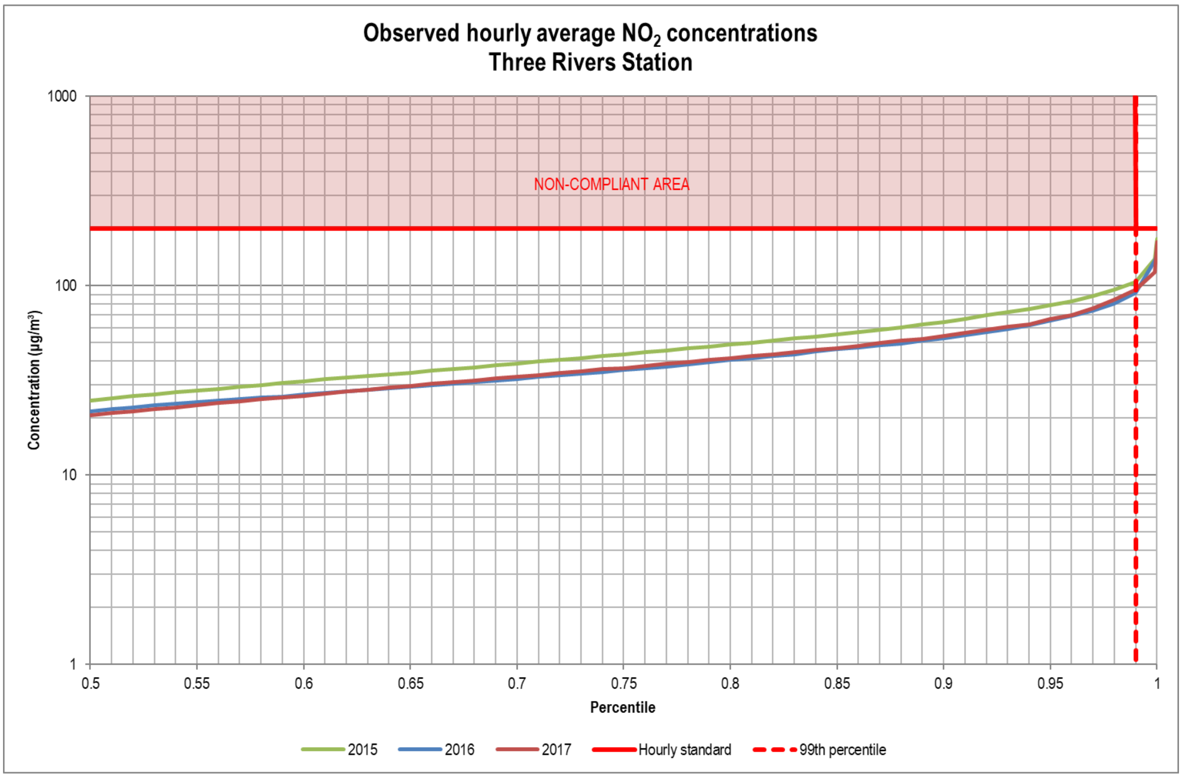

Figure 5-31: Observed hourly average NO_2 concentrations at Three Rivers

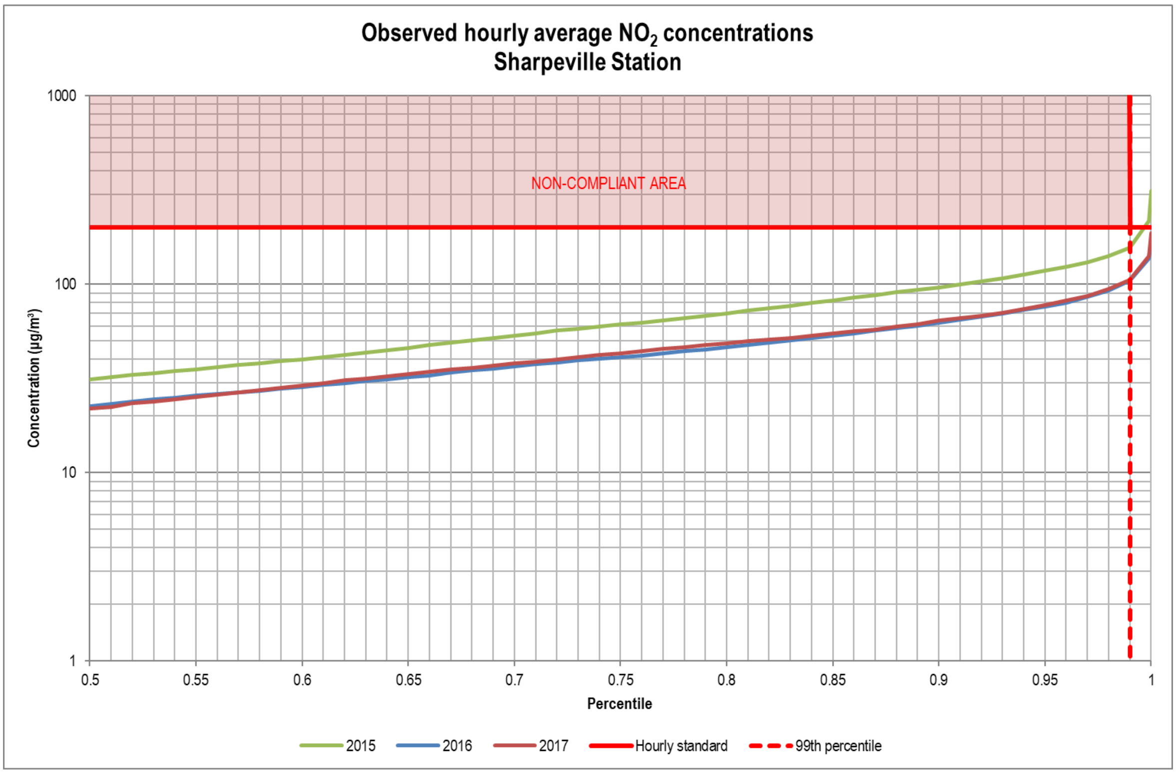

Figure 5-32: Observed hourly average NO_2 concentrations at Sharpeville

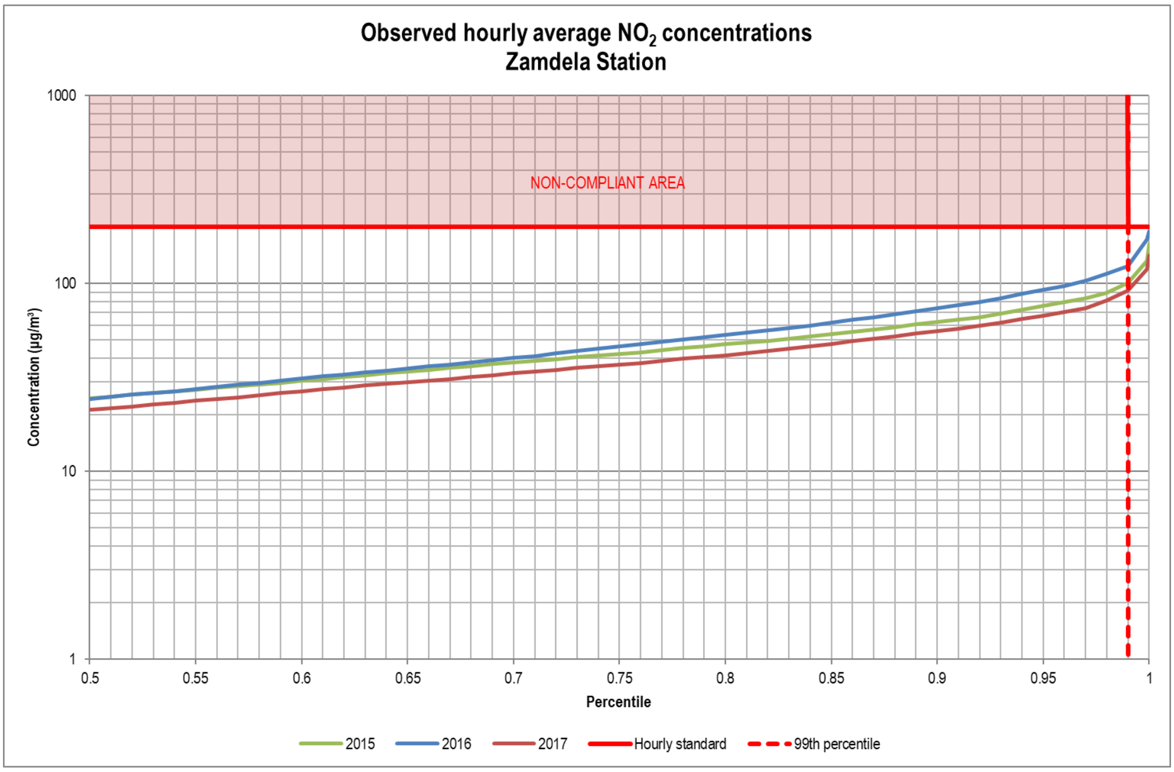

Figure 5-33: Observed hourly average NO_2 concentrations at Zamdela

The daily 99th percentiles for PM_{10} exceed the limit value (75 µg/m³; 2015 standard) at all stations and for all three years (Figure 5-34 to Figure 5-39). Non-compliance varied between 3% and 50% of the three years assessed.

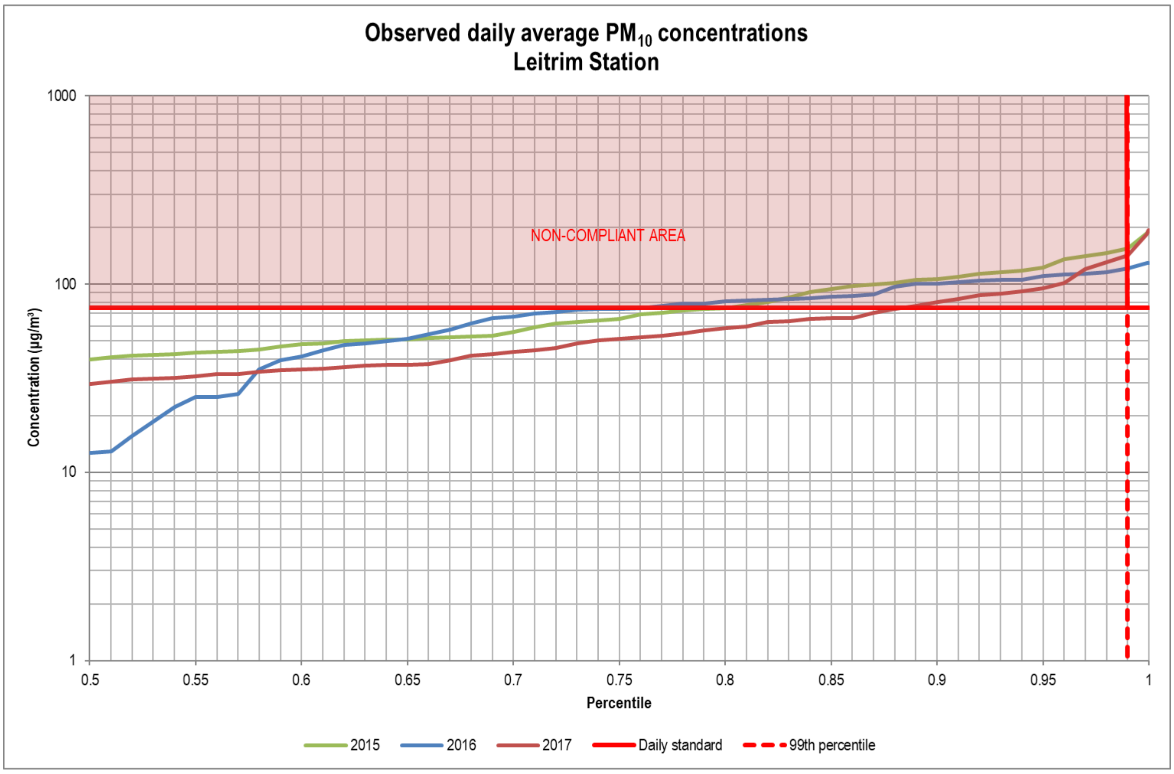

Figure 5-34: Observed daily average PM_{10} concentrations at Leitrim

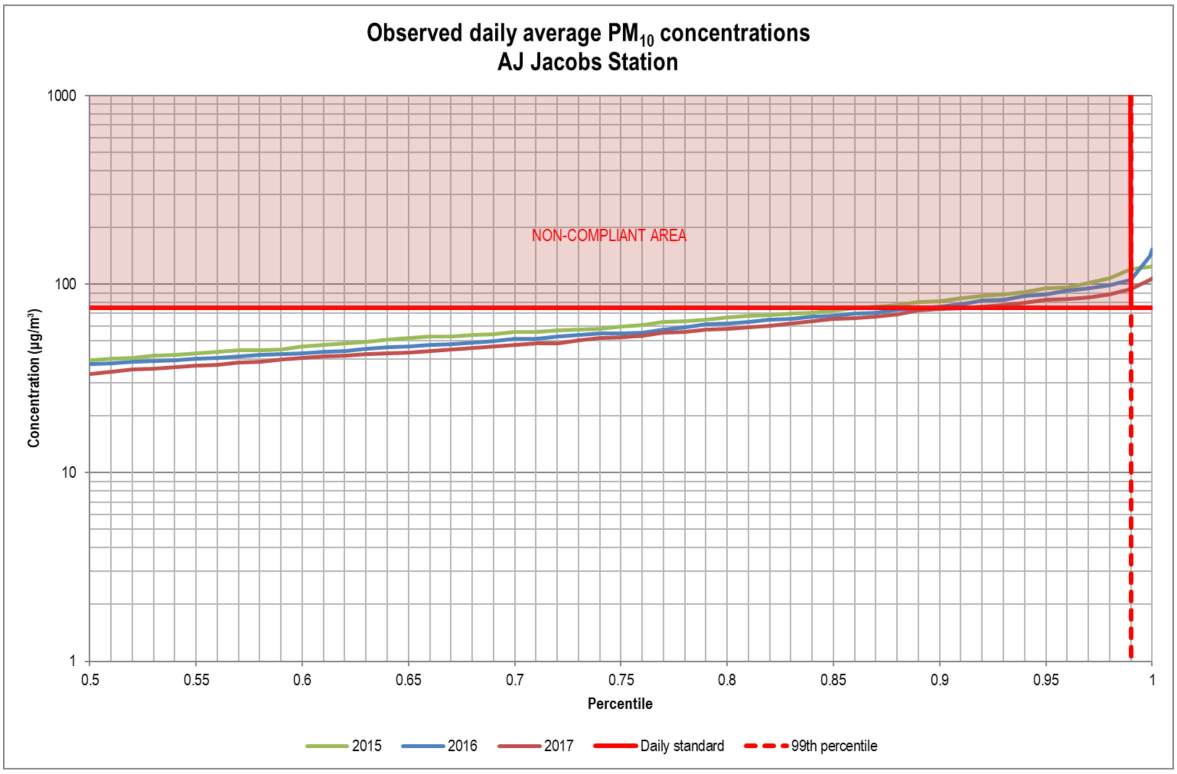

Figure 5-35: Observed daily average PM_{10} concentrations at AJ Jacobs

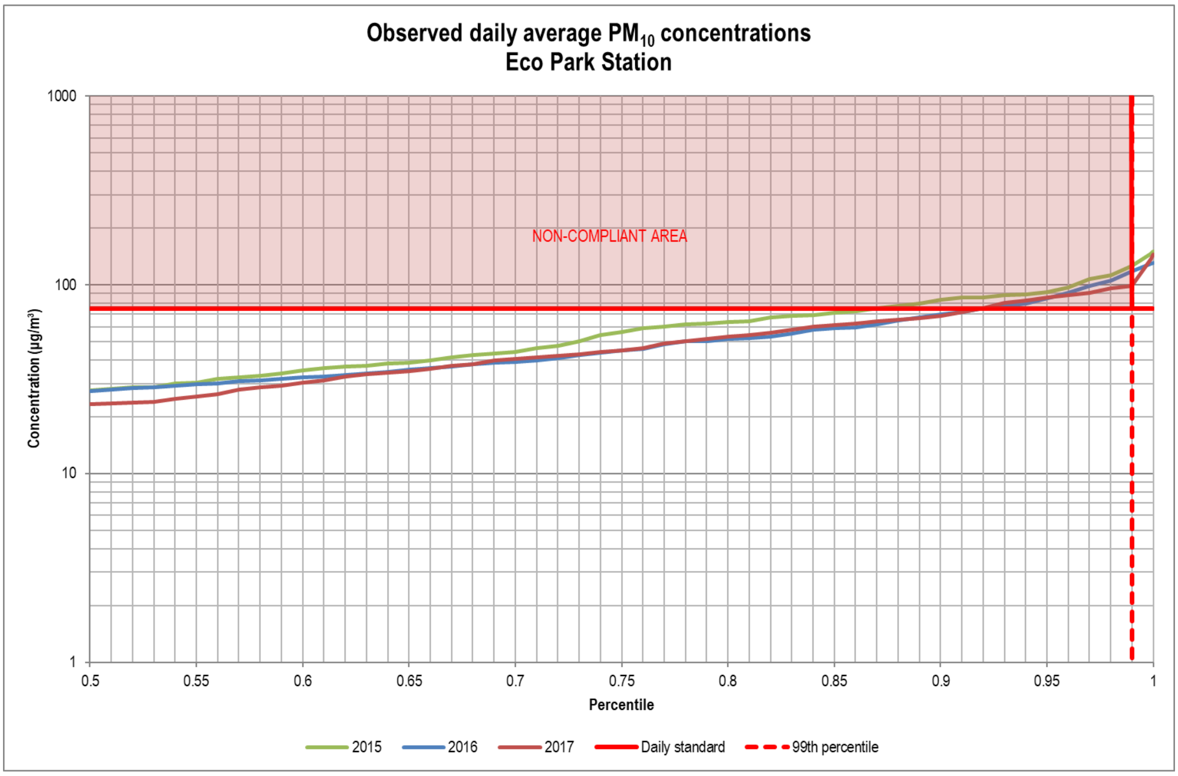

Figure 5-36: Observed daily average PM_{10} concentrations at Eco Park

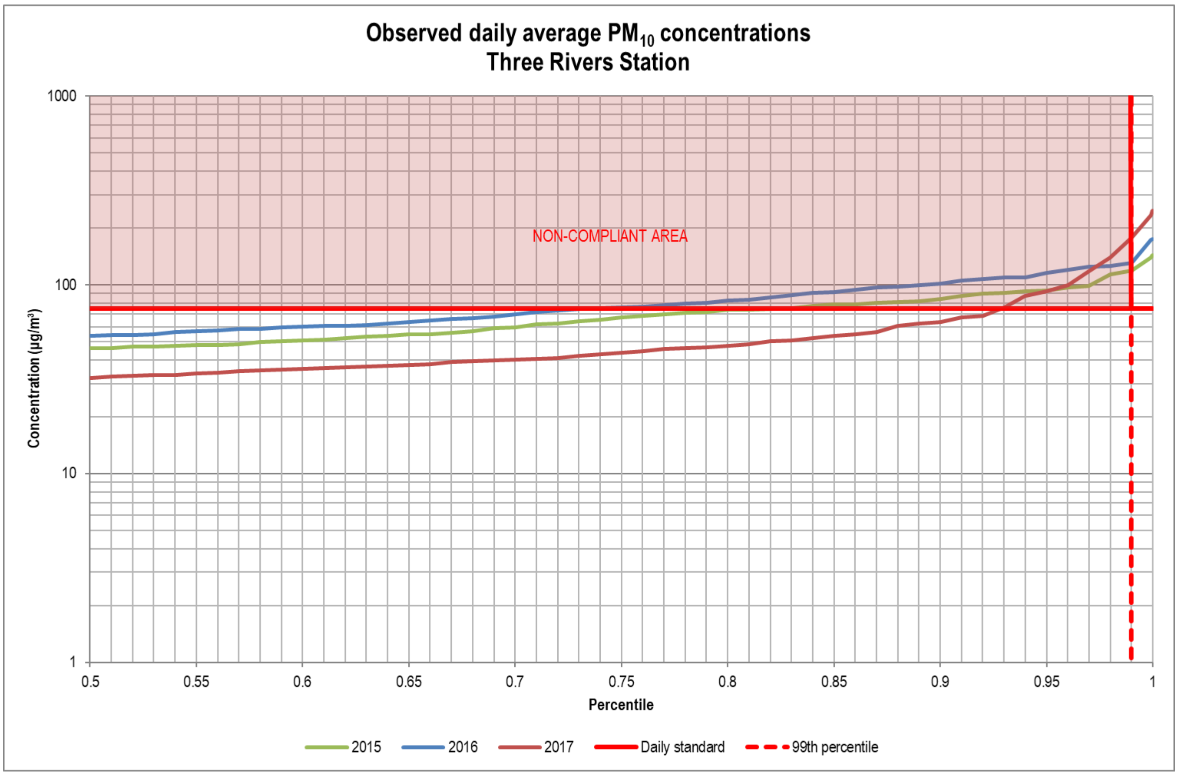

Figure 5-37: Observed daily average PM_{10} concentrations at Three Rivers

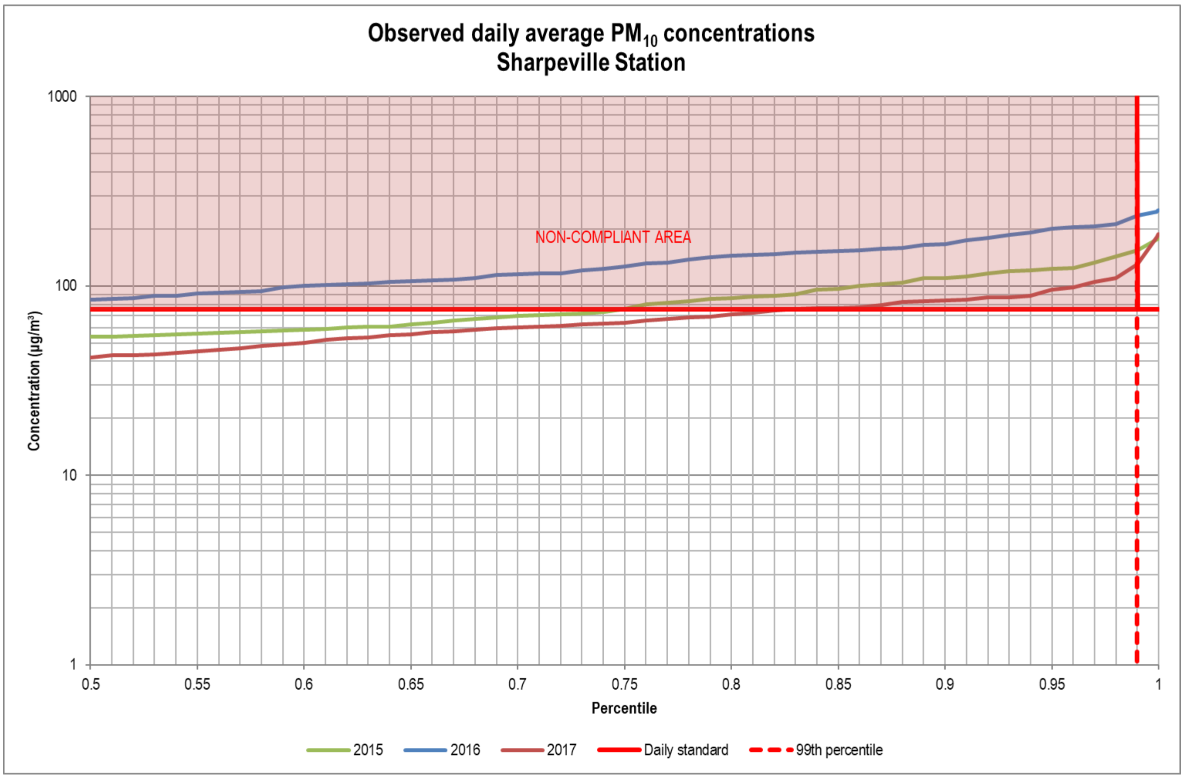

Figure 5-38: Observed daily average PM_{10} concentrations at Sharpeville

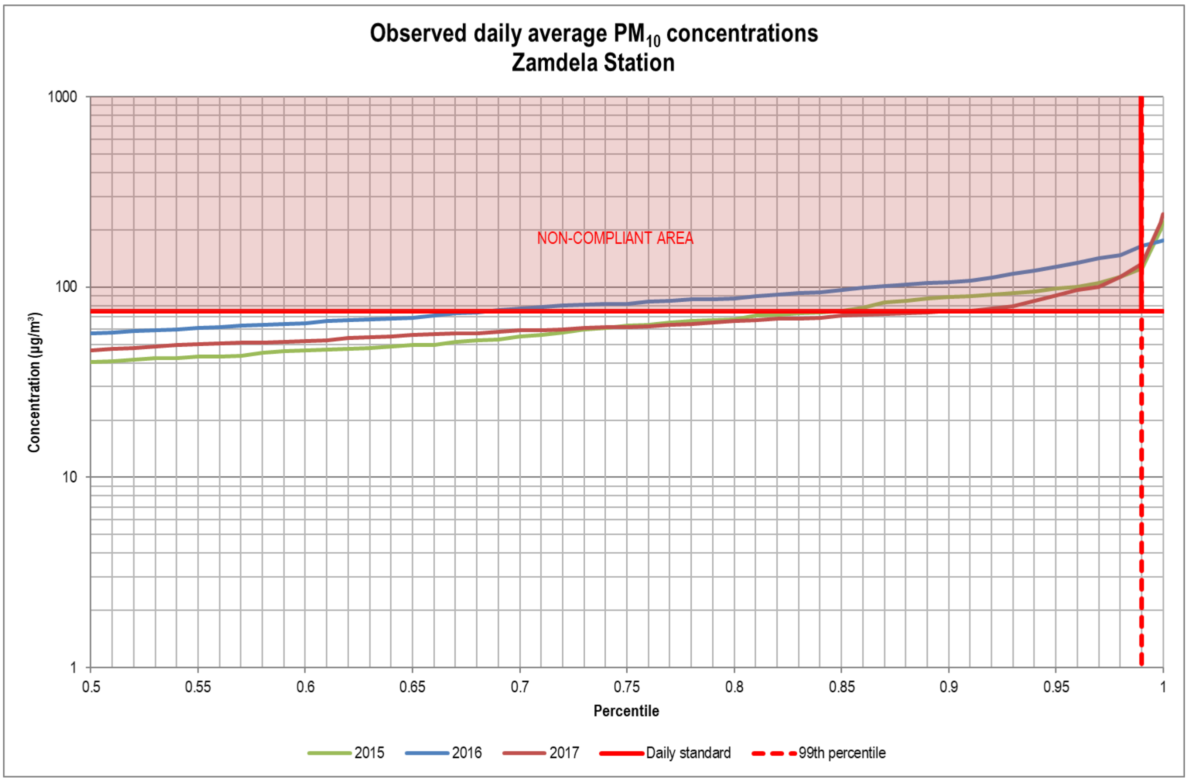

Figure 5-39: Observed daily average PM_{10} concentrations at Zamdela

Time variation plots (mean with 95% confidence interval) of ambient SO_2, NO_2, and particulate matter (PM_{10} and $PM_{2.5}$) concentrations measured the six monitoring stations show the variation of these pollutants over a daily, weekly and annual cycles (Figure 5-40 to Figure 5-51). The daily SO_2 show a typically industrial signature with increased SO_2 concentrations as just before midday due to the break-up of an elevated inversion layer, in addition to the development of daytime convective conditions causing the plume to be brought down to ground level relatively close to the point of release from tall stacks. Increased NO_2 concentrations during peak traffic times (07:00 to 08:00 and 16:00 to 18:00) illustrate the contribution of vehicle emissions to the ambient NO_2 concentrations. The winter (June, July and August) elevation of SO_2 and NO_2 shows the contribution of residential fuel burning to the ambient SO_2 and NO_2 concentrations.

Monthly variation of particulate matter shows elevated concentrations during winter months due to the larger contribution from domestic fuel burning, dust from uncovered soil and the lack of the settling influence of rainfall (Figure 5-46 and Figure 5-51).

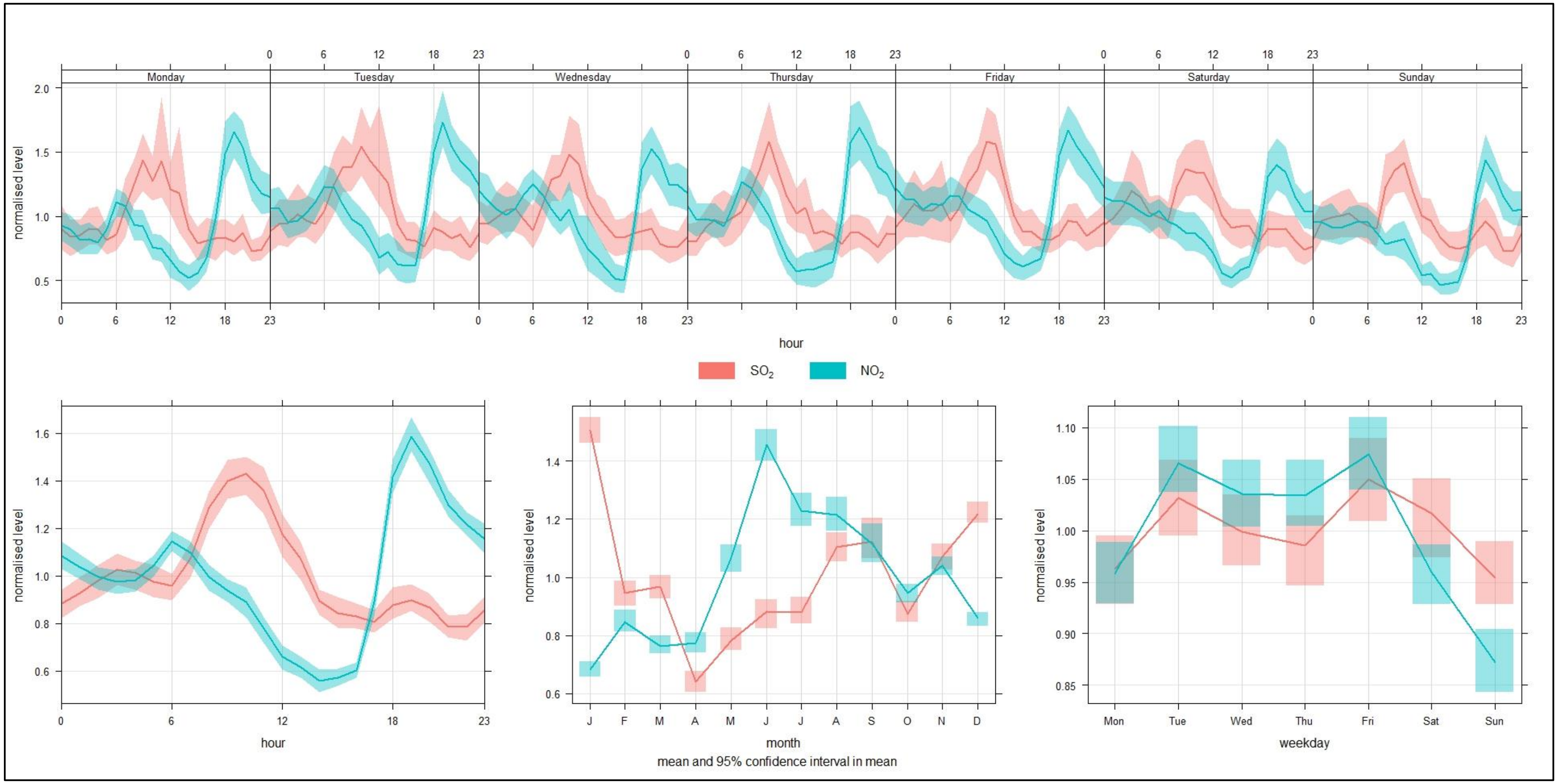

Figure 5-40: Time variation plot of observed SO_2 and NO_2 concentrations at Leitrim (shaded area indicates 95th percentile confidence interval)

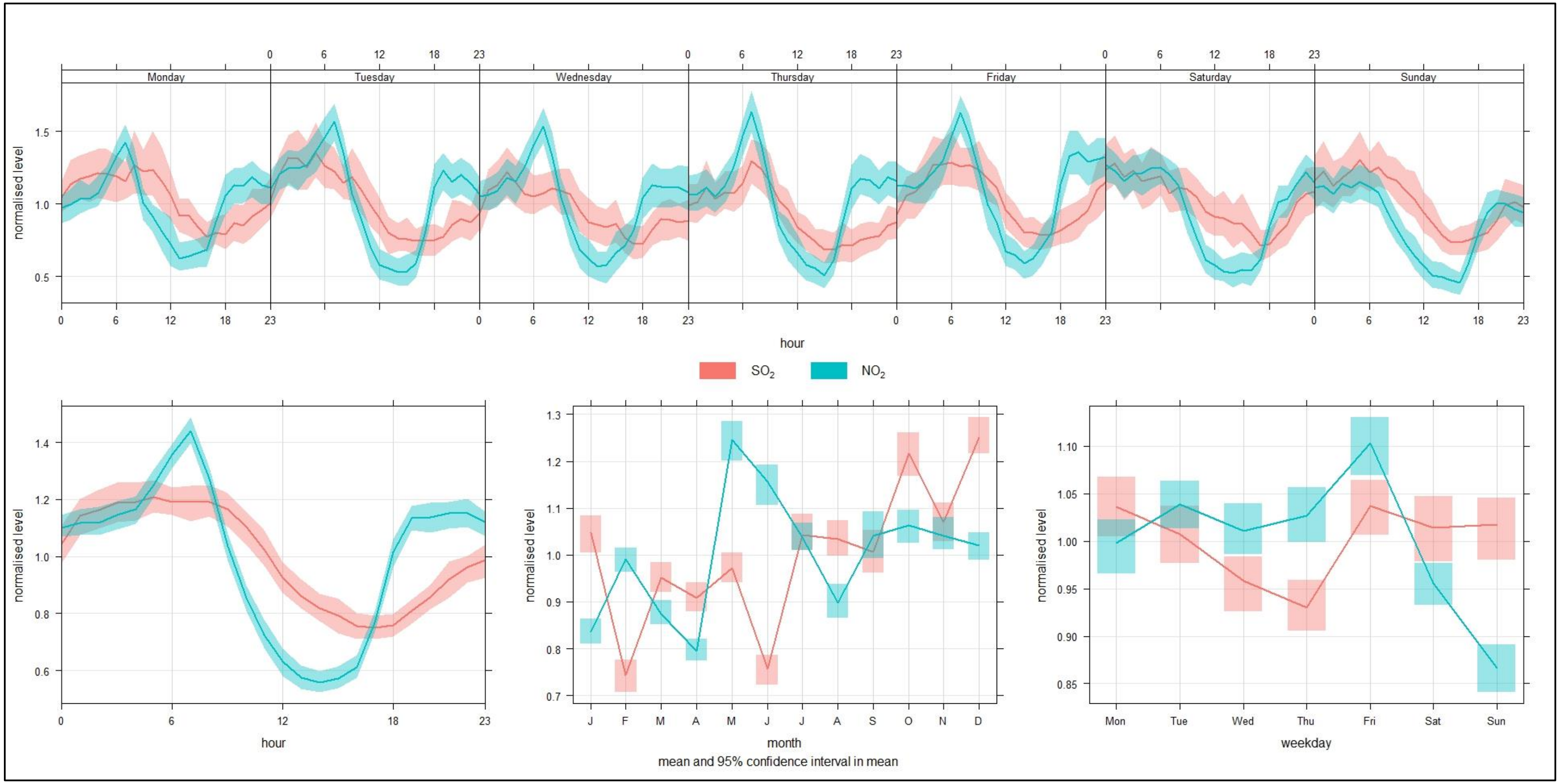

Figure 5-41: Time variation plot of observed SO_2 and NO_2 concentrations at AJ Jacobs (shaded area indicates 95th percentile confidence interval)

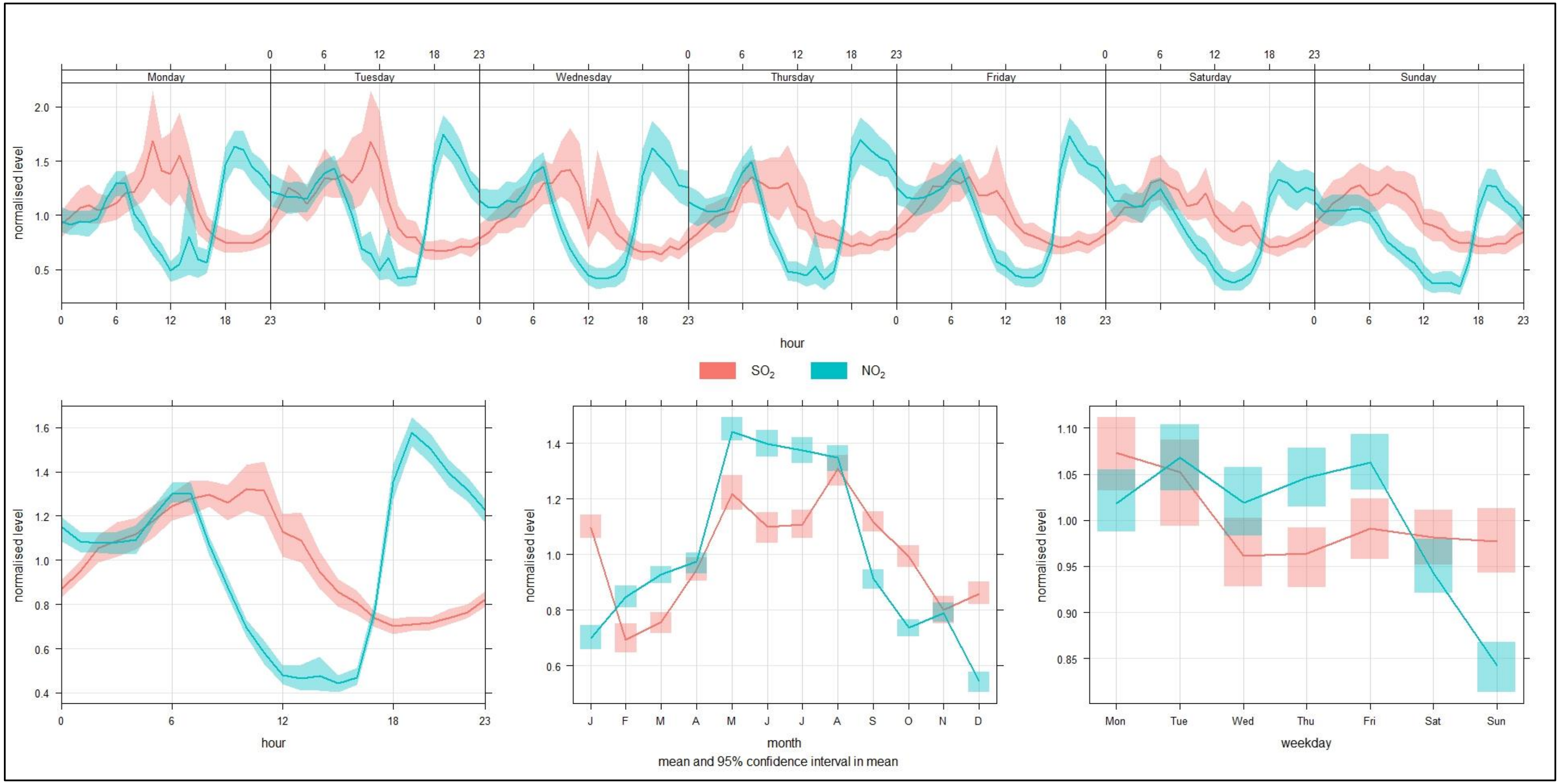

Figure 5-42: Time variation plot of observed SO_2 and NO_2 concentrations at Eco Park (shaded area indicates 95[th] percentile confidence interval)

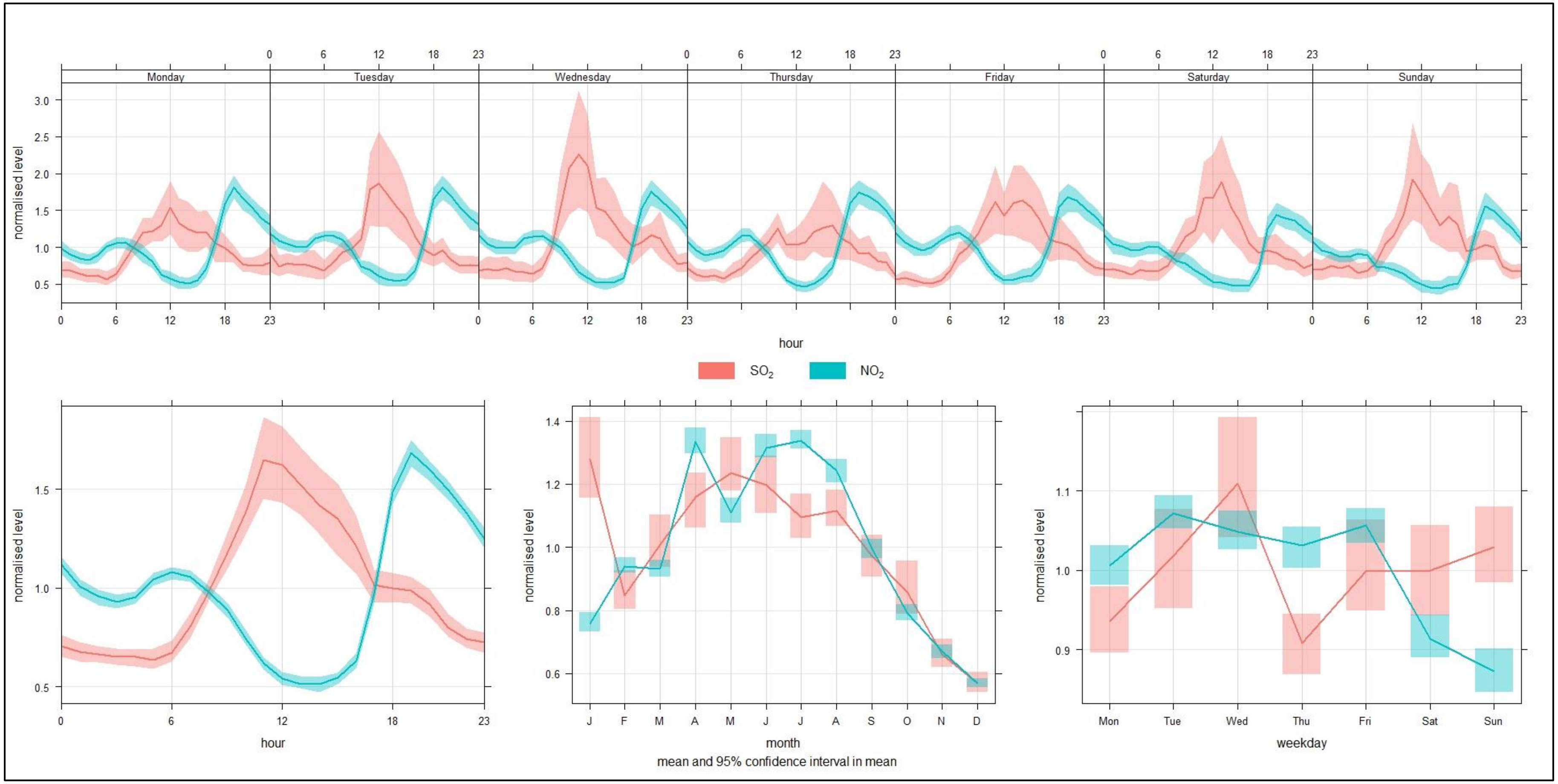

Figure 5-43: Time variation plot of observed SO_2 and NO_2 concentrations at Three Rivers (shaded area indicates 95th percentile confidence interval)

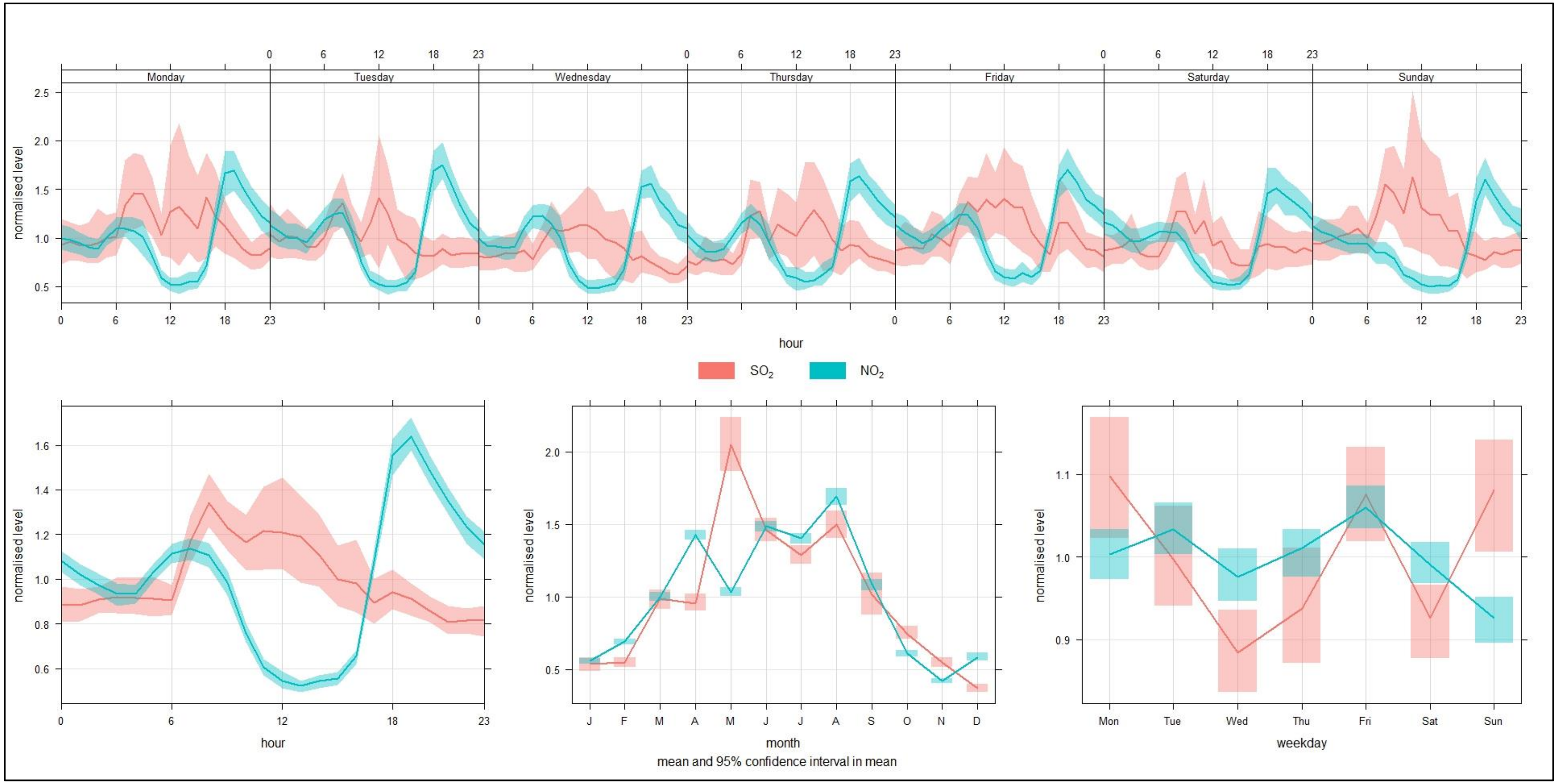

Figure 5-44: Time variation plot of observed SO_2 and NO_2 concentrations at Sharpeville (shaded area indicates 95th percentile confidence interval)

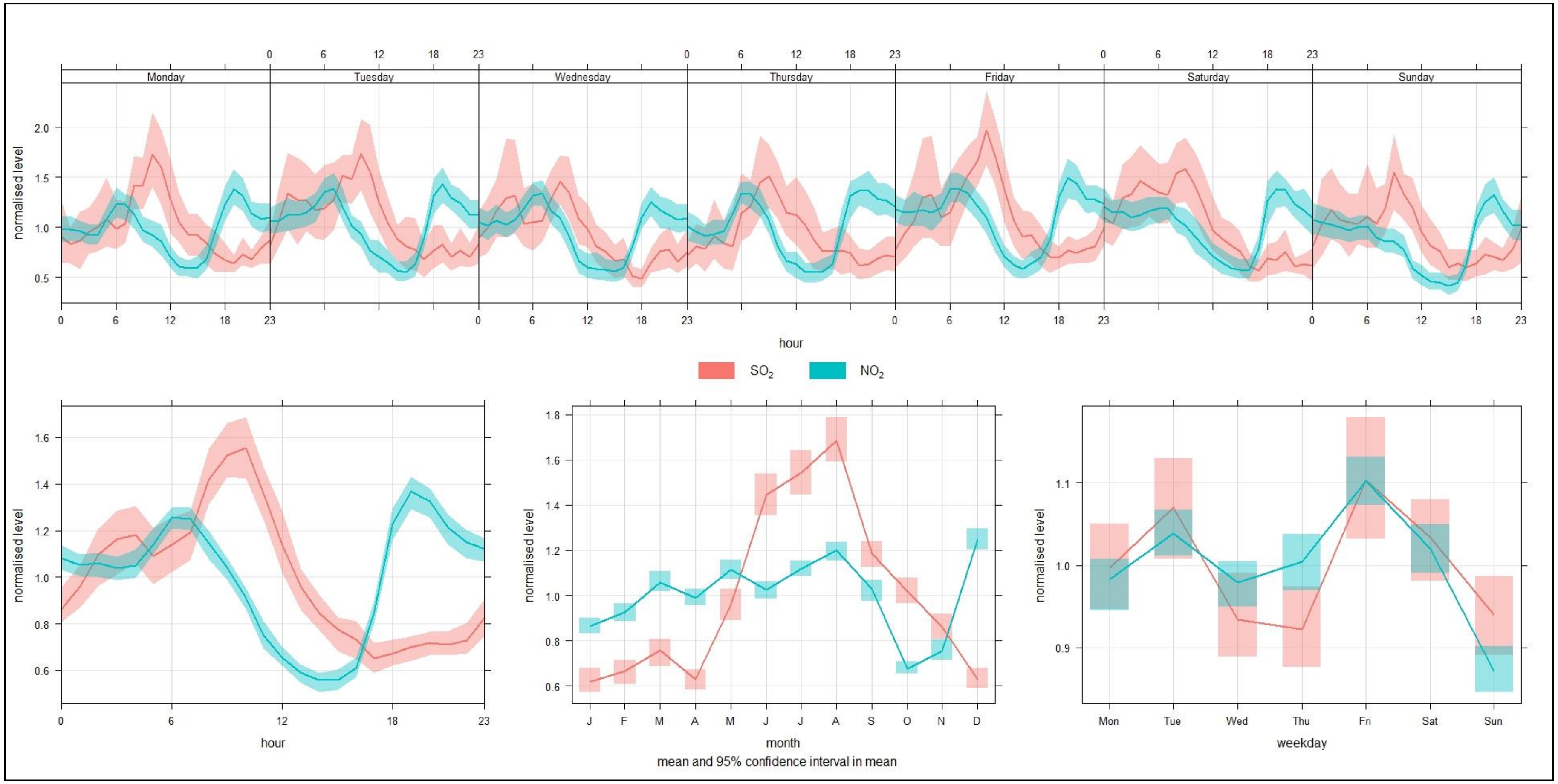

Figure 5-45: Time variation plot of observed SO_2 and NO_2 concentrations at Zamdela (shaded area indicates 95th percentile confidence interval)

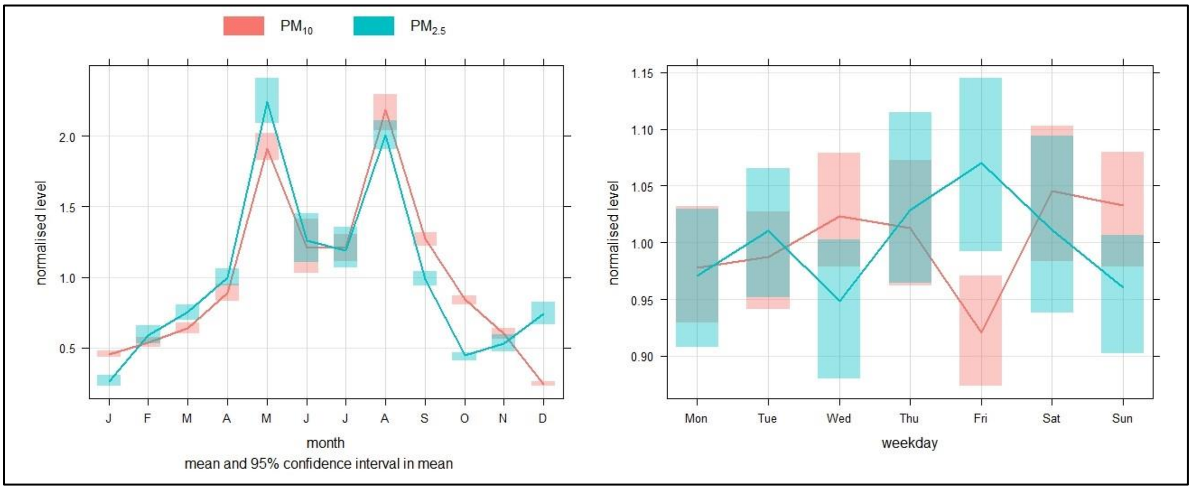

Figure 5-46: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Leitrim

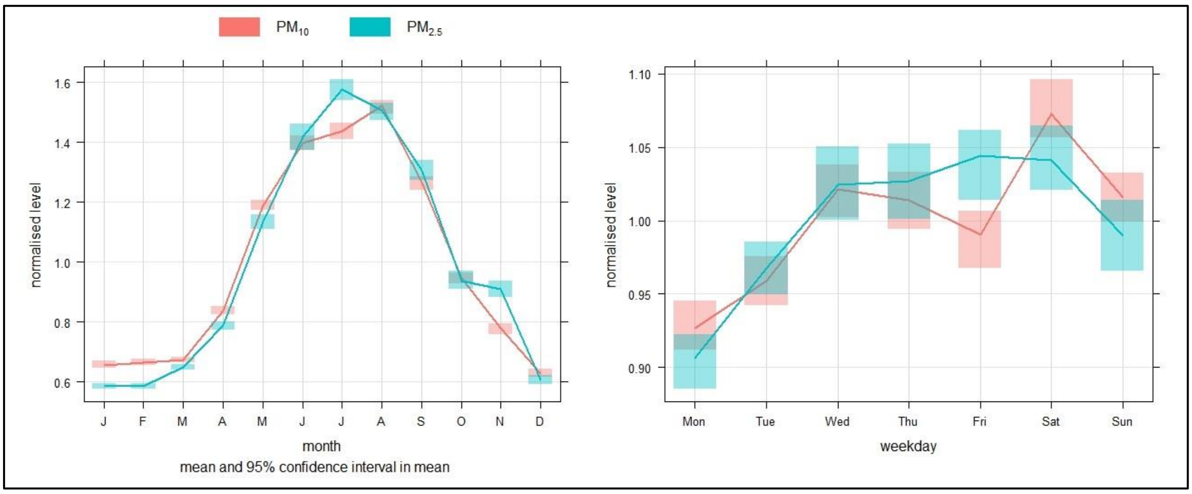

Figure 5-47: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at AJ Jacobs

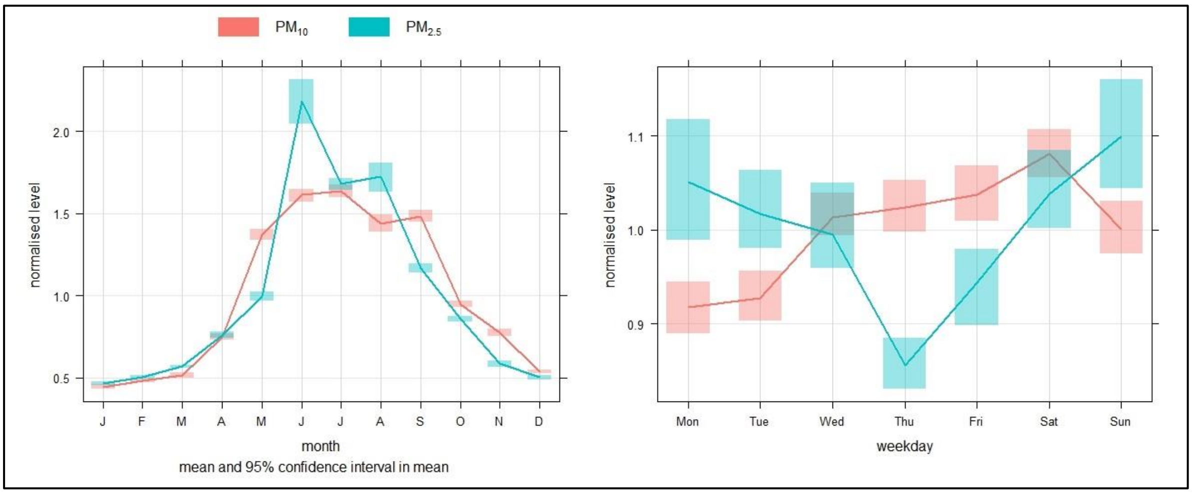

Figure 5-48: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Eco Park

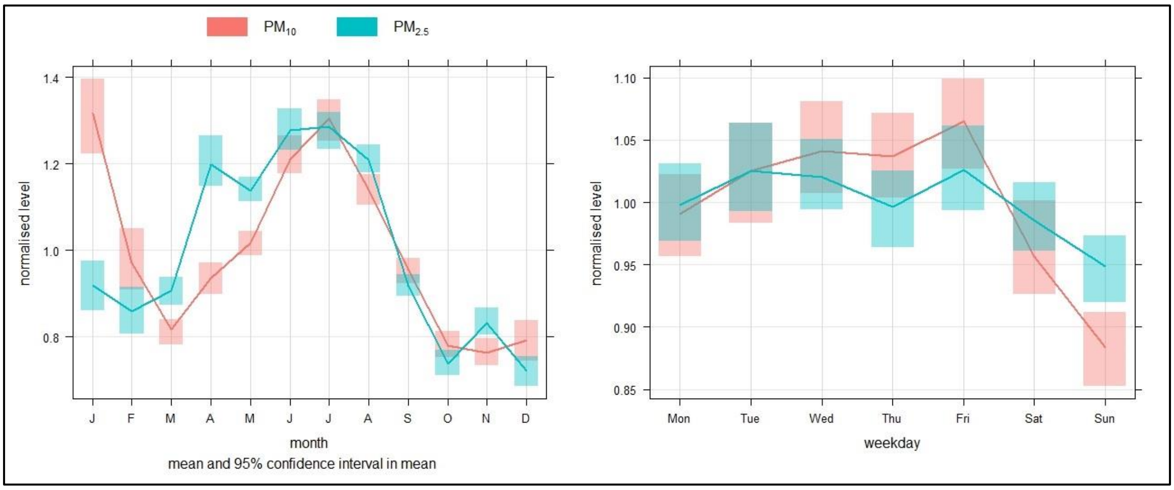

Figure 5-49: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Three Rivers

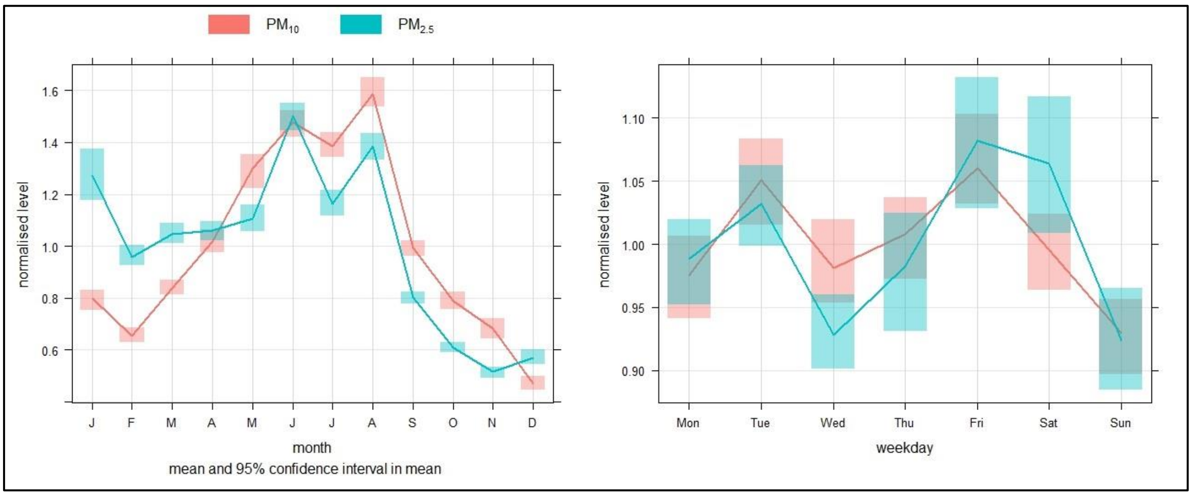

Figure 5-50: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Sharpeville

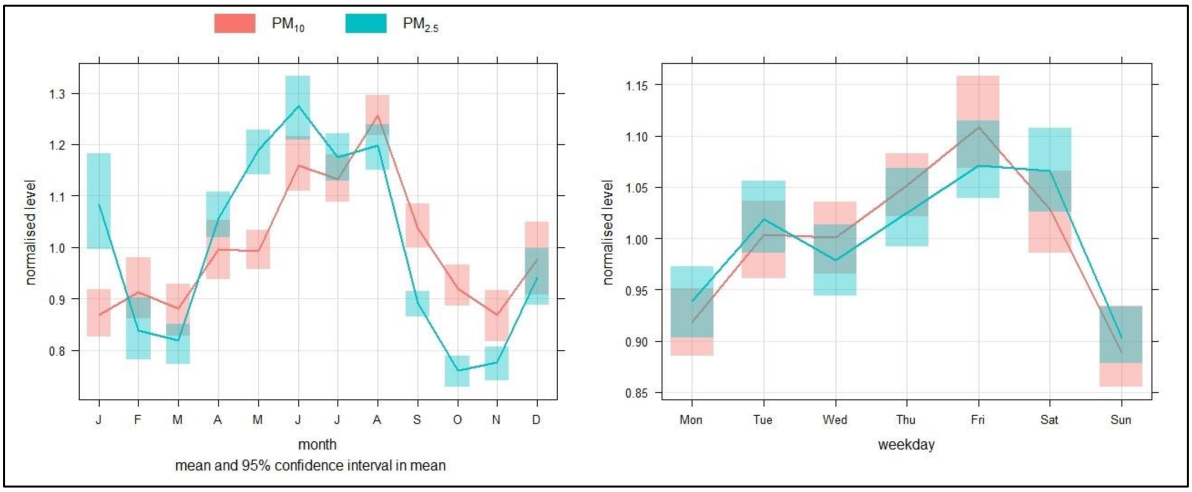

Figure 5-51: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Zamdela

5.1.6 Model Performance

5.1.6.1 Understanding of Observed Concentrations

An analysis of the observed SO_2, NO_2 and PM_{10} concentrations at six monitoring stations was completed, in which the concentration values were categorised into wind speed and direction bins for different concentrations. This information is most easily visualised as polar plots, where the centre of the polar plot refers to the location of the monitoring station, as shown in Figure 5-52 for Leitrim and Figure 5-54 for Eco Park for SO_2 observations (other stations Figure 5-55 to Figure 5-57). The corresponding NO_2 analyses are summarised in Figure 5-58 to Figure 5-63. Polar plots for PM analyses are presented in Figure 5-64 and Figure 5-69.

These polar plots (Carslaw and Ropkins, 2012; Carslaw, 2013) provide an indication of the directional contribution as well as the dependence of concentrations on wind speed. Whereas the directional display is fairly obvious, i.e. when higher concentrations are shown to occur in a certain sector, e.g. east and south for SO_2 at Eco Park (Figure 5-54), it is understood that most of the high concentrations occur when winds blow from that sector (i.e. east or south). When the high concentration pattern is more symmetrical around the centre of the plot, it is an indication that the contributions are near-equally distributed, as is displayed for SO_2 in Figure 5-55.

Furthermore, since the observed concentrations have also been categorised according to wind speed categories, it provides an indication of the plume height. As explained in Section 5.1.4.1 (plume buoyancy), stronger winds reduce the amount of plume rise, and may effectively increase ground level concentrations. However, since an increased wind speed also enhances plume dispersion, a concentration maximum would be reached for a wind speed where the plume rise and dilution effects cancel each other. These conditions would be different for day- and night-time atmospheric stabilities. It is expected that high ground level concentrations from elevated stacks would be more prevalent during stronger wind speeds during stable conditions than daytime, convective conditions, when the plume buoyancy is often not as effective in lifting the plume centreline. Low-level emissions behave differently, and higher concentrations would normally be observed during weak-wind conditions.

The SO_2 concentrations observed at Leitrim (Figure 5-52) show elevated concentrations occurring with north-easterly winds above 5 m/s. Sasol operations are located towards the north-west and the increased concentrations due to emissions from this direction are also evident at wind speeds above 2 m/s. Other SO_2 contributions originate to the north-west of the Leitrim station. The dominant contribution of median SO_2 concentrations above 100 µg/m³ originate to the north-east of the AJ Jacobs at wind speeds between 2 m/s and 8 m/s (Figure 5-53). The SO_2 concentrations observed at Eco Park (Figure 5-54) indicate that most of the high concentrations occur with easterly winds between 6 m/s and 10 m/s. Albeit not as high as the concentrations from the easterly sector, the observations also show elevated concentrations from an southerly direction. The Three Rivers station recorded relatively low median hourly SO_2 concentrations from all directions (Figure 5-55). Median SO_2 concentrations above 50 µg/m³ originate from the east and north-west at wind speeds above 2 m/s at the Sharpeville station (Figure 5-56). The Zamdela station recorded elevated SO_2 concentrations (above 100 µg/m³) at wind speeds above 6 m/s from the north-east (Figure 5-57). Other SO_2 contributions originate to the north-west and north of the Zamdela station.

The NO_2 concentrations observed at Leitrim (Figure 5-58) indicate that most of the elevated concentrations occur from the north-westerly winds of between 2 m/s and 6 m/s, northerly winds at winds less than 2 m/s or above 10 m/s. Since vehicular exhaust emissions are significant NO_2 contributors, the observations from the northern sector most likely indicates this source. Median NO_2 concentrations originate to the north-east of the AJ Jacobs at all wind speeds (Figure 5-59). The NO_2 concentrations observed at Eco Park (Figure 5-60) showed higher concentrations occurring during relatively weak winds of about 2 m/s and at higher wind speeds around 10 m/s, primarily from the south-south-west of the station. Median NO_2 concentrations observed at the Three Rivers station showed a local source at low wind speeds contributing NO_2 concentrations of approximately 50 µg/m³ (Figure 5-61). Higher NO_2 concentrations were recorded during high wind speeds (above 8 m/s) from the east of the Three Rivers station. A similar pattern of a local NO_2 source at low wind speeds is evident at the Sharpeville station (Figure 5-62), while NO_2 concentrations above 50 µg/m³ originate to the west-north-west of the Sharpeville station at wind speeds 8 m/s. Median NO_2 concentrations measured at the Zamdela station show contributions of NO_2 above 50 µg/m³ from the north-west and north east at all wind speeds (Figure 5-63).

Elevated particulate concentrations at Leitrim show contributions from the north and north-west at higher (between 8 and 10 m/s) wind speeds (Figure 5-64). At low wind speeds (2 m/s or less) the almost symmetrical plot shows a local contribution, most likely a result of community activities. Elevated particulate matter concentrations at AJ Jacobs are shown to originate from the northerly sector at wind speeds above 3 m/s (Figure 5-65). Other sources of particulate matter contribute to concentrations of approximately 50 µg/m³ from localised sources at wind speeds below 1 m/s. Particulate concentrations observed at the Eco Park station are lower than at the other stations, where the sources of elevated concentrations (greater than 40 µg/m³) are located to the north-west of the station (Figure 5-66). Other particulate sources are also located to the north-east and south-west of the Eco Park station contributing at lower wind speeds (5 to 10 m/s). A local source also contributes at low wind speeds. The Three Rivers station recorded elevated particulate concentrations from almost all directions at wind speeds greater than 3 m/s (Figure 5-67). A local source contributes at wind speeds lower than 2 m/s. Similarly, the Sharpeville station recorded elevated particulate concentrations from nearly all wind directions at speeds greater than 4 m/s, with the southerly direction showing the lower particulate concentrations (Figure 5-68). A local source (possibly community activities) is a large contributor at low wind speeds (less than 2 m/s). Particulate concentrations recorded at the Zamdela show high concentrations from the north-west and north-east, at high wind speeds (above 4 m/s), and a local source at low wind speeds (Figure 5-69). Sources in the south-westerly sector contribute the lowest concentrations, especially at higher wind speeds.

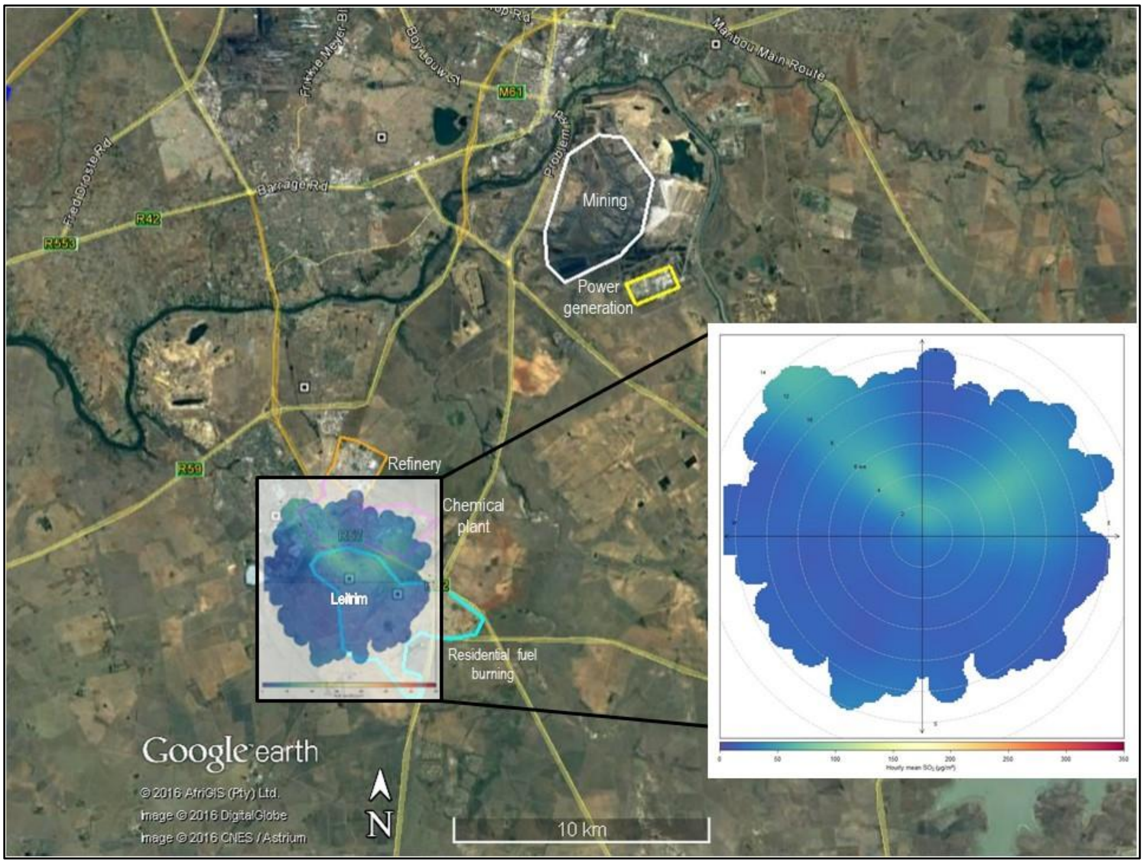

Figure 5-52: Polar plot of hourly median SO_2 concentration observations at Leitrim for 2015 to 2017

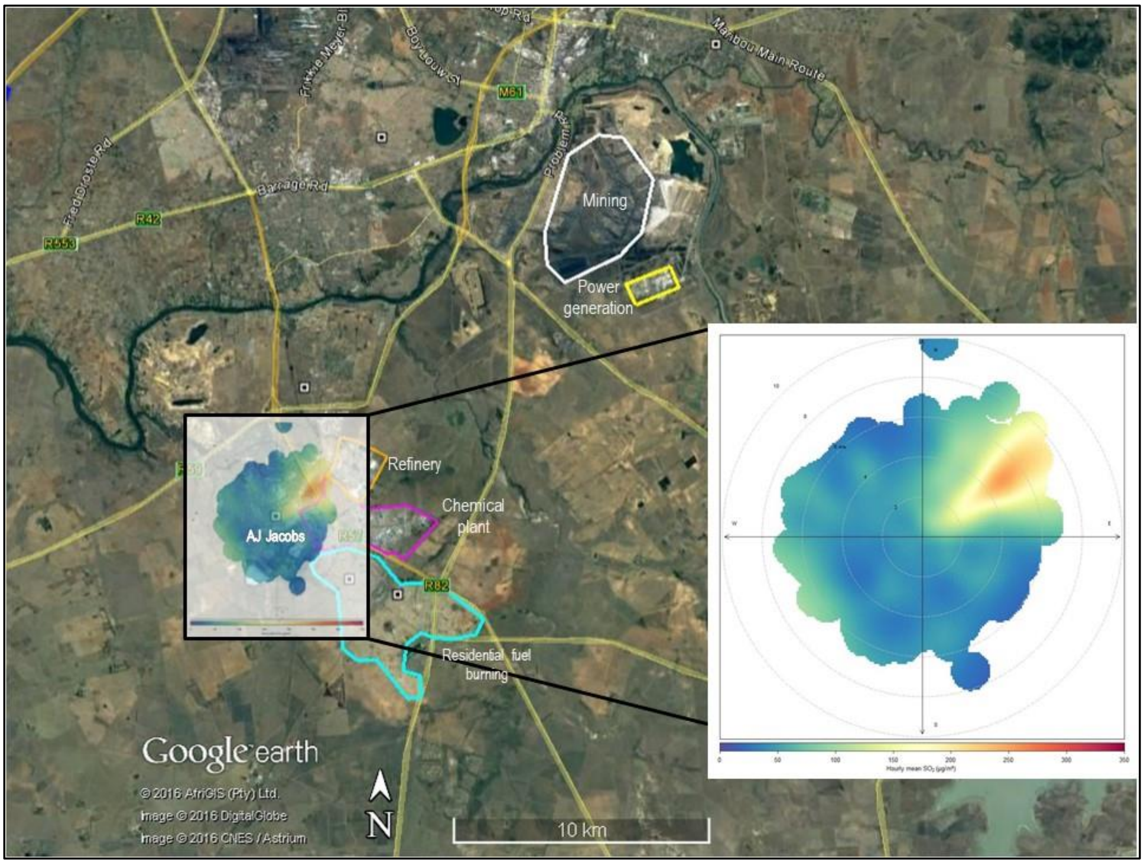

Figure 5-53: Polar plot of hourly median SO_2 concentration observations at AJ Jacobs for 2015 to 2017

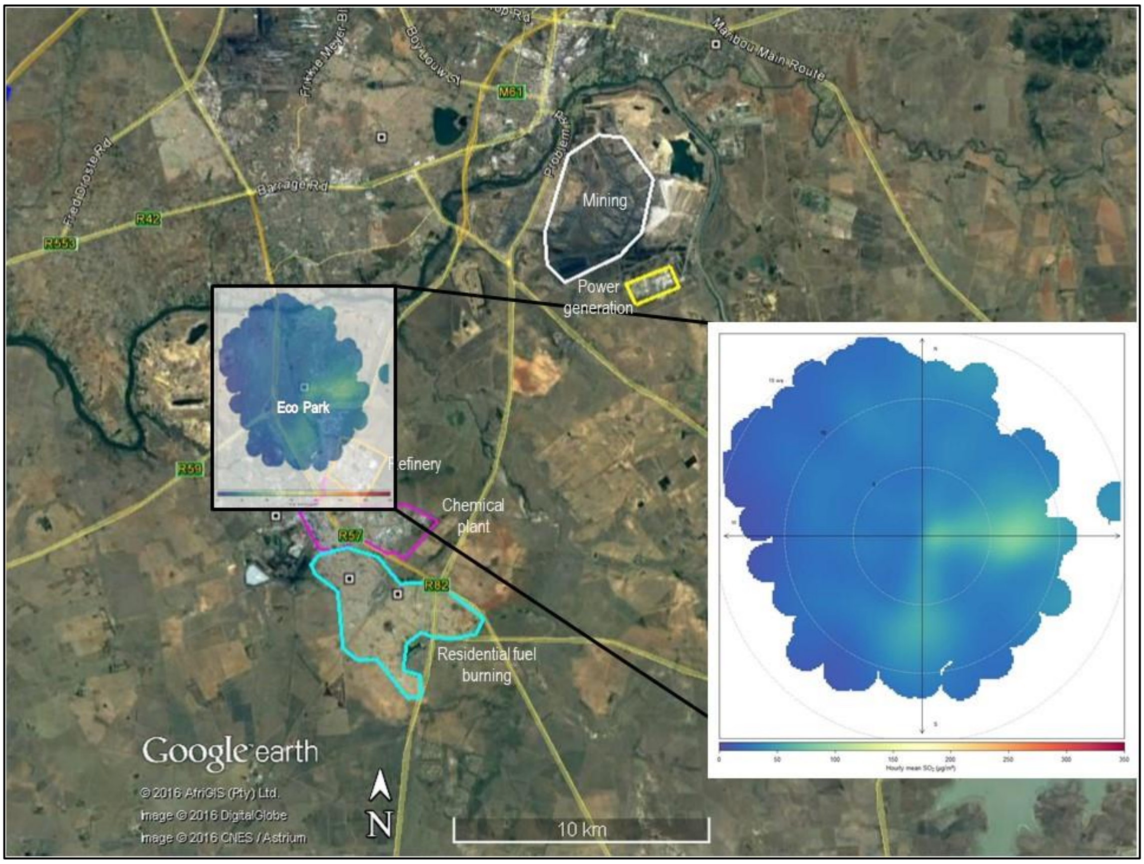

Figure 5-54: Polar plot of hourly median SO_2 concentration observations at Eco Park for 2015 to 2017

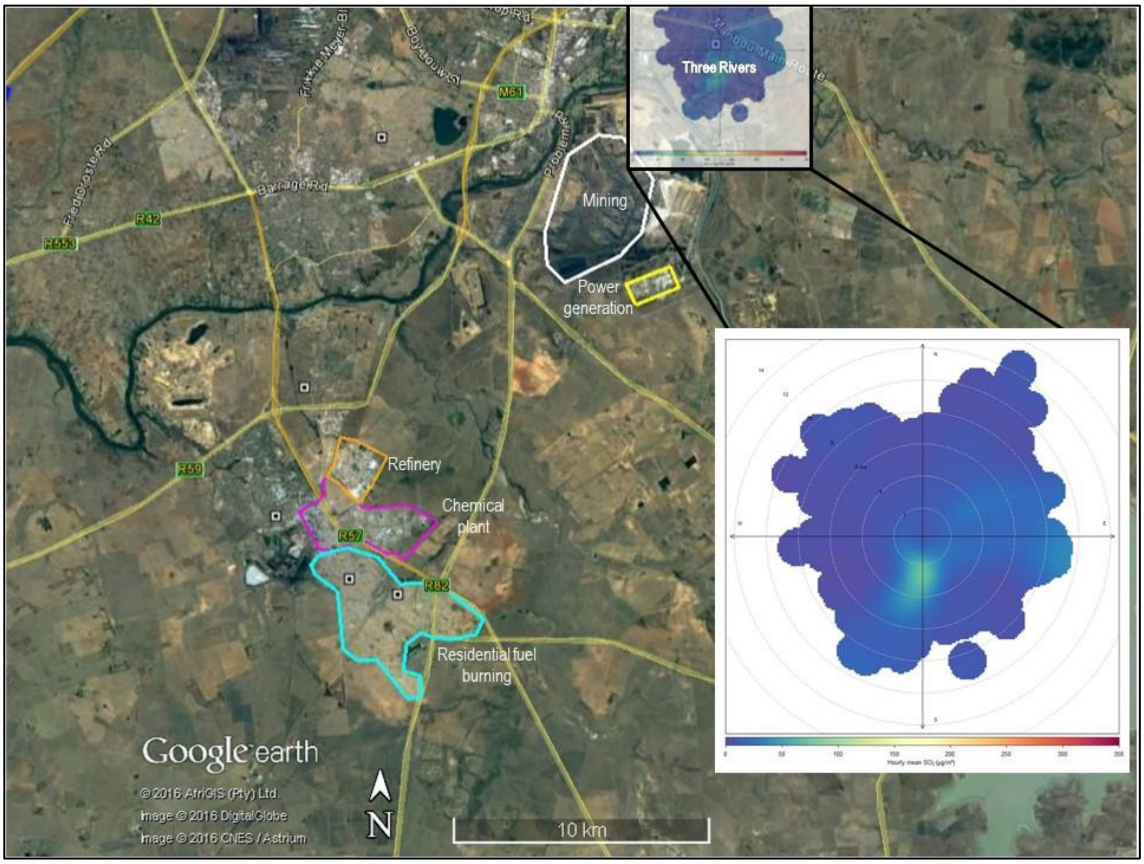

Figure 5-55: Polar plot of hourly median SO_2 concentration observations at Three Rivers for 2015 to 2017

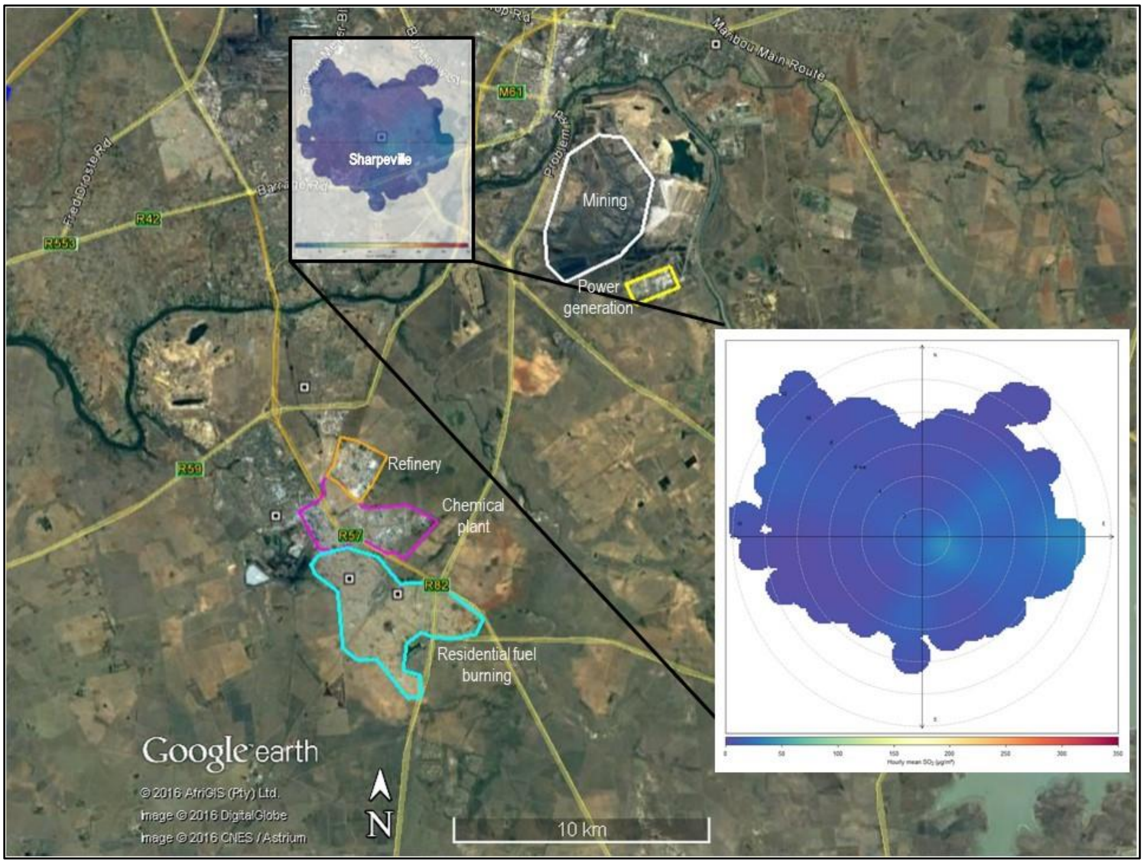

Figure 5-56: Polar plot of hourly median SO_2 concentration observations at Sharpeville for 2015 to 2017

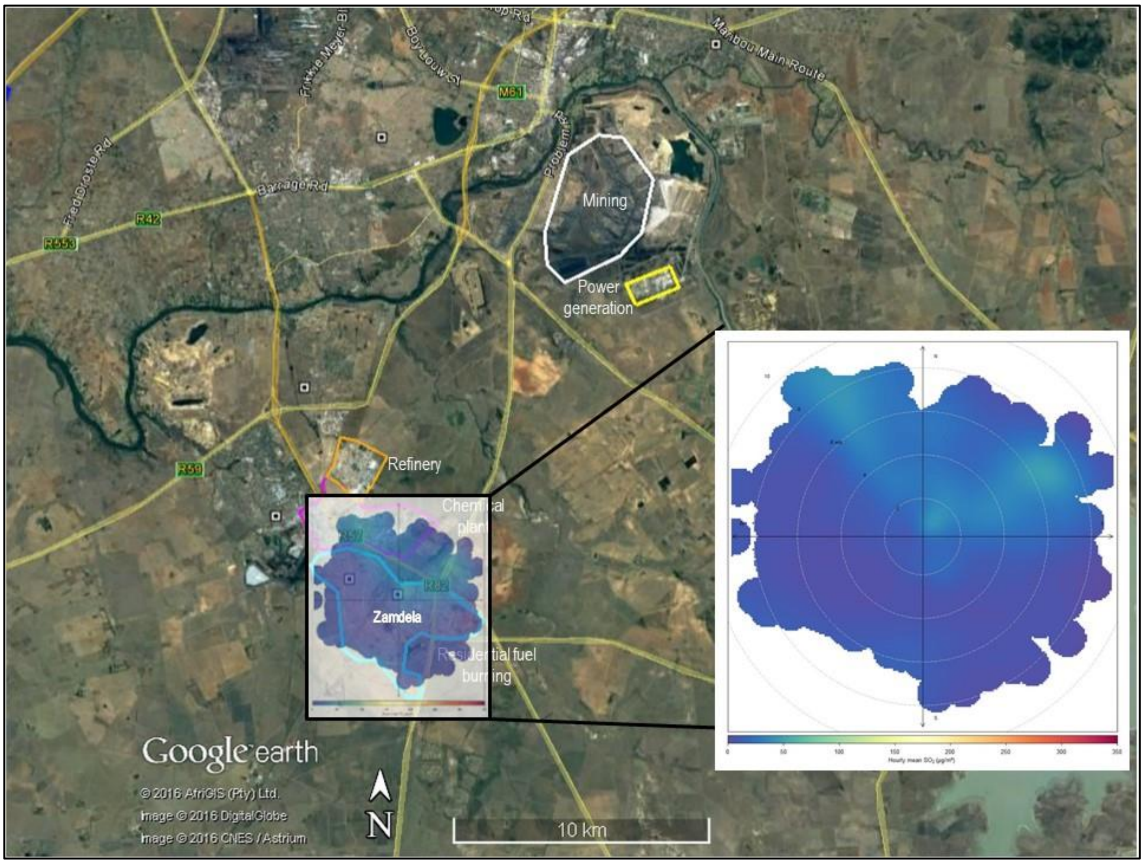

Figure 5-57: Polar plot of hourly median SO_2 concentration observations at Zamdela for 2015 to 2017

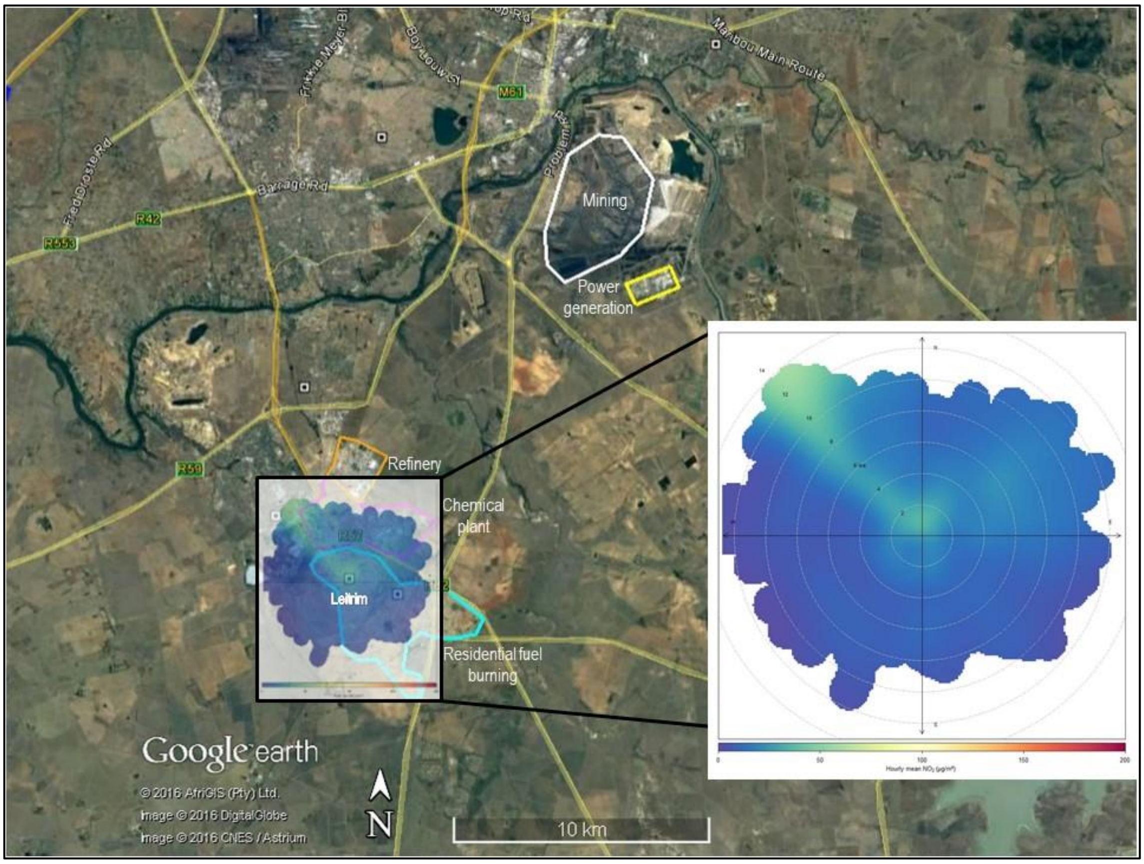

Figure 5-58: Polar plot of hourly median NO_2 concentration observations at Leitrim for 2015 to 2017

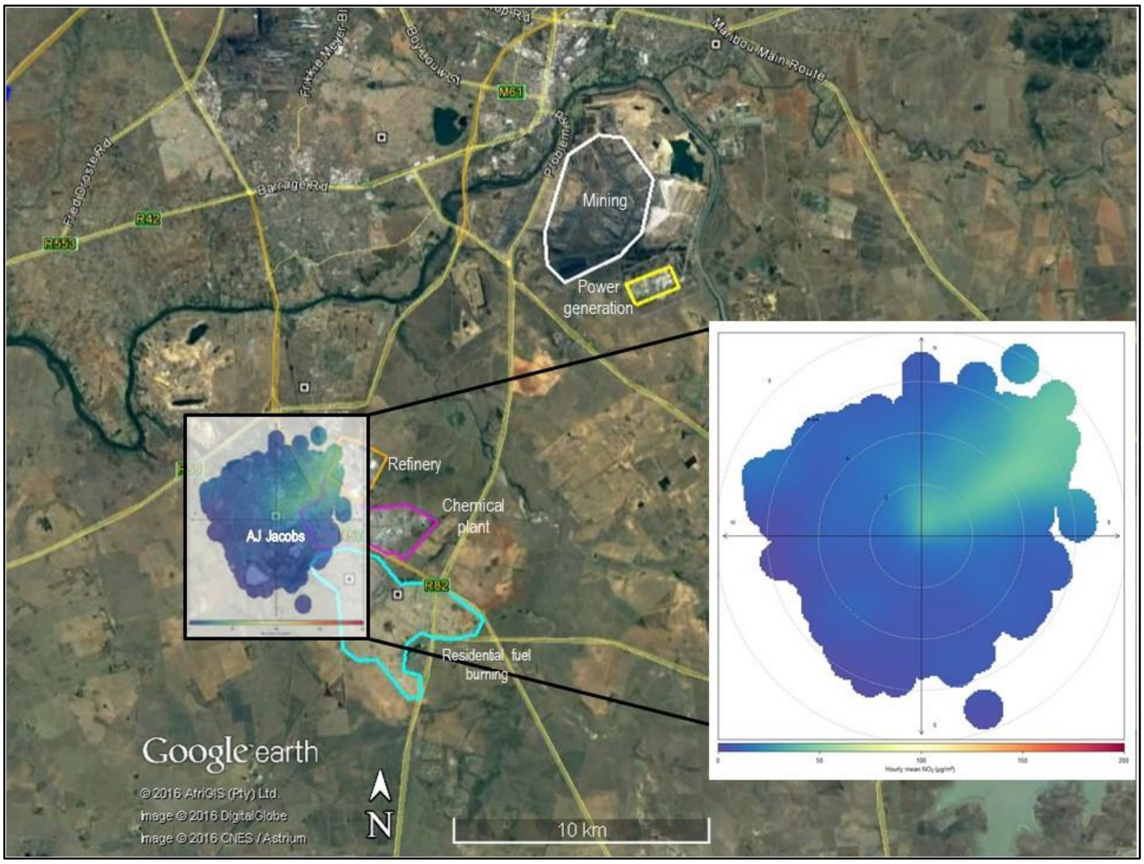

Figure 5-59: Polar plot of hourly median NO_2 concentration observations at AJ Jacobs for 2015 to 2017

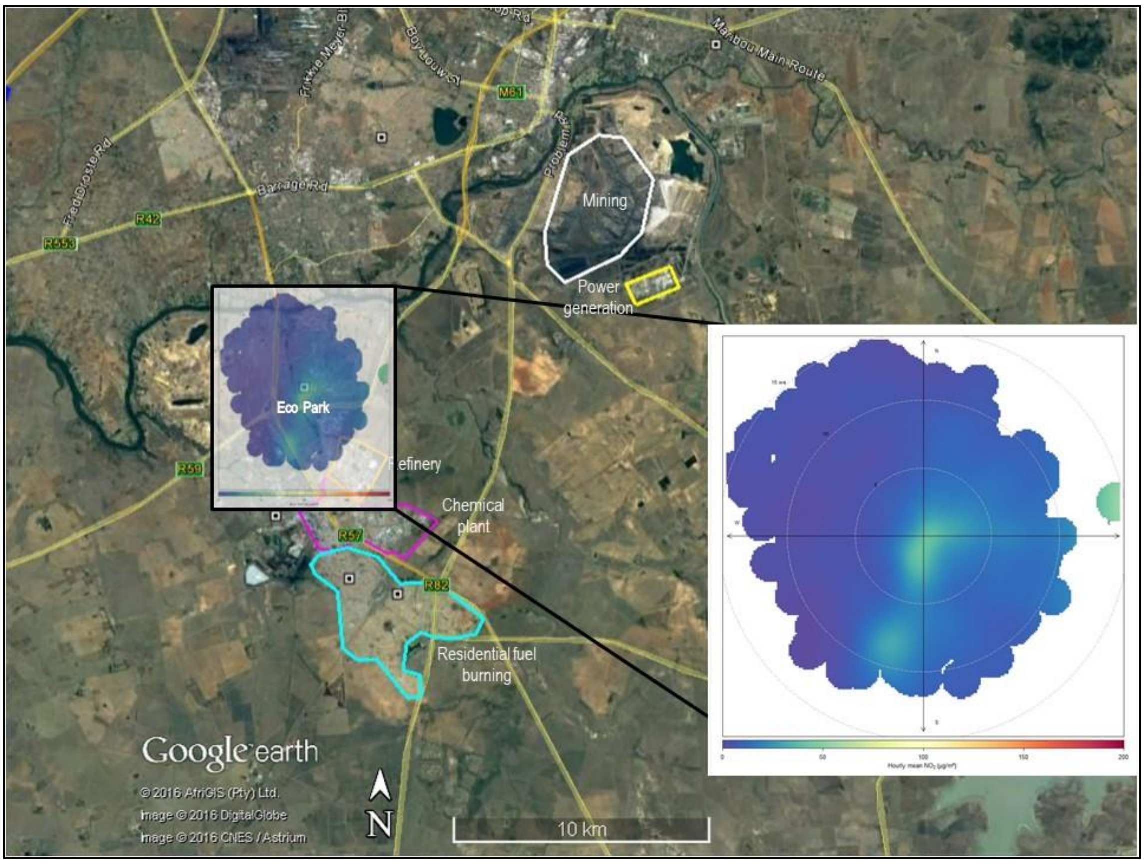

Figure 5-60: Polar plot of hourly median NO_2 concentration observations at Eco Park for 2015 to 2017

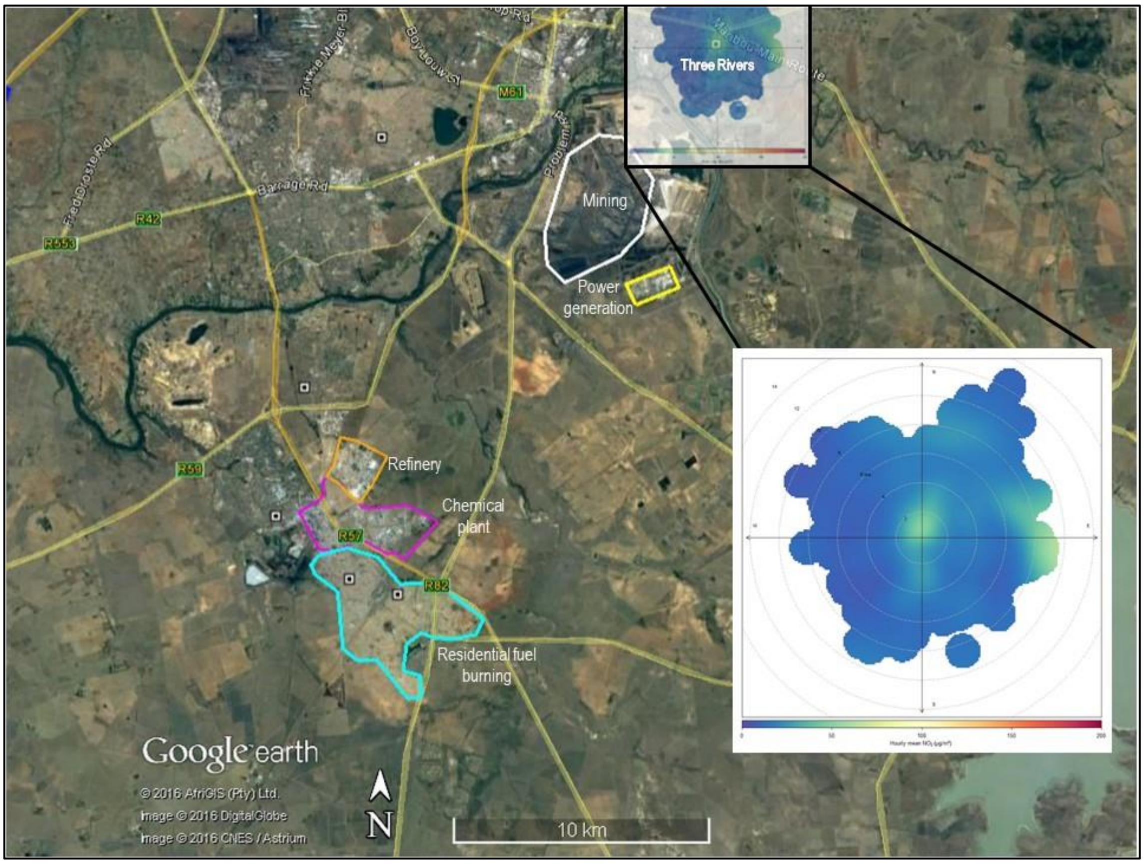

Figure 5-61: Polar plot of hourly median NO_2 concentration observations at Three Rivers for 2015 to 2017

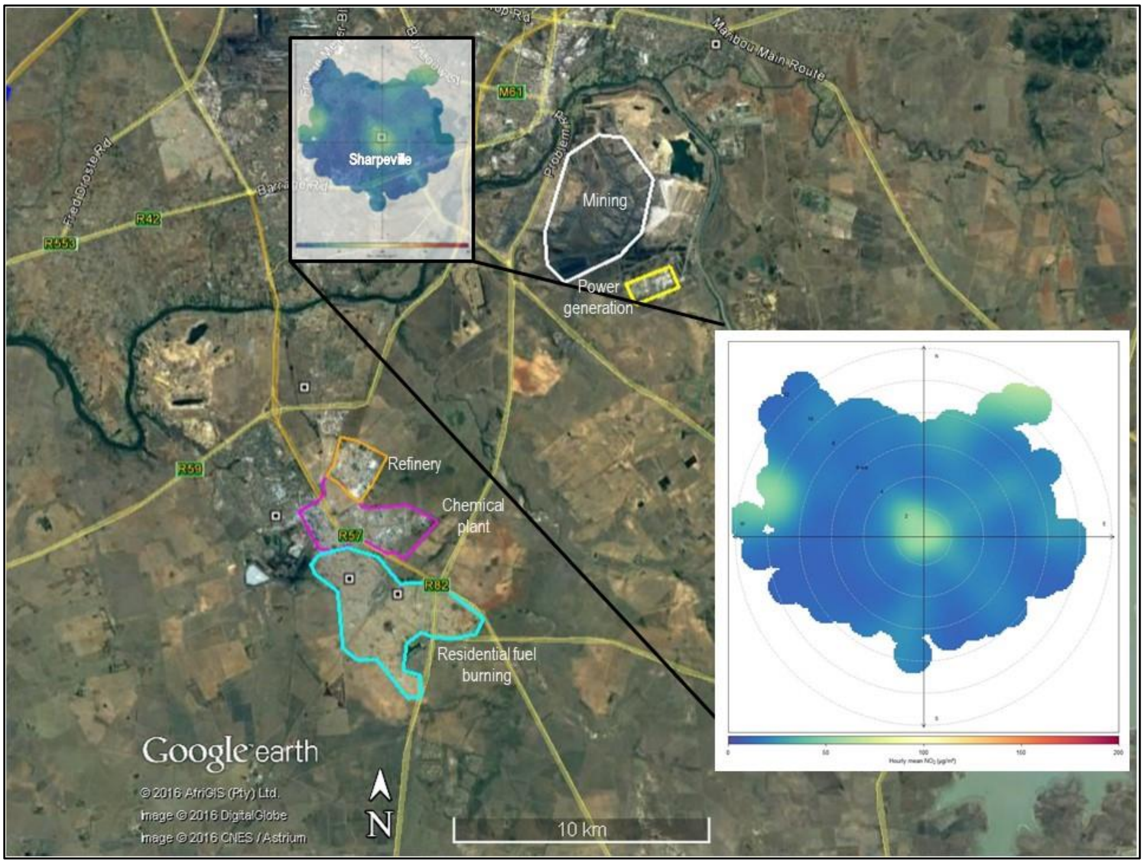

Figure 5-62: Polar plot of hourly median NO_2 concentration observations at Sharpeville for 2015 to 2017

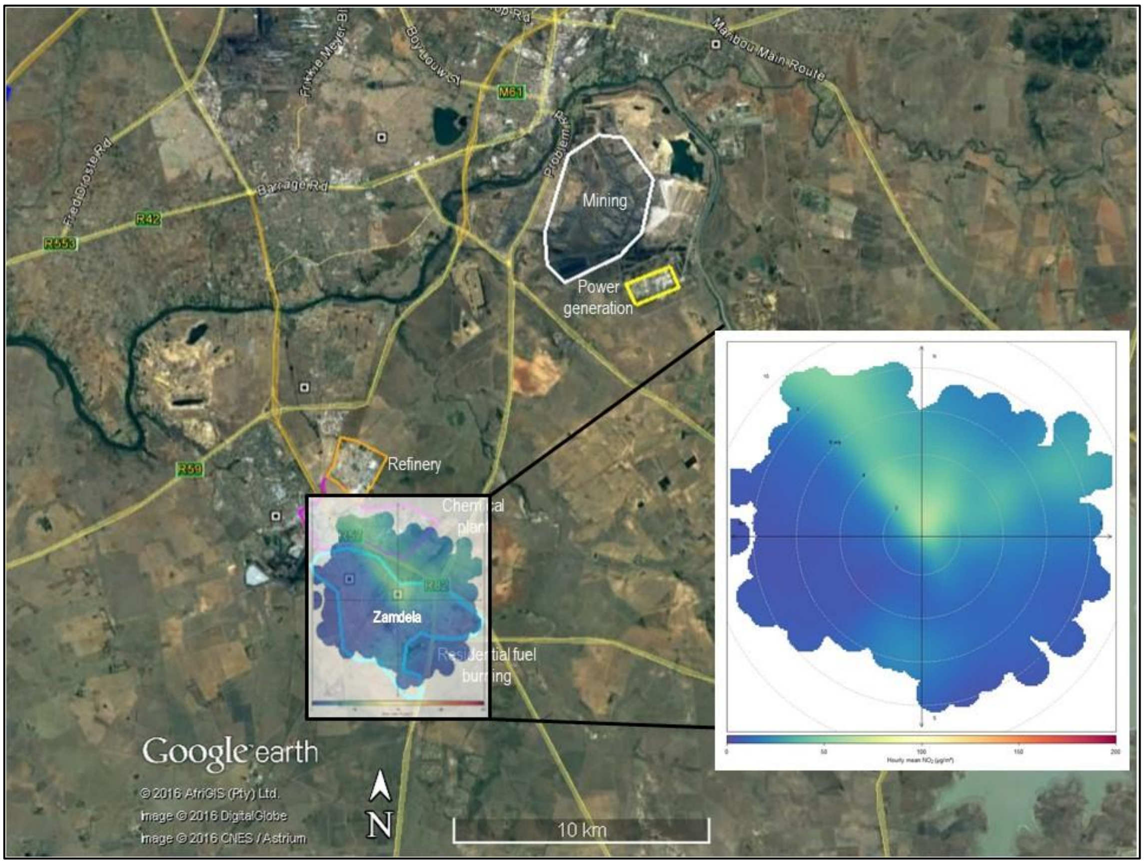

Figure 5-63: Polar plot of hourly median NO_2 concentration observations at Zamdela for 2015 to 2017

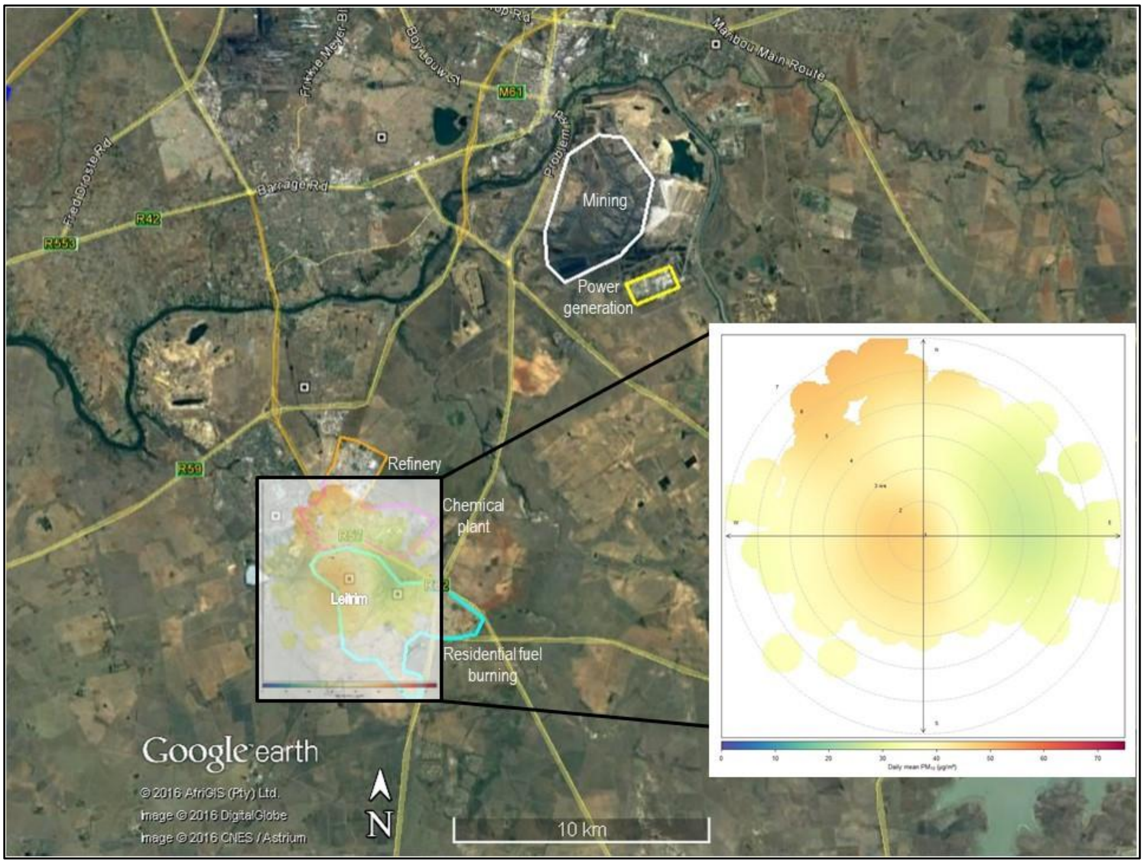

Figure 5-64: Polar plot of hourly median PM_{10} concentration observations at Leitrim for 2015 to 2017

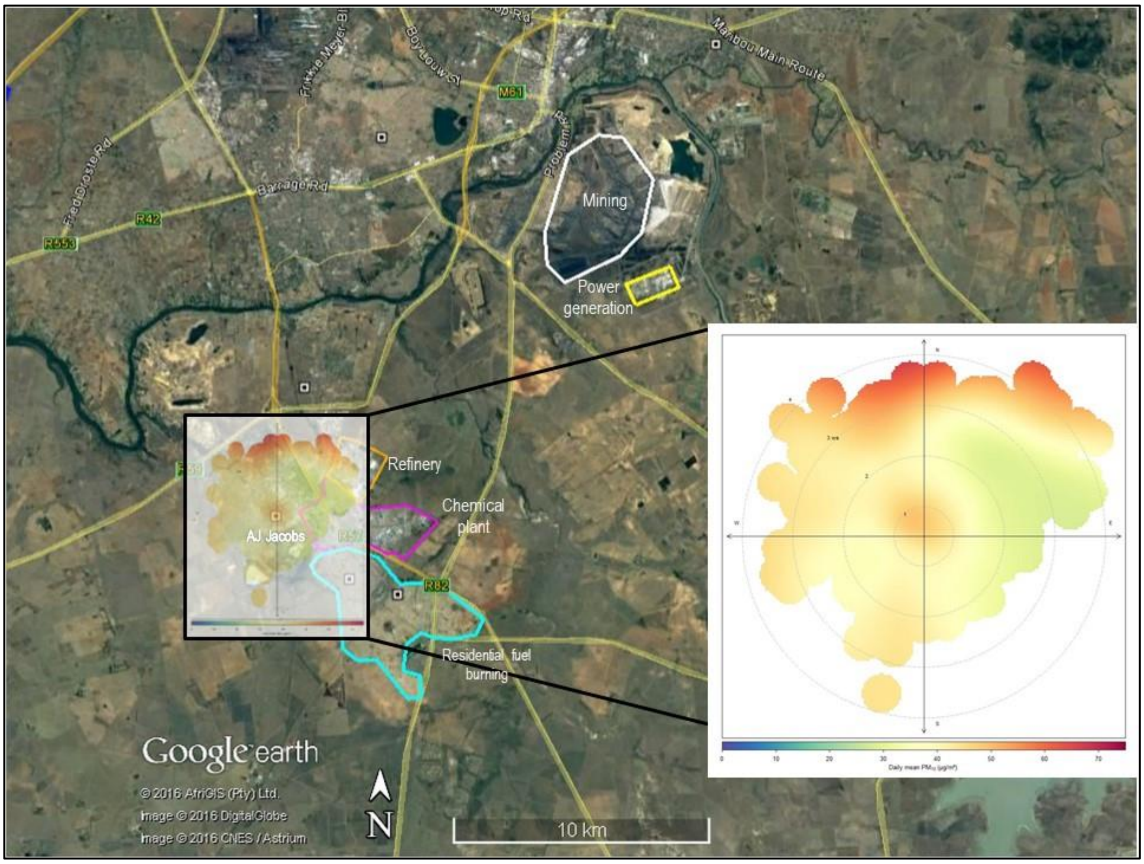

Figure 5-65: Polar plot of hourly median PM_{10} concentration observations at AJ Jacobs for 2015 to 2017

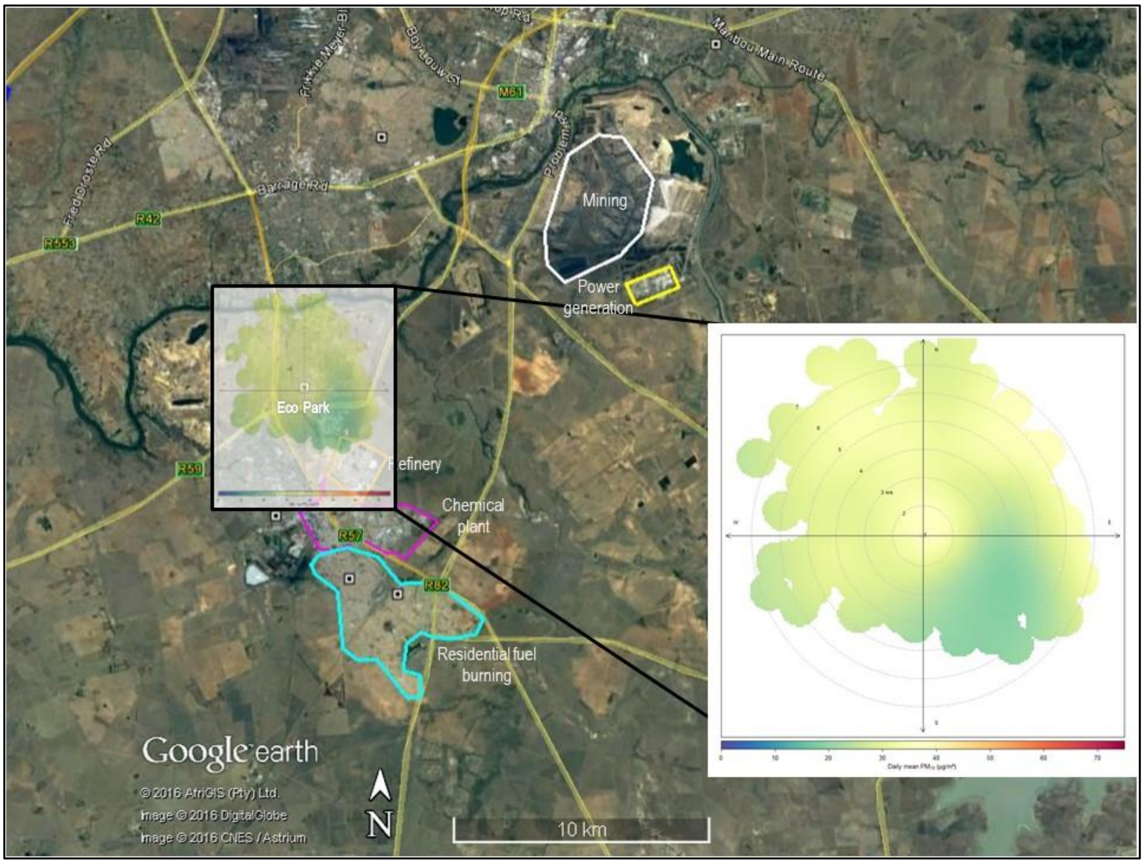

Figure 5-66: Polar plot of hourly median PM_{10} concentration observations at Eco Park for 2015 to 2017

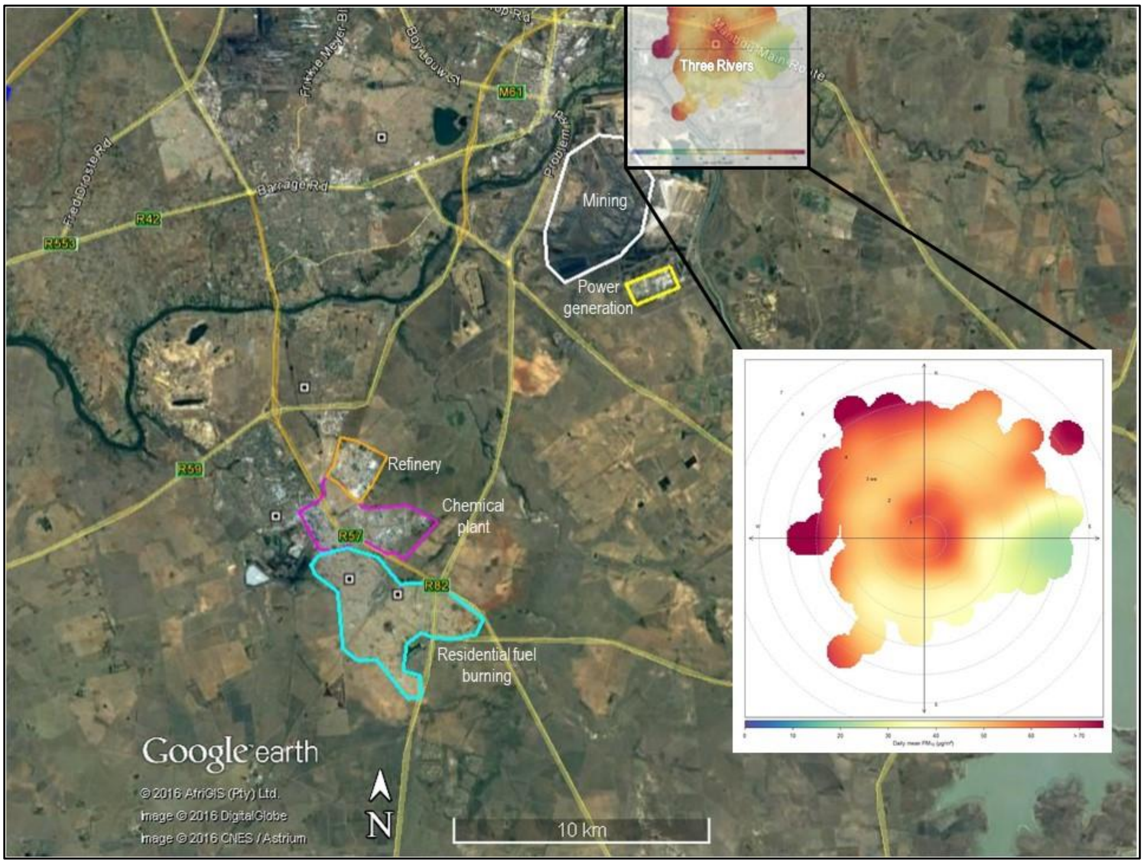

Figure 5-67: Polar plot of hourly median PM_{10} concentration observations at Three Rivers for 2015 to 2017

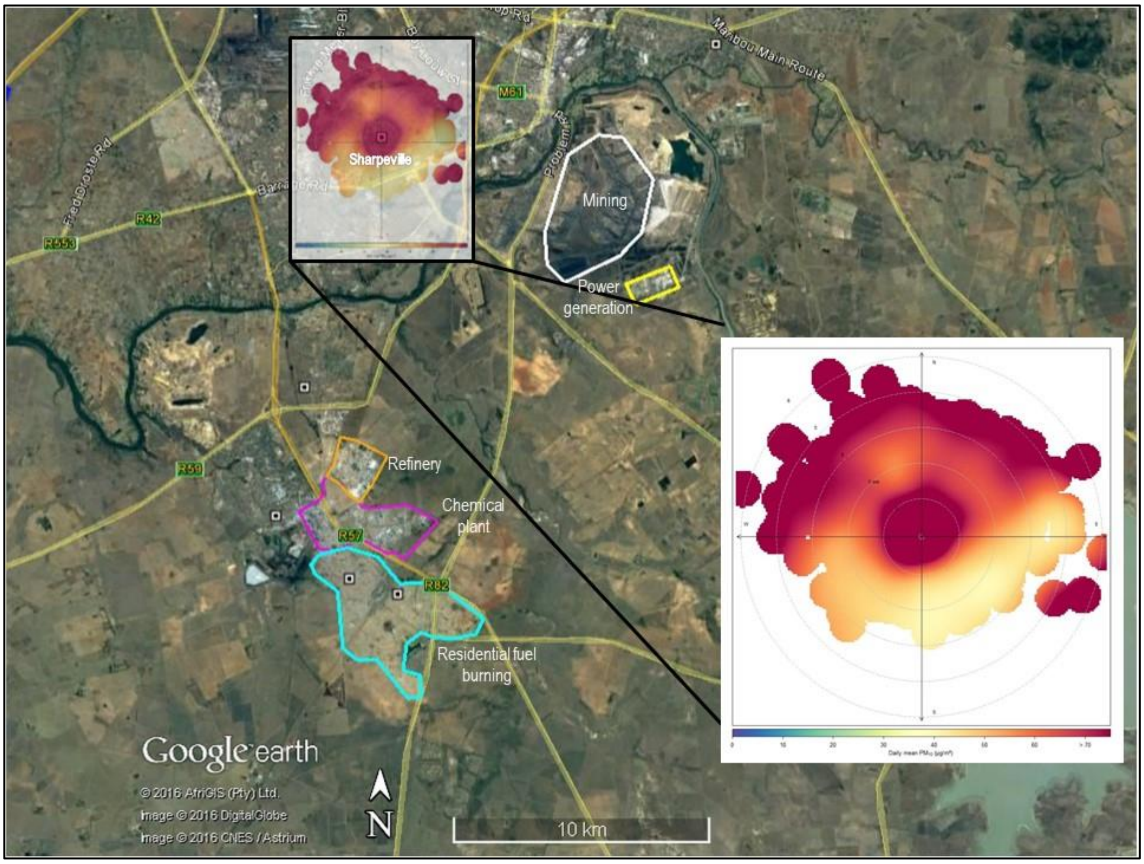

Figure 5-68: Polar plot of hourly median PM_{10} concentration observations at Sharpeville for 2015 to 2017

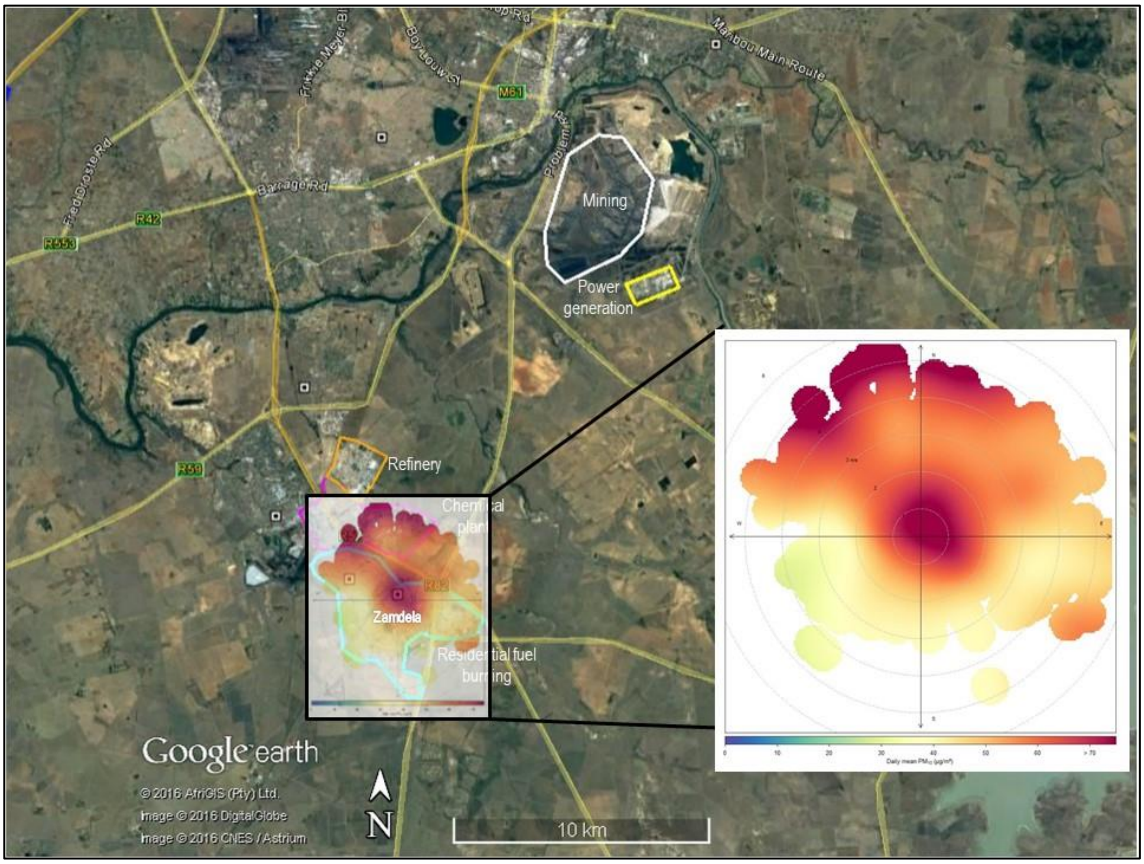

Figure 5-69: Polar plot of hourly median PM_{10} concentration observations at Zamdela for 2015 to 2017

5.1.6.2 Model Validation

Ambient concentrations of NO_2, SO_2, and PM_{10} measured by Sasol and the DEA in Sasolburg help provide an understanding of existing ambient air concentrations as well as providing a means of verifying the dispersion modelling. Since the aim of the investigation is to illustrate the change in ground level concentrations from the current levels (i.e. baseline emission scenario) to those levels resulting from the introduction of the required emission limits (i.e. new plant emission standards), the intention was not to comprehensively include all air emissions within Sasolburg. Unaccounted emissions include those from unintended leaks within the plant (fugitive emissions) and small vents, as well as air emissions from other industries, emissions from activities occurring within the communities, and biomass burning (especially during winter season), as well as long-range transport into the modelling domain. However, information about community activities, such as the amount of traffic within the community and the amount of fuel used for heating is often difficult to estimate.

These emissions, when combined, may potentially add up to be a significant portion of the observed concentrations in the modelling domain. In terms of the current investigation, the portion of air quality due to air emission sources that is not included in the model's emissions inventory constitutes the background concentration.

Discrepancies between predicted and observed concentrations may also be as a result of process emission variations and may include upset emissions and shutdowns. These conditions could result in significant under-estimating or over-estimating the air concentrations. In order to accommodate these upset emission conditions, a time varying emissions database would be required as input into the model.

A summary of the predicted concentrations (SO and Natref) and their comparison with observations are given in Appendix H. In order to establish model performance under average emission conditions, it is not uncommon to use a certain percentile of predicted and observed concentrations for comparison. Although these may range from a 90th to 99.9th percentile, it was decided to use the DEA NAAQS for guidance. For criteria pollutants SO_2, NO_2 and PM_{10}, the NAAQS requires compliance with the 99th percentile. As hourly averages, this allows exceedances of the limit value of 88 hours (SO_2 and NO_2) or 4 days (SO_2 and PM_{10}) per year. Estimated short-term (hourly or daily) background concentrations (not associated with the emissions included in the simulations) used the observed concentration value when simulated concentrations from SO indicate very small contributions (0.1 µg/m³).

Table 5-18Table 5-18 summarises the comparisons between simulated (SO and Natref) and observed SO_2 concentrations at the monitoring stations in the study area. As shown in the table of the observed peak concentrations, 72% and 37% could not be accounted for at Leitrim and AJ Jacobs (the two closest monitoring stations to SO). The difference between simulated and observation increases significantly when considering long-term comparisons (i.e. 50th percentile and annual average) at these 2 stations, clearly illustrating the contribution of emission sources not included in the dispersion model's emissions inventory.

Table 5-18: Comparison of predicted and observed SO_2 concentrations at monitoring station in Sasolburg

Description	SO_2 concentration (µg/m³)			Unaccounted Fraction*
	Simulated	Observed	Unaccounted	
Leitrim				
Peak	182	650	467	0.7
99th Percentile	67	187	120	0.6
90th Percentile	22	77	55	0.7
50th Percentile	0.01	24	24	1.0
Annual Average	4	35	31	0.9
AJ Jacobs				
Peak	422	666	244	0.4
99th Percentile	170	304	134	0.4
90th Percentile	8	135	127	0.9
50th Percentile	0.00	55	55	1.0
Annual Average	6	68	61	0.9
Eco Park				
Peak	214	872	658	0.8
99th Percentile	44	244	200	0.8
90th Percentile	1	79	78	1.0
50th Percentile	0.00	31	31	1.0
Annual Average	1	42	41	1.0
Three Rivers				
Peak	31	535	504	0.9
99th Percentile	11	138	127	0.9
90th Percentile	0.5	32	32	1.0
50th Percentile	0.00	9	9	1.0
Annual Average	0.3	16	16	1.0
Sharpeville				
Peak	47	642	595	0.9
99th Percentile	14	148	134	0.9
90th Percentile	0.6	40	40	1.0
50th Percentile	0.00	9	9	1.0
Annual Average	0.4	18	18	1.0
Zamdela				
Peak	301	473	172	0.4
99th Percentile	98	175	76	0.4
90th Percentile	31	50	19	0.4
50th Percentile	0.05	9	9	1.0
Annual Average	7	21	14	0.7

* unaccounted fraction as a percentage of observed concentration

In Figure 5-70, the fractional bias is plotted with the means on the X-axis and the standard deviations on the Y-axis. The box on the plot encloses the area of the graph where the model predictions are within a fractional bias between -2 and +2; indicating an acceptable correlation. The U.S. EPA states that predictions within a factor of two are a reasonable performance target for a model before it is used for refined regulatory analysis (U.S. EPA 1992). Data points appearing on the left half of the plot indicate an over-prediction and those on the right half of the plot represent under-predictions.

The fractional bias of the means was less than 0.67, clearly showing good model performance at AJ Jacobs and Zamdela. At Three Rivers, Sharpeville, Leitrim and Eco Park the fractional bias of the means was less than 2, indicating an acceptable correlation.

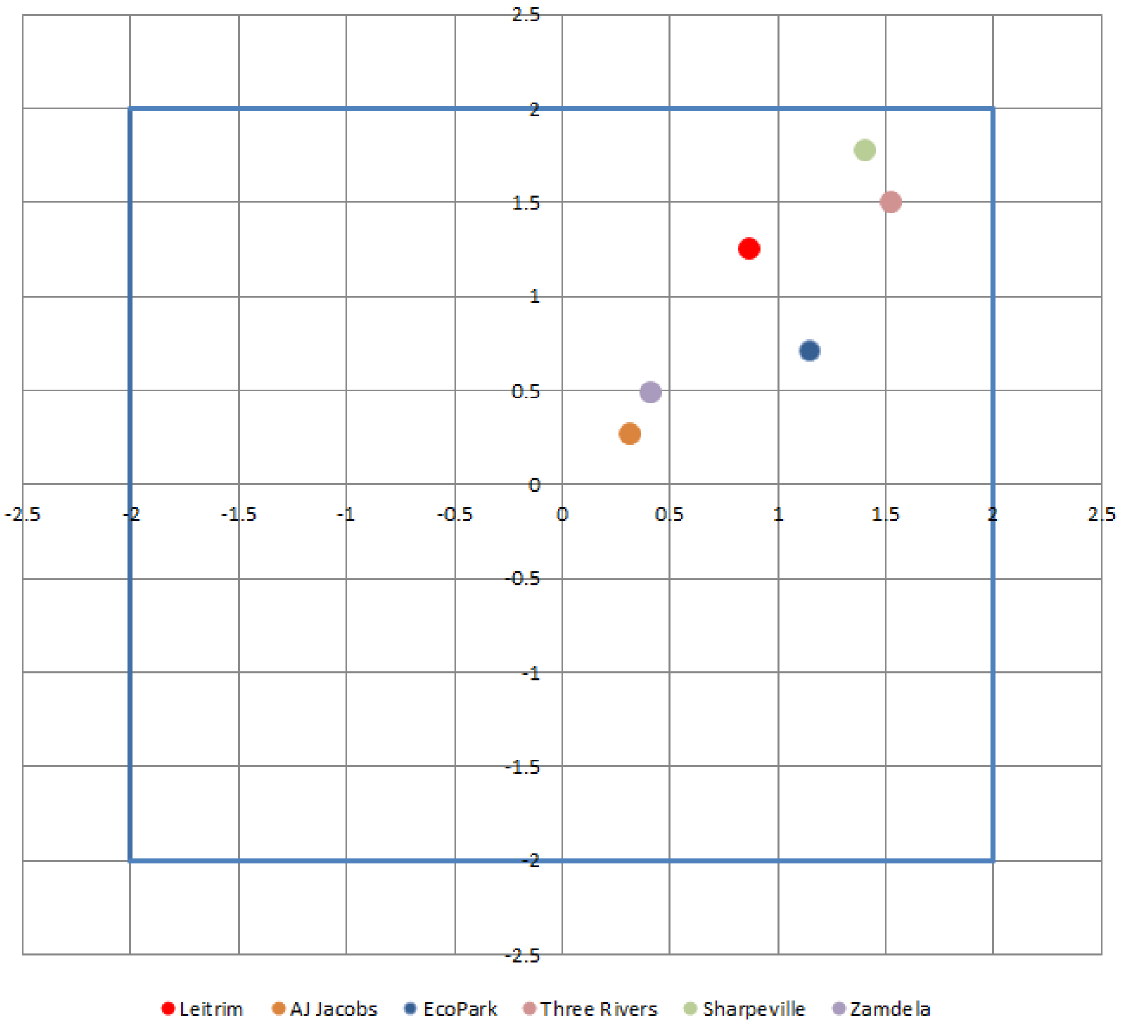

Figure 5-70: Fractional bias of means and standard deviation for SO_2

The same calculations and comparisons were repeated for NO_2 simulations and observations. The CALPUFF simulations were specifically for NO_x and the formation of HNO_3 and other nitrates using the MESOPUFF II chemical transformation mechanism, as discussed in Section 5.1.4.3.

Table 5-19 summarises of comparisons between simulated and observed NO_2 concentrations at the monitoring stations in the study area. For Zamdela, AJ Jacobs and Leitrim higher concentrations were simulated than the observed peak and 99th percentile concentrations. This may be due to the rather simplistic methodology of applying a constant conversion rate from NO_x to NO_2 (Section 5.1.4.3). As shown in Appendix F, the conversion ratio at high concentration levels (i.e. closer to the point of emission) generally varies between 14% and 27% for NO_x concentrations above 188 µg/m³. In this investigation, a NO_2 conservative ratio of not less than 40% was adopted for high concentrations of NO_x. Concentrations similar to the observed peak would be simulated if the lower conversions of 27% were used instead.

As for SO_2, the difference between simulated and observation NO_2 concentrations increases significantly when considering long-term comparisons (i.e. 50th percentile and annual average), clearly illustrating the contribution of emission sources not included in the dispersion model's emissions inventory.

Table 5-19: Comparison of predicted and observed NO_2 concentrations at monitoring stations in Sasolburg

Description	NO_2 concentration (µg/m³)			Unaccounted Fraction*
	Simulated	Observed	Unaccounted	
Leitrim				
Peak	133	145	12	0.08
99th Percentile	58	77	19	0.25
90th Percentile	23	43	21	0.48
50th Percentile	0.01	17	17	1.00
Annual Average	7	21	14	0.66
AJ Jacobs				
Peak	255	139	0	0.00
99th Percentile	111	78	0	0.00
90th Percentile	16	47	31	0.65
50th Percentile	0.00	19	19	1.00
Annual Average	8	23	15	0.65
Eco Park				
Peak	136	532	396	0.74
99th Percentile	44	85	41	0.49
90th Percentile	2	51	49	0.97
50th Percentile	0.00	15	15	1.00
Annual Average	2	21	20	0.92
Three Rivers				
Peak	51	168	117	0.70
99th Percentile	13	97	84	0.87
90th Percentile	0.6	57	57	0.99
50th Percentile	0.00	23	23	1.00
Annual Average	0.5	28	28	0.98
Sharpeville				
Peak	79	208	129	0.62
99th Percentile	18	106	87	0.83
90th Percentile	0.8	64	64	0.99
50th Percentile	0.00	22	22	1.00
Annual Average	0.8	30	29	0.97
Zamdela				
Peak	203	170	0	0.00
99th Percentile	62	105	43	0.41
90th Percentile	38	64	26	0.41
50th Percentile	0.08	23	23	1.00
Annual Average	10	30	19	0.65

* unaccounted fraction as a percentage of observed concentration

In contrast to Zamdela, AJ Jacobs and Leitrim, where the peak concentration was definitely shown to be from SO and Natref, only about 26%, 30% and 38% of the observed concentration was simulated at Eco Park, Three Rivers and Sharpeville respectively. Although this may still have resulted from SO and Natref, there is also a strong likelihood that more localised sources may have added to the observed peak. Other sources of NO_2 concentrations are also observed at these sites in the polar plots (Figure 5-60 for Eco Park, Figure 5-61 for Three Rivers and Figure 5-62 for Sharpeville). This is also illustrated by the 99th percentile that indicates a notable fraction of unaccounted for concentrations.

Subsequently, fractional biases (i.e. using the 99th percentile simulated concentrations and the estimated background concentration) were calculated for the monitoring stations within the study area. The results are summarised in Figure 5-71. The fractional bias of the means and standard deviations for AJ Jacobs indicated an over-prediction of the simulated NO_2 concentrations. The fractional bias of the means and standard deviations for Leitrim and AJ Jacobs were within -0.67 to +0.67, clearly showing good model performance. The model's simulations are shown to within the acceptable model performance range (-2.0 to +2.0) at Three Rivers, Sharpeville, Eco Park and Zamdela.

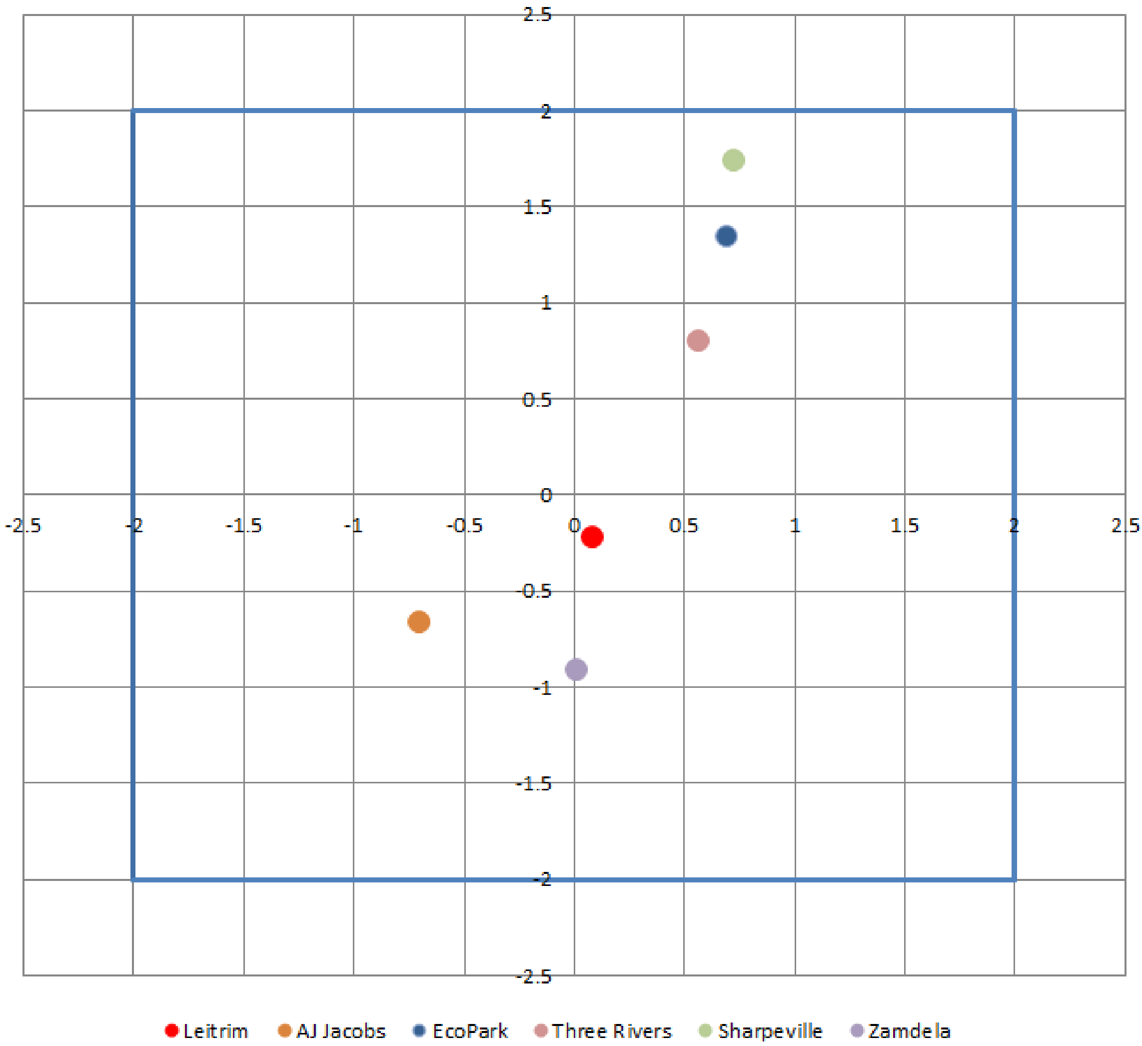

Figure 5-71: Fractional bias of means and standard deviation for NO_2

5.1.7 Scenario Emission Inventory

Dispersion modelling included all point sources in all scenarios (Table 4-1 and Table 4-2); however only seven sources (Steam Stations 1 and 2; and, Section 6900 Thermal Oxidation sources) had emission rates which varied between the three scenarios assessed. All the sources were modelled as per parameters and emission rates provided in Table 4-1 and Table 4-2. The varying source (Steam Stations 1 and 2; and, Section 6900 Thermal Oxidation sources) emission rates per scenario were provided by Sasol for the assessment and are given in Table 5-20. Emission rates for the Alternative Emission scenario are the same as for the Baseline scenario (Table 5-20).

Table 5-20: Varying source emissions per scenario provided for SO (units: g/s)

Source group	Source name	SO_2	NO_X as NO_2	PM	CO	HF	Sum of heavy metals	Hg	Cd+Tl	TOCs	HCl	NH_3	Dioxins/Furans
Baseline													
Steam Stations	SS1 Boiler 4	30.49	55.27	6.28									
	SS1 Boiler 5&6	59.51	107.88	12.27									
	SS1 Boiler 7&8	62.08	112.51	12.81									
	SS2 Boiler 9-15	226.51	353.91	28.32									
Incinerators	B6990	2.47	1.34	1.40	0.03	7.8E-03	1.4E-01	3.17E-05	3.17E-05	1.69E-01	1.07E-02	4.25E-03	3.79E-10
	B6930	40.68	9.04	1.14	0.11	1.4E-02	6.8E-02	5.07E-04	5.71E-04	2.17E-01	4.77E-02	1.43E-02	1.48E-09
	B6993	2.82	4.57	3.27	12.08	6.5E-03	2.2E-01	9.51E-05	3.17E-05		2.21E-02	4.06E-02	1.75E-10
At New Plant Emission Standards													
Steam Stations	SS1 Boiler 4	30.49	35.73	2.38									
	SS1 Boiler 5&6	59.51	69.74	4.65									
	SS1 Boiler 7&8	62.08	72.75	4.85									
	SS2 Boiler 9-15	226.51	265.44	17.70									
Incinerators	B6990	0.13	0.48	0.03	0.12	2.22E-03	1.27E-03	3.17E-05	3.17E-05	3.53E-02	1.07E-02	4.25E-03	3.79E-10
	B6930	0.57	2.25	0.13	0.56	1.14E-02	5.71E-03	5.07E-04	5.71E-04	1.13E-01	4.77E-02	1.43E-02	1.48E-09
	B6993	0.54	2.19	0.10	0.54	1.08E-02	5.39E-03	9.51E-05	3.17E-05	1.09E-01	2.21E-02	4.06E-02	1.75E-10
At Alternative Emissions													
Steam Stations	SS1 Boiler 4	30.49	55.27	6.28									
	SS1 Boiler 5&6	59.51	107.88	12.27									
	SS1 Boiler 7&8	62.08	112.51	12.81									
	SS2 Boiler 9-15	226.51	353.91	28.32									
Incinerators	B6990	2.47	1.34	1.40	0.03	7.8E-03	1.4E-01	3.17E-05	3.17E-05	1.69E-01	1.07E-02	4.25E-03	3.79E-10
	B6930	40.68	9.04	1.14	0.11	1.4E-02	6.8E-02	5.07E-04	5.71E-04	2.17E-01	4.77E-02	1.43E-02	1.48E-09
	B6993	2.82	4.57	3.27	12.08	6.5E-03	2.2E-01	9.51E-05	3.17E-05		2.21E-02	4.06E-02	1.75E-10

5.1.8 Model Results

Air quality standards are fundamental tools to assist in air quality management. The NAAQS (Section 5.1.2.2) are intended to reduce harmful effects on health of the majority of the population, including the very young and the elderly. In this section, predicted ambient concentrations of criteria pollutants at specific sensitive receptors are compared against the promulgated local NAAQS (Table 5-2).

Prior to dispersion modelling, 42 receptors were identified in the vicinity of SO (within the 57-by-57 km modelling domain). Sensitive receptors included residential areas, schools, hospitals and clinics, as well as monitoring stations (Figure 5-72 and Table 5-21). Ambient air quality monitoring stations (AQMS) were the first receptors identified because comparison of the predicted concentrations could be compared with measured concentrations for model validation. Schools, hospitals and clinics within the domain were identified and included as sensitive receptors in the dispersion model (full list provided in Appendix K). All receptors are presented in the isopleth plots, where the AQMS are included in results figures and the 20 closest receptors are included in the results tables at increasing distance from the centre of SO.

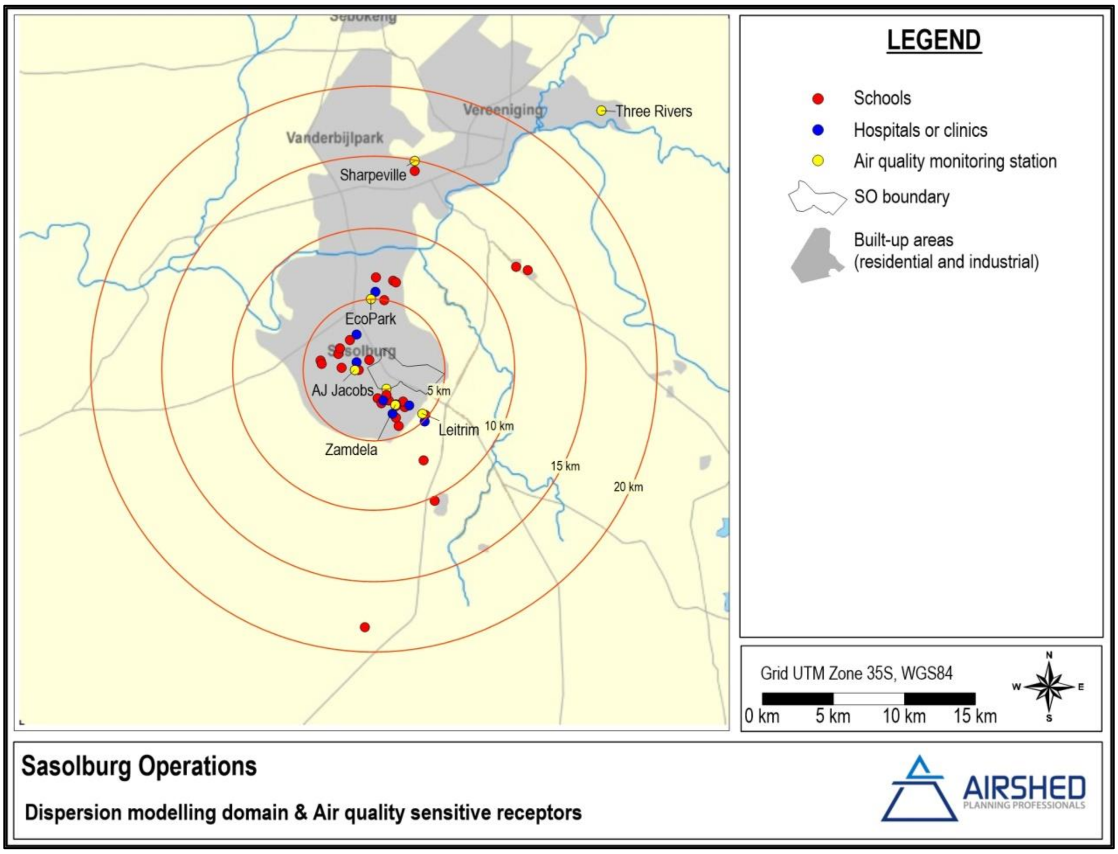

Figure 5-72: Sensitive receptors identified for assessment of impact as a result of Sasol Operations, Sasolburg

Table 5-21: Receptors identified for assessment of impact as a result of SO emissions

Receptor code name [a]	Receptor details	Distance from centre of operations (km)[b]
Zamdela	VTAPA Zamdela monitoring station	2.1
Leitrim	Sasol Leitrim monitoring station	3.1
AJ Jacobs	Sasol AJ Jacobs monitoring station	3.2
EcoPark	Sasol EcoPark monitoring station	5.7
Sharpeville	VTAPA Sharpville monitoring station	15.1
Three Rivers	VTAPA Three Rivers monitoring station	23.4
25	Malakabeng Primary School	1.7
32	Cedar Secondary School	1.9
15	Bofula-Tshepe Primary School	2.0
49	Clinic A Zamdela	2.1
51	Zamdela Hospital Zumayear	2.2
35	Iketsetseng Secondary School	2.2
48	Clinic B Zamdela	2.2
29	Tsatsi Primary School	2.3
20	Isaac Mhlambi Primary School	2.3
37	Nkopoleng Secondary School	2.4
34	HTS Secondary School	2.4
44	Zamdela Community Clinic	2.8
14	AJ Jacobs Primary School	2.9
28	Theha Setjhaba Primary School	3.0
52	Sasolburg Clinic	3.2
18	Credo Primary School	3.3
23	Lehutso Primary School	3.6
50	Harry Gwala Clinic | Creche	3.7
36	Kahobotjha-Sakubusha Secondary School	4.1
43	Sasolburg Provincial Hospital	4.2

Since the focus of the study is to illustrate the relative changes in ambient concentrations of pollutants theoretically arising from different point source emission scenarios, the predicted concentration differences from scenario to scenario were provided as percentage increase or decrease over the modelled baseline scenario ($C_{Baseline\ Scenarrio}$).

$$\frac{C_{S,\ Future\ Scenario} - C_{S,\ Baseline\ Scenario}}{C_{Baseline\ Scenario}}$$

Equation 1

It should be noted that the changes in ground-level concentrations, at the receptors, between the scenarios shown in the results: (1) are theoretical changes and may not necessarily be technically possible, and; (2) represent the maximum achievable improvements and are, therefore, not indicative of the day-to-day average reduction at every receptor point cumulatively.

5.1.8.1 *Criteria pollutants*

The findings for each of the criteria pollutants (SO_2, NO_2 and PM) are presented for the SO in three forms. The first figure presents the predicted pollutant concentration (99th percentile) at the AQMS (Table 5-21) for each of the emission scenarios (baseline operating conditions, emissions in theoretical compliance with New Plant Standards [2020]; and the Alternative Emission) relative to the appropriate NAAQS. A table then presents the percentage change in ground-level concentrations between the emission scenarios and the baseline at the AQMS and 20 closest sensitive receptors (Table 5-21). Finally, isopleth plots have been included for all the relevant emission scenarios and pollutants.

5.1.8.1.1 Sulfur dioxide (SO_2)

Ambient concentrations of SO_2 as a result of SO baseline emissions are predicted to fall below the hourly NAAQS at the AQMS (Figure 5-73 to Figure 5-75) and receptors (Table 5-22 to Table 5-24). Reductions in ambient SO_2 concentrations are evident with theoretical compliance with new plant emission standards, by up to 29% (Table 5-22 to Table 5-24). The alternative emission scenario is the same as the baseline scenario (Figure 5-73 and Table 5-22 to Table 5-24) so no change is observed in the simulated concentrations.

Isopleth plots are presented for all averaging periods ground-level SO_2 concentrations as a result of all emission scenarios for SO, as per the figure numbers below:

Scenario	Hourly	Daily	Annual
Baseline concentrations	Figure 5-76	Figure 5-79	Figure 5-82
New Plant standards	Figure 5-77	Figure 5-80	Figure 5-83
Alternative emissions	Figure 5-78	Figure 5-81	Figure 5-84

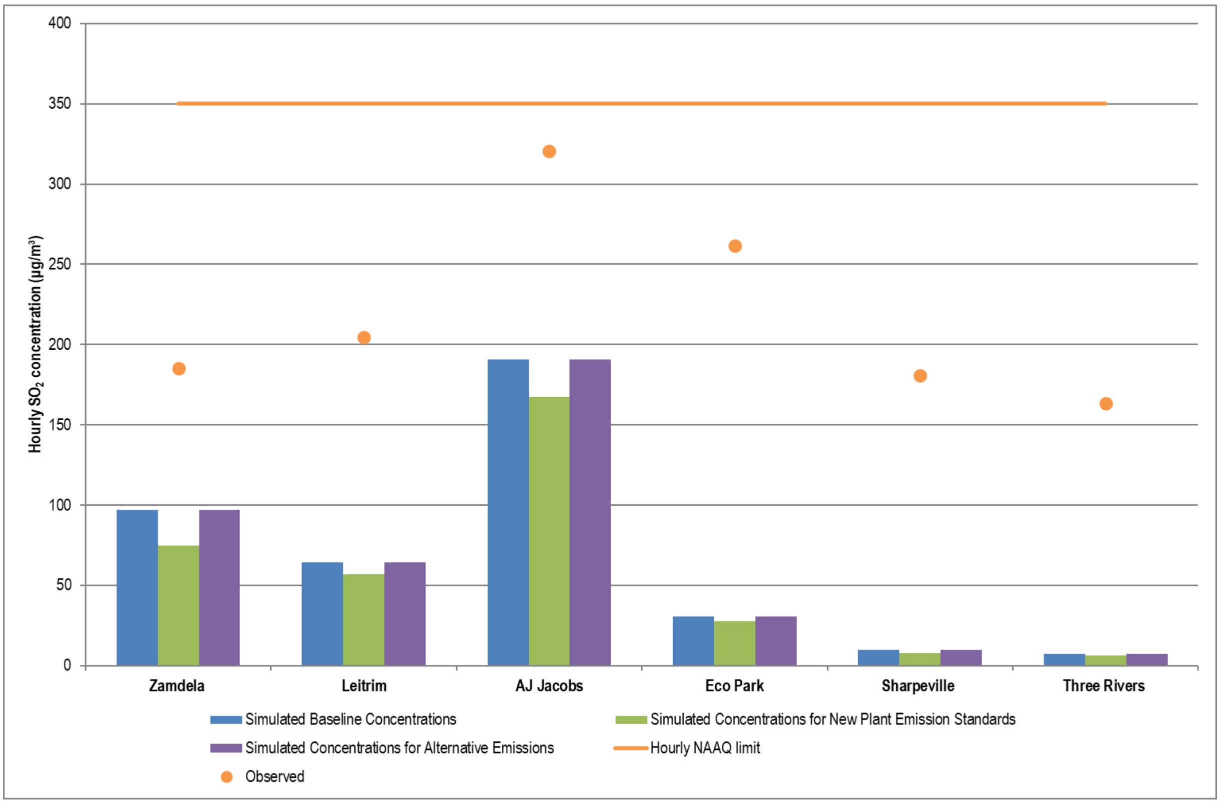

Figure 5-73: Simulated hourly SO_2 concentrations (99th percentile) at AQMS for Sasolburg Operations

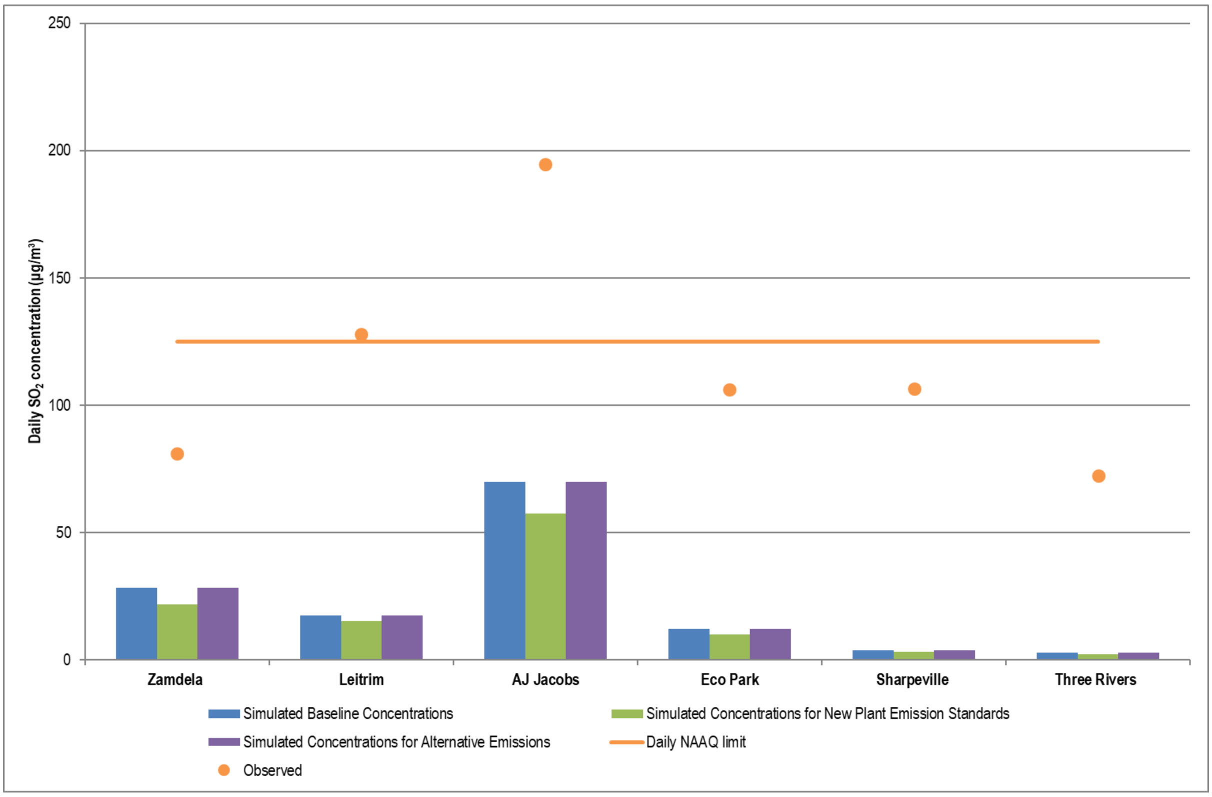

Figure 5-74: Simulated daily SO_2 concentrations (99th percentile) at AQMS for Sasolburg Operations

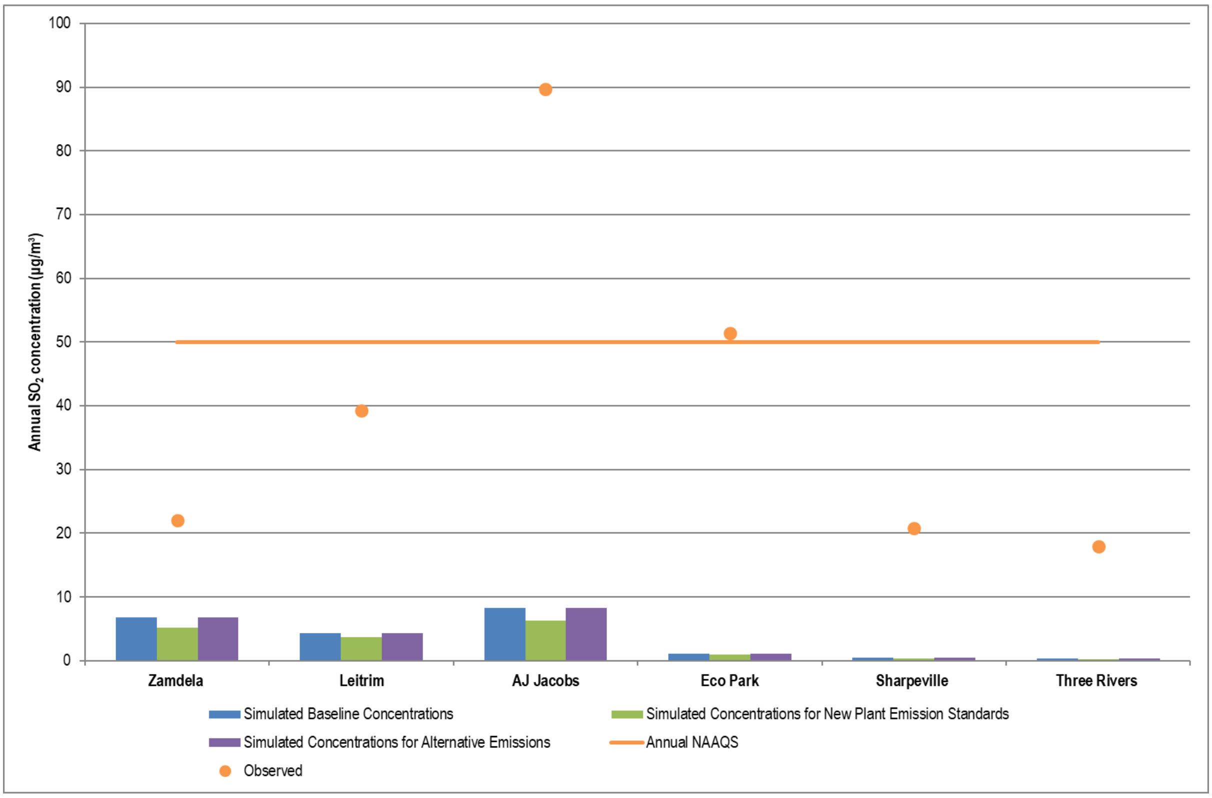

Figure 5-75: Simulated annual SO_2 concentrations at AQMS for Sasolburg Operations

Table 5-22: Simulated baseline hourly SO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Hourly SO_2 (99th percentile)				
	Baseline	New		Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Zamdela AQMS	93.7	72.1	-23.1%	93.7	0%
Leitrim AQMS	62.7	56.4	-10.2%	62.7	0%
AJ Jacobs AQMS	167.7	141.0	-15.9%	167.7	0%
Eco Park AQMS	27.5	23.9	-13.1%	27.5	0%
Sharpeville AQMS	9.3	7.1	-24.0%	9.3	0%
Three Rivers AQMS	7.0	5.7	-17.5%	7.0	0%
Malakabeng Primary School	135.1	95.4	-29.3%	135.1	0%
Cedar Secondary School	86.1	72.6	-15.7%	86.1	0%
Bofula- Tshepe Primary School	90.4	70.7	-21.8%	90.4	0%
Clinic A Zamdela	95.3	73.8	-22.6%	95.3	0%
Zamdela Hospital Zumayear	117.1	84.0	-28.3%	117.1	0%
Iketsetseng Secondary School	90.4	70.7	-21.8%	90.4	0%
Clinic B Zamdela	77.7	67.5	-13.1%	77.7	0%
Tsatsi Primary School	152.6	102.6	-32.7%	152.6	0%
Isaac Mhlambi Primary School	77.5	66.8	-13.8%	77.5	0%
Nkopoleng Secondary School	115.9	81.6	-29.6%	115.9	0%
HTS Secondary School	188.5	146.3	-22.4%	188.5	0%
Zamdela Community Clinic	77.7	62.0	-20.1%	77.7	0%
AJ Jacobs Primary School	194.4	161.3	-17.0%	194.4	0%
Theha Setjhaba Primary School	72.2	59.1	-18.0%	72.2	0%
Sasolburg Clinic	150.9	126.0	-16.5%	150.9	0%
Credo Primary School	58.9	53.0	-9.9%	58.9	0%
Lehutso Primary School	66.2	53.9	-18.6%	66.2	0%
Harry Gwala Clinic | Creche	58.3	50.5	-13.3%	58.3	0%
Kahobotjha-Sakubusha Secondary School	104.5	83.8	-19.8%	104.5	0%
Sasolburg Provincial Hospital	50.1	42.6	-15.0%	50.1	0%

Table 5-23: Simulated baseline daily SO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Daily SO_2 (99th percentile)				
	Baseline	New		Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Zamdela AQMS	27.2	20.9	-23.2%	27.2	0%
Leitrim AQMS	16.2	14.5	-11.0%	16.2	0%
AJ Jacobs AQMS	63.2	51.9	-17.8%	63.2	0%
Eco Park AQMS	10.7	8.8	-17.7%	10.7	0%
Sharpeville AQMS	3.5	3.0	-15.5%	3.5	0%
Three Rivers AQMS	2.4	2.0	-16.5%	2.4	0%
Malakabeng Primary School	34.9	26.4	-24.5%	34.9	0%
Cedar Secondary School	26.1	22.0	-15.7%	26.1	0%
Bofula- Tshepe Primary School	26.2	20.5	-21.8%	26.2	0%
Clinic A Zamdela	27.9	21.1	-24.4%	27.9	0%
Zamdela Hospital Zumayear	30.1	23.0	-23.6%	30.1	0%
Iketsetseng Secondary School	26.2	20.5	-21.8%	26.2	0%
Clinic B Zamdela	21.5	19.2	-10.6%	21.5	0%
Tsatsi Primary School	38.1	28.0	-26.4%	38.1	0%
Isaac Mhlambi Primary School	22.8	19.3	-15.3%	22.8	0%
Nkopoleng Secondary School	29.5	22.1	-24.9%	29.5	0%
HTS Secondary School	54.4	41.1	-24.4%	54.4	0%
Zamdela Community Clinic	21.4	17.1	-20.2%	21.4	0%
AJ Jacobs Primary School	72.3	55.7	-23.0%	72.3	0%
Theha Setjhaba Primary School	20.1	16.1	-19.7%	20.1	0%
Sasolburg Clinic	47.4	40.4	-14.8%	47.4	0%
Credo Primary School	15.4	14.0	-8.8%	15.4	0%
Lehutso Primary School	18.1	14.5	-20.1%	18.1	0%
Harry Gwala Clinic | Creche	14.7	13.5	-8.1%	14.7	0%
Kahobotjha-Sakubusha Secondary School	42.8	35.5	-17.1%	42.8	0%
Sasolburg Provincial Hospital	16.0	13.5	-15.7%	16.0	0%

Table 5-24: Simulated baseline annual SO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Annual SO_2				
	Baseline	New		Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Zamdela AQMS	6.7	5.1	-23.1%	6.7	0%
Leitrim AQMS	4.2	3.6	-15.4%	4.2	0%
AJ Jacobs AQMS	6.3	4.8	-23.8%	6.3	0%
Eco Park AQMS	1.0	0.8	-15.9%	1.0	0%
Sharpeville AQMS	0.4	0.3	-21.7%	0.4	0%
Three Rivers AQMS	0.3	0.2	-18.0%	0.3	0%
Malakabeng Primary School	9.5	6.7	-29.3%	9.5	0%
Cedar Secondary School	6.5	5.3	-19.0%	6.5	0%
Bofula- Tshepe Primary School	6.4	5.0	-23.0%	6.4	0%
Clinic A Zamdela	6.8	5.2	-22.9%	6.8	0%
Zamdela Hospital Zumayear	7.3	5.3	-27.8%	7.3	0%
Iketsetseng Secondary School	6.4	5.0	-23.0%	6.4	0%
Clinic B Zamdela	5.6	4.6	-17.3%	5.6	0%
Tsatsi Primary School	8.0	5.6	-29.9%	8.0	0%
Isaac Mhlambi Primary School	5.7	4.6	-18.9%	5.7	0%
Nkopoleng Secondary School	6.6	4.8	-27.4%	6.6	0%
HTS Secondary School	5.6	4.3	-22.3%	5.6	0%
Zamdela Community Clinic	5.1	3.9	-22.8%	5.1	0%
AJ Jacobs Primary School	7.4	5.6	-25.0%	7.4	0%
Theha Setjhaba Primary School	4.7	3.6	-22.0%	4.7	0%
Sasolburg Clinic	4.7	3.8	-18.9%	4.7	0%
Credo Primary School	3.9	3.3	-15.3%	3.9	0%
Lehutso Primary School	4.0	3.1	-21.4%	4.0	0%
Harry Gwala Clinic | Creche	3.6	3.0	-16.0%	3.6	0%
Kahobotjha-Sakubusha Secondary School	3.9	3.1	-20.5%	3.9	0%
Sasolburg Provincial Hospital	1.6	1.3	-17.4%	1.6	0%