eThekwini Municipality AQMP Review and Update: Baseline Assessment

uMN032-15

eThekwini Municipality

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EXECUTIVE SUMMARY

eThekwini Municipality developed and implemented its first Air Quality Management Plan (AQMP) in 2007. In terms of good practice, the review of an AQMP is promoted through the National Framework for Air Quality Management and the Department of Environmental Affairs Manual for Air Quality Management Planning. eThekwini Municipality is therefore embarking on a project to assess, evaluate, review, and update their AQMP.

This 18 month project consists of four major components. These are: i) the facilitation of the public participation process, ii) the review of the 2007 AQMP document and implementation thereof, iii) the description of the current state of air quality in the eThekwini Municipality and the identification of gaps, issues and challenges for air quality management and iv) the development of the AQMP document and the supporting implementation plan.

eThekwini Municipality is one of eight Category A municipalities in South Africa, and one of 11 district municipalities in KwaZulu-Natal. It spans an area of approximately 2 297 km^2 and is home to nearly 3.5 million people. eThekwini Municipality includes the City of Durban, covering 225.91 km^2. Durban is the largest city in KwaZulu-Natal and home to the Port of Durban, the busiest port in Africa. Durban is a major manufacturing hub and a tourism destination.

eThekwini Municipality has a long involvement in ambient air quality management, dating back to the 1990's. A significant increase in activity was brought about by the Multi-Point Plan (MPP) in 2004 in the South Industrial Basin with an increase in capacity, expansion of the ambient air quality monitoring capability, emission inventory development, modelling and data reporting. This effort brought about a significant reduction in SO_2 emissions from 2006 with a concomitant improvement in ambient air quality and compliance with the National Ambient Air Quality Standards.

A component of the MPP, the epidemiological study and health risk assessment, which was carried out in 2004 and 2006 showed that persistent asthma was the most prevalent health problem among children in the south of Durban, occurring in 12% of children and somewhat higher than in children in the north. Marked airway hyper-responsiveness as a marker of asthma was found to be 3-fold higher in the south than in the north. The health status in eThekwini Municipality has not been updated since the 2006 study, despite the marked improvement in ambient air quality over the last few years.

A summary of the main components of the air quality baseline assessment, i.e. emissions, ambient concentrations of pollutants and the capacity to manage air quality is outlined in the following sections:

Emissions

Emissions of priority pollutants in eThekwini result from a number of different source types. These include industrial facilities that are regulated in terms of their Atmospheric Emission Licenses, i.e. Listed Activities. They also include industrial facilities that operate medium-sized boilers, which are regulated as Controlled Emitters. Smaller facilities that operate Fuel Burning Devices of less than 10 MW heat input are regulated in terms of municipal by-laws. Transportation, which includes motor vehicles and activities in the Port of Durban and the King Shaka International Airport (KSIA) is an important source of emissions. Residential fuel burning is also a source of air pollutants as many homes do not have access to electricity in eThekwini Municipality. Here wood, coal, paraffin and gas are used for cooking, lighting and heating purposes. In the north, sugarcane burning is a seasonal source of air pollutants. There are a number of quarries in eThekwini, which are a source of dust.

A comprehensive emission inventory was developed as part of the baseline assessment, using 2012 as the reference year. The greatest emission from priority pollutants in eThekwini is CO, totalling 154 089 tons per annum, with 97% of the emission attributed to transportation, dominated by motor vehicle emissions (Table E-1). The total NO_X emission is 82 388 tons per annum, resulting primarily from transportation, and mostly heavy duty vehicles with a notable contribution from shipping and Listed Activities. The total SO_2 emission is 26 191 tons per annum with 73% of the emission attributed to industrial sources (Listed Activities and Controlled Emitters) with a significant contribution from transportation, notably shipping.

Table E-1: Total emissions of air pollutants from the different source sectors in eThekwini in tons per annum

Sectors	SO_2	NO_x	CO	PM_{10}	VOC	Benzene
Listed Activities	13 197	5 090	2 482	2 036	5 307	68
Controlled Emitters	5 845	895	425	1 055	2	
Residential fuels	14	29	437	56		
Motor vehicles	1 585	68 292	147 327	2 439	24 642	38
Port of Durban	5 490	7588	1 898	33	2 421	2[1]
King Shaka IA	60	469	702	78[2]	112	
Biomass burning		25	818	68[2]	151	
Mining				100[2]		
Total	**26 191**	**82 388**	**154 089**	**5 865**	**32 635**	**108**

1: Benzene from storage tanks included in Listed Activities
2: Total particulates

By comparison with other pollutants, the total emission of PM_{10} is relatively low at 5 865 tons per annum. Collectively industrial sources account for 53% of the total PM_{10} emissions with motor vehicles accounting for 41% of the total emissions. The emission of total VOCs is 32 635 tons per annum with 75% from heavy duty vehicles and 16% from Listed Activities. Benzene constitutes 3.3% of the total VOC emission. Benzene emissions account for 108 tons per annum with Listed Activities accounting for 63% of the total emission, followed by light motor vehicles accounting for about 30% of the emission.

Ambient air quality

eThekwini Municipality started ambient air quality monitoring in the 1990's using smoke and SO_2 bubblers. This monitoring was augmented in 2005 with 14 fully automated ambient air quality monitoring stations. In 2013 the network expanded with a further four ambient monitoring stations, while the smoke and SO_2 bubbler stations continued to operate. The municipality has also done a number of monitoring campaigns. A good record therefore exists for the criteria pollutants, including SO_2, NO_2, CO, O_3, PM_{10} and benzene.

eThekwini experiences a high frequency of moderate to strong winds, being located on the coast. The influence of the warm Indian Ocean impedes the development of strong temperature inversions and air pollutants generally disperse well along the coast. Persistent inversions can develop inland, especially in valleys in the winter, when pollutants can accumulate. Air quality in eThekwini is therefore relatively good in general, complying with NAAQS as a result of the meteorology and emission reduction measures by major industrial facilities. However, industry and motor vehicle emissions do result in exceedances of the NAAQS for PM_{10}, NO_2 and benzene. Most air quality complaints concern chemical odour south of the city.

Ambient air quality is informed by measured and predicted data. Monitoring data, where available in the eThekwini Municipality is presented. Using the emission inventory developed for the AQMP, dispersion modelling outputs present a complementary picture of air quality in the region. The CALPUFF dispersion model was used to estimate ambient concentrations of SO_2, NO_2 and particulates resulting from industrial emissions, the Port of Durban and the King Shaka International Airport.

Key points to note regarding ambient air quality from monitoring data and dispersion model predictions include:

a) A dramatic decrease in ambient SO_2 in the South Industrial Basin in 2006 following the implementation of emission reduction measures by a number of large industrial facilities;
b) There is general compliance with the NAAQS for SO_2 throughout eThekwini since 2006, except in the Umkomaas area where exceedances occur;
c) Ambient SO_2 concentrations from industrial facilities are predicted to exceed the NAAQS near the Port of Durban, in Clairwood, Jacobs, Wentworth, Merewent and at Umbogintwini;
d) There is general compliance with the NAAQS for NO_2 throughout eThekwini except in high traffic zones where exceedances of the limit value occur;
e) The background PM_{10} concentration in eThekwini is about 16 $\mu g/m^3$;

f) There is general compliance with the NAAQS for PM_{10} throughout eThekwini except in high traffic zones where exceedances occur. The number of exceedances has however decreased following the phase-in of clean diesel;
g) Annual ambient concentrations of benzene are relatively high in high traffic zones and in the vicinity of Umlaas Canal which is impacted on by industrial emissions and the Southern Treatment Works;
h) The background O_3 concentrations in eThekwini are relatively high and exceedances of the NAAQS have occurred;
i) Ambient CO concentrations in eThekwini are low relative to the NAAQS;
j) Ambient lead concentrations are very low throughout eThekwini relative to the NAAQS;
k) The combination of a number of sources of dust in the Coedmore Road area result in nuisance and quality of life issues;
l) Most air pollution related complaints received by eThekwini Municipality relate to emissions and to chemical smell; and
m) Most complaints received are in the South 3, South 4 and North 1 sub-districts.

Capacity for air quality management

eThekwini Municipality has excelled in fulfilling the requirements of the NEM:AQA, at times under challenging conditions and without the appropriate institutional structures. However, the management of air quality in the eThekwini Municipality continues to increase in complexity with growth and development in the municipality. The improvement of technical skills and interdisciplinary studies should be driven by an overarching strategy that is robust and holistic. For the eThekwini Municipality to evolve into a multi-faceted, technically strong and diverse group of Air Quality Management professionals there are gaps that need to be addressed and challenges which need to be overcome, these are highlighted in Table E-2.

Table E-2: **Summary of the baseline capacity at eThekwini for air quality management considering the components capacity**

Assessment	Function/responsibility
Structure	The Air Quality Officer was designated in 2011
	The Air Quality Management function is in the Health Department
	Reporting and communication lines are defined
	The organogram is outdated
Systems	A defined approach for Air Quality Management is limited
	Performance indicators for Air Quality Management exist
	The emission inventory has been updated but gaps exist
	Ambient air quality monitoring is comprehensive, but old
	Data are managed via an air quality data management system
	Atmospheric emission licensing function is established and in operation
	Controlled Emitters are regulated in terms of Schedule Trade Permits
	Air quality by-laws are in draft
Skills	Suitability of staff profiles is mostly in monitoring and related activities

	Departmental learning processes are available
	Skill sharing opportunities are limited
	Technical skills development are limited
	Management skills development is limited
Incentives	A conducive culture and work environment exists
	Opportunities for career growth are limited
	Established partnerships are limited
	There is no external funding to support the function
Strategy	AQMP review is in progress
	AQMP implementation is limited to mandated function
	Vision, mission internalisation is limited
	Flexibility of strategy is limited
Interrelationships	Internal working partnerships exist
	External working partnerships exist
	Working relationship with other organisations exists

The baseline assessment shows that the air quality management requirements of the NEM: AQA are being met in eThekwini. There is a dedicated section for air quality management in the eThekwini Municipality. An AQO has been designated and staff are competent and confident in their abilities to fulfil the AQM function. An Air Quality Officer (AQO) has been designated, the municipality has a dedicated air quality management section and the AEL function is being performed. In addition, the ambient air quality monitoring network is being upgraded and expanded to other parts of the municipality besides the South Industrial Basin. Ambient air quality data is processed and archived, and is critical to directing AQM activities and ensuring that impacts on human and environmental health and well-being are reduced. The AEL function is performed, and routine reporting occurs, ensuring compliance of Listed Activities.

However, the baseline assessment has highlighted gaps, issues and challenges in air quality management in eThekwini Municipality that inhibit fulfilment of the mandate and should be addressed in the AQMP. These are listed in Table E-3 for the different aspects of air quality.

Table E-3: Gaps, issues and challenges for air quality management in eThekwini Municipality

Air quality aspect	Gaps, issues and challenges
Capacity	The structure for the air quality function is not ideal: • It is based on a dated organogram that does not account for mandated functional requirement of the NEM: AQA; • Vacancies exist on the organogram, but job descriptions for the posts do not account for mandated functional requirement of the NEM: AQA; • Mandated functional requirement of the NEM: AQA has increased the work load without staff numbers increasing; • There is a risk of appointing staff with inappropriate skills if the current organogram and job descriptions are used as the

	benchmark.
	Systems for AQM in eThekwini are lacking: • Emission inventory is incomplete; • Ambient monitoring equipment is old and there are procedural shortcomings; • The is no dispersion modelling capability; • The AEL function is not recognised in the organogram.
	Skills on incumbent staff for air quality management are limited: • Skills exist mostly in ambient monitoring and data management, AELs and reporting; • There are limited opportunities for skills sharing as well as technical and management training.
	Incentives for air quality management are driven by resources to perform the function: • The function has been expanded by the mandated requirements of the NEM: AQA; • Financial resources for the function are currently limited to the available municipal budget; • Available financial resources inhibit function.
Human health	The health study in eThekwini Municipality showed persistent asthma in children was higher in the south than in the north.
	Other than in the South Durban Basin the health status is less well understood.
	The health status in eThekwini Municipality has not been updated since 2006, prior to the marked SO_2 reductions.
Emissions	The emissions for 2012 developed for the baseline assessment includes information for 84 industrial facilities that hold AELs: • AELs have not been issued to all facilities with Listed Activities so not all sources are included; • Emission testing has not been done at all facilities and emissions have not been estimated; • Emissions of SO_2, NO_X, PM_{10} and VOC from Listed Activities are significant; • Most emissions result from the pulp and paper sector, crude oil refining, the metallurgical sector and sugar milling and refining.
	The Controlled Emitter database: • Information is available in the database for 13 facilities operating 33 boilers; • Not all Controlled Emitters are included; • Most emissions result from coal and (heavy fuel oil) HFO combustion.
	Motor vehicles: • Heavy duty vehicles are significant sources of PM_{10}, CO and NO_X in eThekwini; • Light motor vehicles are a source of benzene emissions; • Emissions from motor vehicles are concentrated in Durban and Pinetown, with lesser emissions elsewhere; • Motor vehicle emissions are estimated using a top-down approach for 9 areas in eThekwini, providing a reasonable coarse estimation.

	The Port of Durban: • Emission is based on 2009 data using the Intergovernmental Panel on Climate Change (IPCC) Tier 1 methodology; • Port of Durban is a major source of SO_2, NO_X and VOCs; • Information from a number of sources in the chemical cluster was omitted from the inventory.
	Airports: • KSIA is not a major source of emission in eThekwini; • Emissions were not estimated for small airports.
	Residential fuel burning: • Emissions of NO_X and PM_{10} from residential fuel burning are relatively small in eThekwini.
	Biomass burning: • Emissions of CO and PM from sugarcane burning are seasonal and relatively small in eThekwini; • Sugarcane burning is common practice and occurs in close proximity to residential and commercial properties, resulting in nuisance impacts.
	Waste management: • Emissions of air pollutants from Wastewater Treatment Works (WWTW) and landfills are relatively small; • The impacts are mostly nuisance related and are localised.
	Mining: • Emissions of particulates from mining are relatively small; • The impacts are mostly nuisance related and are localised.
Ambient monitoring	A number of technical shortcomings were identified during a supporting study, including: • The monitoring network plan is outdated; • It is not necessary to perform meteorological monitoring at so many locations; • There is no formal QA/QC system in place that documents operational procedures and the basis for the establishment of the monitoring network; • The municipality does utilise a SANAS accredited laboratory, but the calibrations are only performed annually; • External audits performed as a means of independently verifying eThekwini Municipality monitoring activities.
Ambient modelling	Air quality modelling is not used to inform decisions in eThekwini Municipality.
	eThekwini Municipality does not have a modelling capability.

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μg/m^3	Micrograms per cubic metre
μm	Micrometres
ACGIH	American Conference of Government Industrial Hygienists
AEL	Atmospheric Emission Licence
AGL	Above ground level
APPA	Atmospheric Pollution Prevention Act
AQM	Air Quality Management
AQMP	Air Quality Management Plan
AQO	Air Quality Officer
ATSDR	American Toxic Substances and Disease Registry
BTEX	Benzene, toluene, ethylbenzene and xylene
BVOC	Biogenic Volatile Organic Compounds
C_6H_6	Benzene
CO	Carbon monoxide
DEA	Department of Environmental Affairs
DM	District Municipality
EHP	Environmental Health Practitioner
EMI	Environmental Management Inspectors
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
H_2S	Hydrogen sulphide
HPA	Highveld Priority Area
IDP	Integrated Development Plan
LPG	Liquid Petroleum Gas
MEC	Member of Executive Council
MODIS	Moderate-resolution Imaging Spectroradiometer
NMHC	Non-methane hydrocarbons
NEM:AQA	National Environmental Management: Air Quality Act
NO	Nitrous oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
O_3	Ozone
PAH	Polycyclic aromatic hydrocarbons
Pb	Lead
PM	Particulate matter
PM_{10}	Particulate matter of aerodynamic diameter less than 10 micrometres
$PM_{2.5}$	Particulate matter of aerodynamic diameter less than 2.5 micrometres
ppb	parts per billion
ppm	parts per million
PSC	Project Steering Committee
SADHS	South African Demographic and Health Survey
SAPIA	South African Petroleum Industry Association
SAWS	South African Weather Service
SO_2	Sulphur dioxide
STP	Standard temperature and pressure, which is 25ºC and 1 kilopascal
t/a	Tons per annum
TSP	Total suspended particulates
VOC	Volatile organic compounds
WHO	World Health Organisation

1 INTRODUCTION

1.1 Background

eThekwini Metropolitan Municipality (eThekwini Municipality) is located on the east coast of South Africa in the Province of KwaZulu-Natal (KZN) and spans an area of approximately 2 297 km^2. eThekwini Municipality is one of eight Category A municipalities in South Africa, and one of 11 district municipalities in KZN (Figure 1-1).

eThekwini Municipality includes the City of Durban, covering 225.91 km^2. Durban is the largest city in KZN and home to the Port of Durban, the busiest port in Africa. Durban is a major manufacturing hub and tourism destination. The main commercial and residential centres in eThekwini Municipality are shown in Figure 1-2.

The importance of the environment and air quality is highlighted in Section 24 of the Bill of Rights, which states, amongst others, that everyone has the right to an environment that is not harmful to health or well-being. Air pollution in eThekwini Municipality and its potential impacts on human health have been highlighted for a number of years. This led to the development and implementation of the Multi-Point Plan (MPP) in 2002, which focused largely on the South Durban Basin (SDB) (DEA, 2007). The associated health study confirmed high levels of exposure to air pollution in the residential areas surrounding the SDB (University of KwaZulu-Natal, 2006). The MPP, amongst others, resulted in a dramatic decrease in the emission of sulphur dioxide (SO_2) by industries in the SDB and a concomitant decrease in ambient SO_2 concentrations.

The Municipal Systems Act (No.32) of 2000 requires that local government structures prepare Integrated Development Plans (IDPs) which guide the transformation of local governments toward facilitation and management of development within their areas of jurisdiction.

In terms of Section 15 (2) of the National Environmental Management: Air Quality Act (Act No.39 of 2004), (eThekwini Municipality: AQA) municipalities are mandated to include an Air Quality Management Plan (AQMP) in their IDPs. The AQMP provides definitive objectives, strategies, plans and procedures, for the relevant spheres of government to meet the requirements of the NEM: AQA, with respect to good air quality management planning and reporting. The Pollution Control and Risk Management (PCRM) section of eThekwini Municipality Health Unit developed and implemented an AQMP in 2007 (NILU,2006). In terms of good practice, AQMP review is promoted through the National Framework for Air Quality Management (DEA, 2012a) and the Department of Environmental Affairs (DEA) Manual for Air Quality Management Planning (DEA, 2012b). eThekwini Municipality's Health Unit is therefore embarking on a project to assess, evaluate, review and update their AQMP.

Figure 1-1: District and metropolitan municipalities in KZN

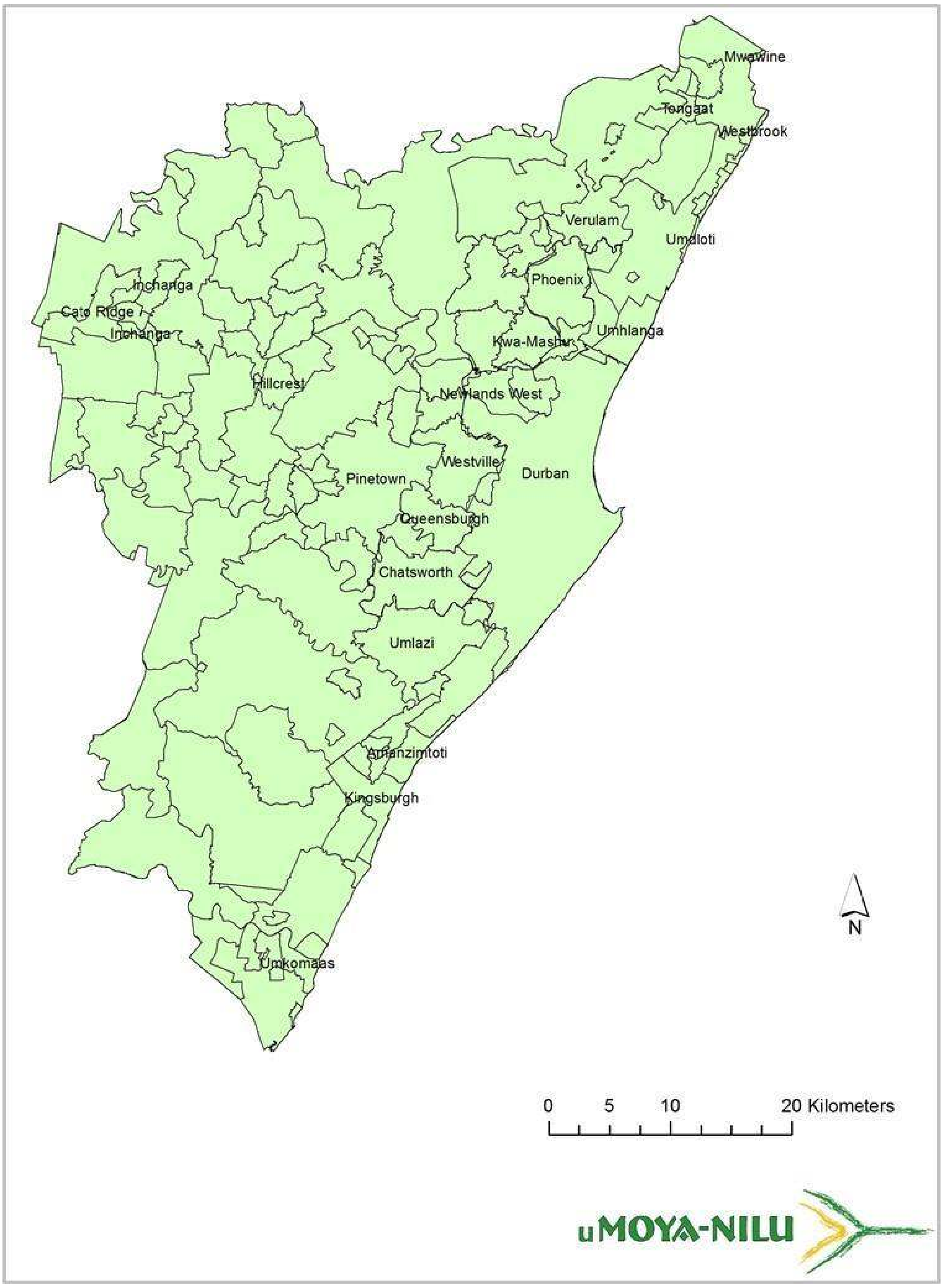


Figure 1-2: Commercial and residential centres in eThekwini Municipality

uMoya-NILU Consulting (Pty) Ltd, a Durban-based air quality management consultancy, was appointed in 2014 to lead this project which spans 18 months and consists of four major components. These are i) facilitation of the public participation process, ii) review of the 2007 AQMP document and its implementation, iii) the description of the current state of air quality in the eThekwini Municipality and the identification of gaps, issues and challenges for air quality management and iv) the development of the AQMP document and the supporting implementation plan. This report addresses point (iii) and provides a description of the current status of air quality in the eThekwini Municipality, highlighting strengths, weaknesses, gaps in air quality management and future challenges.

1.2 AQMP development process

An AQMP is a strategic document with a vision and a goal that endeavours to ensure that air quality meets the requirements of Section 24 of the National Environmental Management Act (eThekwini Municipality) and Section 24 of the Bill of Rights, i.e. air quality that is not harmful to health and wellbeing. This implies that governance and management efforts are directed towards maintaining or improving air quality so that it complies with health based national ambient air quality standards (DEA, 2009a and 2012c).

An AQMP must seek to give effect to Chapter 3 of the NEM: AQA. It should aim to:

- improve (or maintain) air quality;
- identify and reduce the negative impact of air pollution on human health and the environment;
- address the effects of emissions from fossil fuel use in residential areas;
- address the effects of emissions from industrial sources;
- address the effects of emissions from other sources;
- implement obligations in respect of international agreements;
- give effect to best practice in air quality management; and
- describe how implementation will be effected and measured

AQMP development is a dynamic process that is enhanced by active engagement with a wide range of stakeholders. The baseline assessment describes the current state of air quality in an area and the trends, identifying gaps and issues and recommendations to improve air quality and air quality service delivery. The baseline assessment is followed by the development of the strategic implementation plan that involves setting a vision and mission, supported by short and long-term goals and objectives for the implementation of defined management measures. The process to review and update the eThekwini AQMP follows the process defined in the Manual for Air Quality Management Planning (DEA, 2012b) and is outlined in the National Framework illustrated in Figure 1-3 (DEA, 2012a).

Stage 1 includes the establishment of a stakeholder database and an assessment of baseline air quality. Stakeholders include amongst others the three spheres of government, parastatals, industry, planners, business, communities and non governmental organisations

(NGOs). The establishment of the air quality baseline in the eThekwini Municipality includes an assessment of climate and meteorological information, ambient monitoring data, emission inventory data, the existing air quality management capacity and practices in the eThekwini Municipality. Areas where ambient air quality standards are exceeded or may be exceeded are identified as potential areas of concern.

Stage 2 is the gap and issue analysis which is based on findings of the baseline assessment and is informed by legislative requirements and stakeholder engagement.

Stage 3 is the initial phase of the development of the implementation plan and sets the strategic intent through establishing a vision, mission and goals.

Stage 4 considers the develoment of interventions that address each gap and issue that are SMART (Specific, Measurable, Achievable, Relevant, & Time based).

Stage 5 focuses on the development of an implementation plan where accountability is assigned and timeframes for implementation are established. The implementation plan defines what needs to be done, how it should be done, who is responsible and when it will be done for each intervention.

Stage 6 addresses monitoring and reporting progress with implementaion of the AQMP and evaluating the success of the interventions.

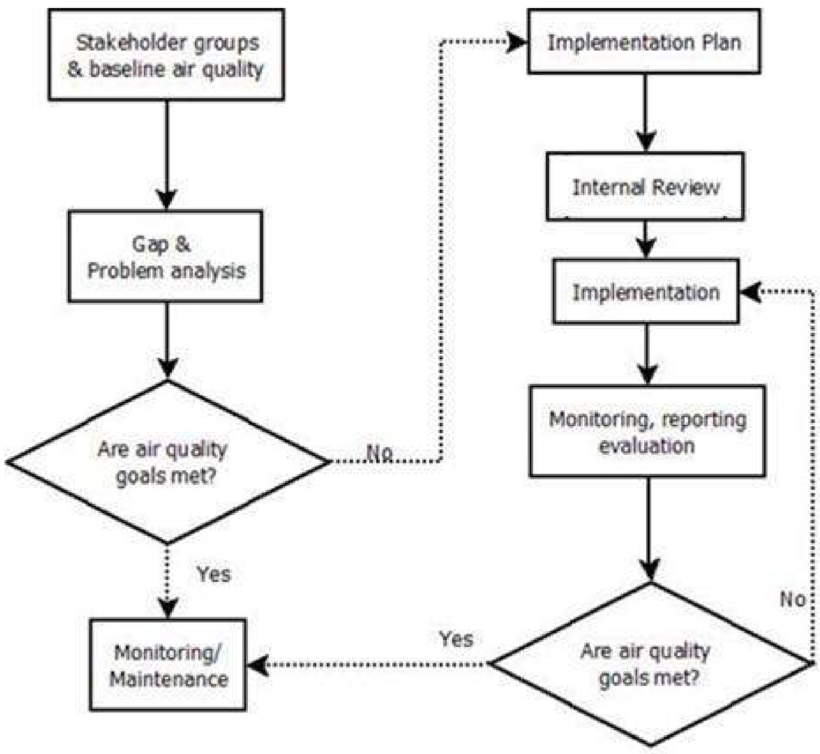


Figure 1-3: Schematic of the AQMP development process (after DEA, 2012b)

1.3 Report structure

As part of the AQMP development process this document describes the baseline or status quo of air quality in the eThekwini Municipality (Stage 1), and identifies gaps and problems (Stage 2). The process is informed by an in depth analysis of available data, and consultations with the eThekwini Municipality Air Quality Officer (AQO) and the PCRM group and other relevant stakeholders.

Chapter 1 introduces the project and the theoretical and legislative context of air quality management planning. **Chapter 2** provides a background to the eThekwini Municipality and a description of topography, land use, climate and meteorology and socio-economics. The description of the air quality baseline is included in **Chapter 3** and considers emissions from different sources, the state of ambient air quality using monitored data and dispersion modelling, and eThekwini Municipality's air quality management capacity and capability. Strategic development in eThekwini Municipality and the potential threats to air quality in the future are discussed in Chapter 4. Gaps, issues and challenges for air quality management in the eThekwini Municipality are highlighted in Chapter 5. Chapter 6 describes how these lead into the AQMP development process.

2 THE ETHEKWINI MUNICIPALITY

Chapter 2 presents a background to the eThekwini Municipality, including the political demarcation, a description of topography and land use, the climate and meteorology and the socio-economic status. This information provides important context to the baseline assessment

2.1 Political demarcation

The eThekwini Municipality covers an area of approximately 2 297 km^2 and is home to approximately 3.5 million people. It is bordered in the north by the Ilembe District Municipality, to the south by the Ugu and the Umgungundlovu District Municipalities and to the east by the Indian Ocean. It stretches beyond the Mkomazi River in the south to the Tongati River in the north, and to Cato Ridge in the west.

In South Africa, municipal wards are the geopolitical subdivisions of municipalities used for electoral purposes. Each metropolitan and local municipality is delimited by the Municipal Demarcation Board into half as many wards as there are seats on the municipal council. Each ward then elects one councillor directly, and the remaining councillors are elected from party lists so that the overall party balance is proportional to the proportion of votes received by each party. There are 103 municipal wards in eThekwini Municipality. They are shown in Figure 2-1 and are listed in Appendix 1.

2.2 Topography and land use

The eThekwini Municipality is situated at the centre of the Maputaland-Pondoland-Albany Region, an area described by Conservation International as a "Biodiversity Hotspot", one of only 34 in the world (eThekwini, 2012). The eThekwini Municipality is characterised by diverse topography, from steep escarpments in the west to a relatively flat coastal plain in the east. This is illustrated by the topographical cross section from the CBD in the east to Cato Ridge in the Outer West (Figure 2-2), with a steady increase from sea level to an elevation of 800 m, 30 km inland at Botha's Hill, with valleys and ridges over the 15 km to Cato Ridge.

The topographical cross section from the coast across the Bluff and inland to Chatsworth emphasises the significance of the coastal dune ridge, the South Industrial Basin and the flats and Mobeni and the Mobeni Ridge for the dispersion of air pollutants (Figure 2-2). The physical barriers imposed by the Bluff and the higher topography west of Mobeni and the prevailing northeasterly and southwesterly winds (see Section 2.3) inhibit the dispersion of pollutants to the valley areas where they are released. Similarly, the topography that slopes generally from west to east towards the coast promotes drainage of air from the interior (see Section 2.4).

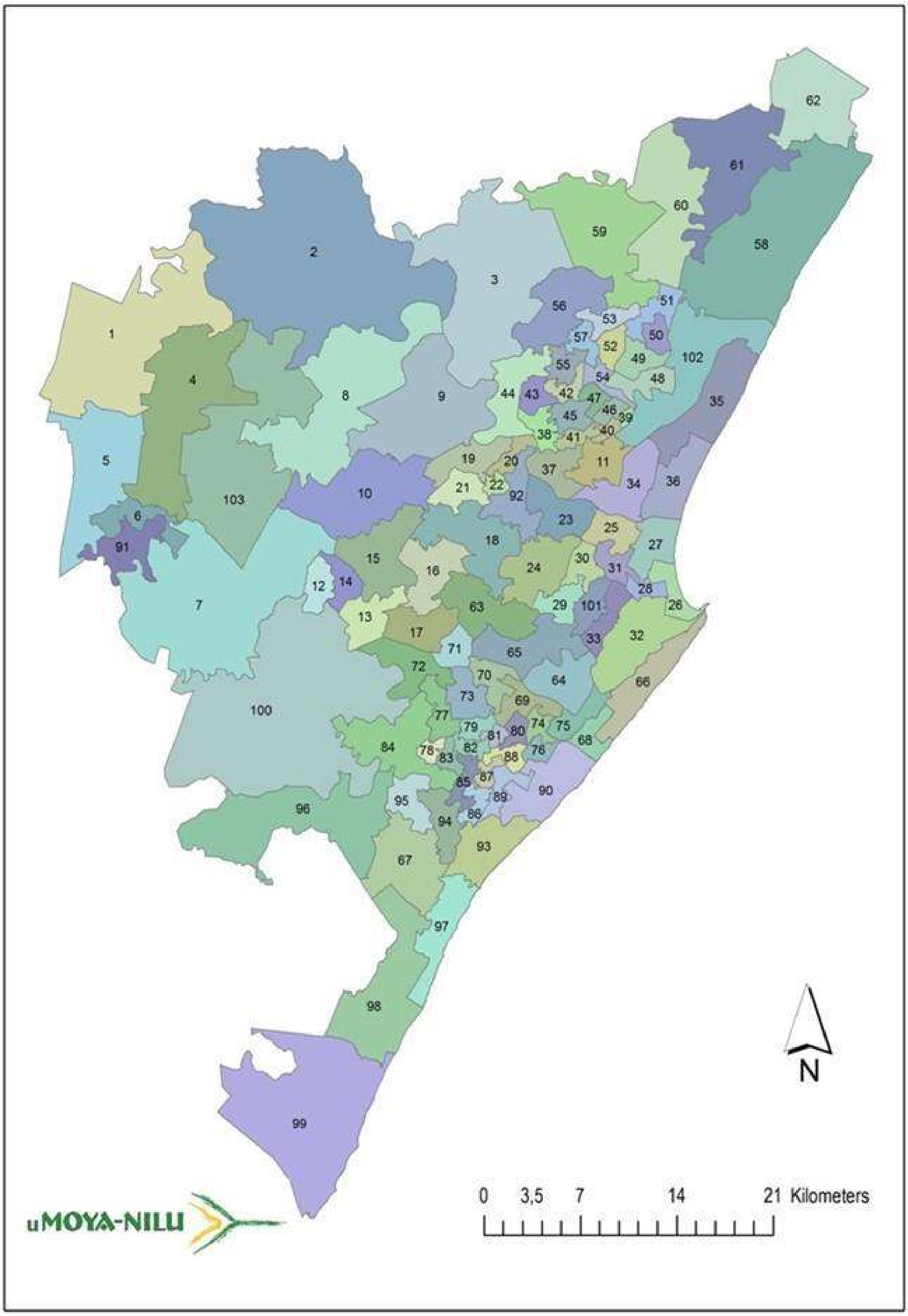


Figure 2-1: Municipal wards in eThekwini. The corresponding ward names are listed in Appendix 1

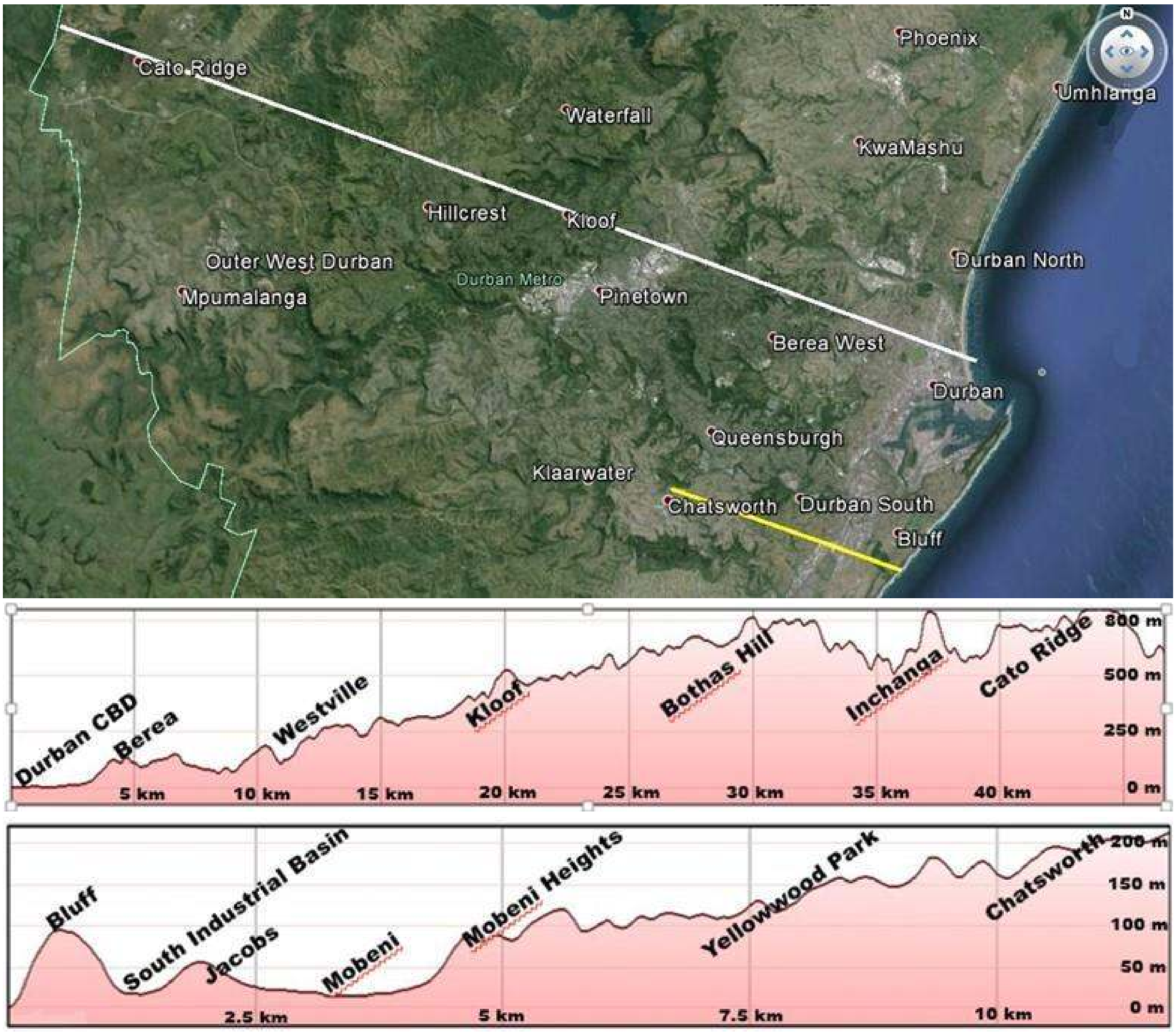


Figure 2-2: Relief map of eThekwini (top) showing a 45 km topographical cross section from the CBD to Cato Ridge (white line, centre) and a 12 km topographical cross section from the coast to Chatsworth (yellow line, bottom) (from Google Earth, 2015). The vertical scale is exaggerated.

The total area covered by eThekwini Municipality is 229 191 ha. The municipality has a 98 km coastline, 18 major catchments and 16 estuaries, 4 000 km of river, and nearly 75 000 ha of land identified as part of the Durban Metropolitan Open Space System (D'MOSS) (eThekwini, 2012). The distribution of the dominant land use types in eThekwini is illustrated in Figure 2-3). As might be expected in a metropolitan municipality, the majority of the area has been modified residential and economic land uses covering 122 641 ha or 53.5% of the land area (eThekwini, 2013). Natural land cover occurs mostly to the south and outer west, comprising 106 017 ha or 46.3% of the total area. Cultivation as a land use is dominated by sugarcane farming, comprising 19 604 ha or 8.6% of the total area and occurs mostly in the north.

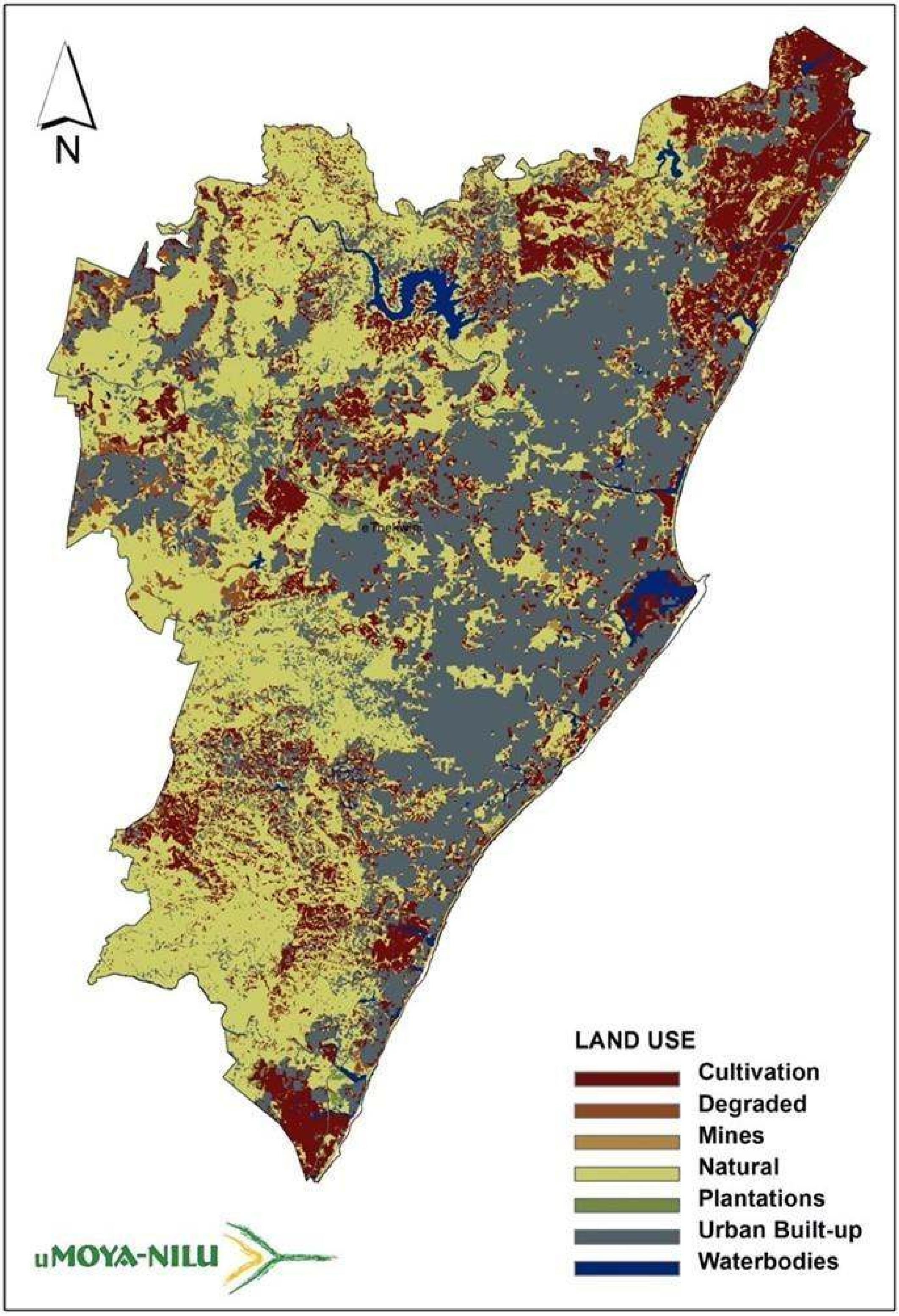


Figure 2-3: Land uses in eThekwini Municipality (eThekwini Corporate GIS, 2015)

2.3 Climate and meteorology of eThekwini

The three main factors that influence the climate of a location are latitude, elevation and distance from the sea. eThekwini Municipality is located on South Africa's east coast, at approximately 29.5 °S and 30 °E. It is adjacent to the warm Indian Ocean and elevation increases from sea-level at the coast to more than 500 m above sea level in the Outer West. Its sub-tropical latitude and proximity to the warm Indian Ocean ensures warm temperatures, high humidity, and summer rainfall. The lower elevation on the coast ensures higher temperatures than on the escarpment towards the Outer West.

The general circulation of the atmosphere and its perturbations also influences the climate of a location. The main synoptic-scale features that control atmospheric circulation over the east coast of South Africa and eThekwini are the Indian Ocean Anticyclone (IOA), the sub-continental high, westerly waves and the coastal low.

The strength of the IOA and its relative location to the South African coast plays a major role in eThekwini's climate. In summer, the IOA is more intense and is situated relatively close to the sub-continent with a low pressure trough adjacent to the South African interior. This results in strong insolation, hot temperatures and north-easterly winds. It also results in advection of tropical air over the eastern interior and coast which results in convection summer showers and thundershowers. In winter the main synoptic features move northward as the sun moves northward. The IOA is weaker and situated further north and a semi-permanent high pressure system establishes over the South African interior. Temperatures are cooler and the high pressure system results in generally clear skies and light winds. The westerly wave systems that move south of the country in summer move northward in winter. The generally mild and calm winter conditions are sometimes interrupted by the passage of cold fronts, resulting in cold temperatures, winter rain and south-westerly winds.

Coastal lows move northward up the KZN coast, particularly in winter ahead of westerly waves. Hot and dry Berg Winds are often associated with well-developed coastal lows when winter temperatures can exceed 30 °C. Strong north-easterly winds ahead of the low, followed by so-called southwesterly busters occur. Land-sea breezes are common winter meso-scale circulation features on the east coast in winter resulting in off-shore winds during the day and generally onshore winds at night.

There are two South African Weather Service (SAWS) climate stations in eThekwini, at the old Durban International Airport in the south and at Mount Edgecombe in the north. SAWS included climate statistics for these two stations for the 30-year period 1961 to 1990 (SAWB, 1998). Average monthly and extreme temperatures are presented in Table 2-1 with the average monthly rainfall and are shown in Figure 2-4. eThekwini has a humid subtropical climate (*Cfa*) according to the Köppen climate classification. It experiences hot and humid summers and warm, relatively dry winters. Summer rainfall starts in late October to early April.

The average temperature in summer ranges from 21 °C to 25 °C, but daytime maximums can exceed 30 °C. During the summer the average humidity is in the region of 70%. In winter the average temperature is between 16 °C and 19 °C, with average maximum daytime temperatures reaching 23 °C. During the winter the average humidity is in the region of 55%. The annual average rainfall varies from 1 009 mm in the south to 973 mm at Mount Edgecombe in the north.

Table 2-1: Climate statistics for eThekwini (SAWB, 1998)

Old Durban International Airport

	Max (˚C)	Min (˚C)	Mean (˚C)	Highest Max (˚C)	Lowest Min (˚C)	Rainfall (mm)
Jan	27.8	21.1	24.4	36.2	19.5	134
Feb	28.0	21.1	24.6	33.9	20.9	113
Mar	27.7	20.2	23.9	34.8	17.5	120
Apr	26.1	17.4	21.7	36.0	18.0	73
May	24.5	13.8	19.1	33.8	13.7	59
Jun	23.0	10.6	16.8	35.7	14.0	28
Jul	22.6	10.5	16.6	33.8	13.4	39
Aug	22.8	12.5	17.7	35.9	13.7	62
Sep	23.3	15.3	19.3	36.9	14.4	73
Oct	24.0	16.8	20.4	40.0	14.1	98
Nov	25.2	18.3	21.8	33.5	17.0	108
Dec	26.9	20.0	23.4	35.9	19.4	102
Annual	**25.2**	**16.5**	**20.8**	**40.0**	**13.4**	**1009**

Mount Edgecombe

	Max (˚C)	Min (˚C)	Mean (˚C)	Highest Max (˚C)	Lowest Min (˚C)	Rainfall (mm)
Jan	27.2	20.1	23.7	38.3	19.8	134
Feb	27.3	20.2	23.7	34.0	19.5	124
Mar	26.8	19.3	23.1	34.4	17.0	114
Apr	25.3	16.7	21.0	35.8	17.1	63
May	23.8	13.8	18.8	38.6	14.8	49
Jun	22.4	11.2	16.8	35.0	12.8	29
Jul	22.1	10.9	16.5	33.2	12.8	24
Aug	22.4	12.2	17.3	36.4	13.3	51
Sep	23.0	14.6	18.8	38.1	13.4	77
Oct	23.6	15.9	19.8	38.7	13.5	94
Nov	24.8	17.5	21.2	37.6	15.7	115
Dec	26.4	19.1	22.8	37.5	19.0	99
Annual	**24.6**	**16.0**	**20.3**	**38.7**	**12.8**	**973**

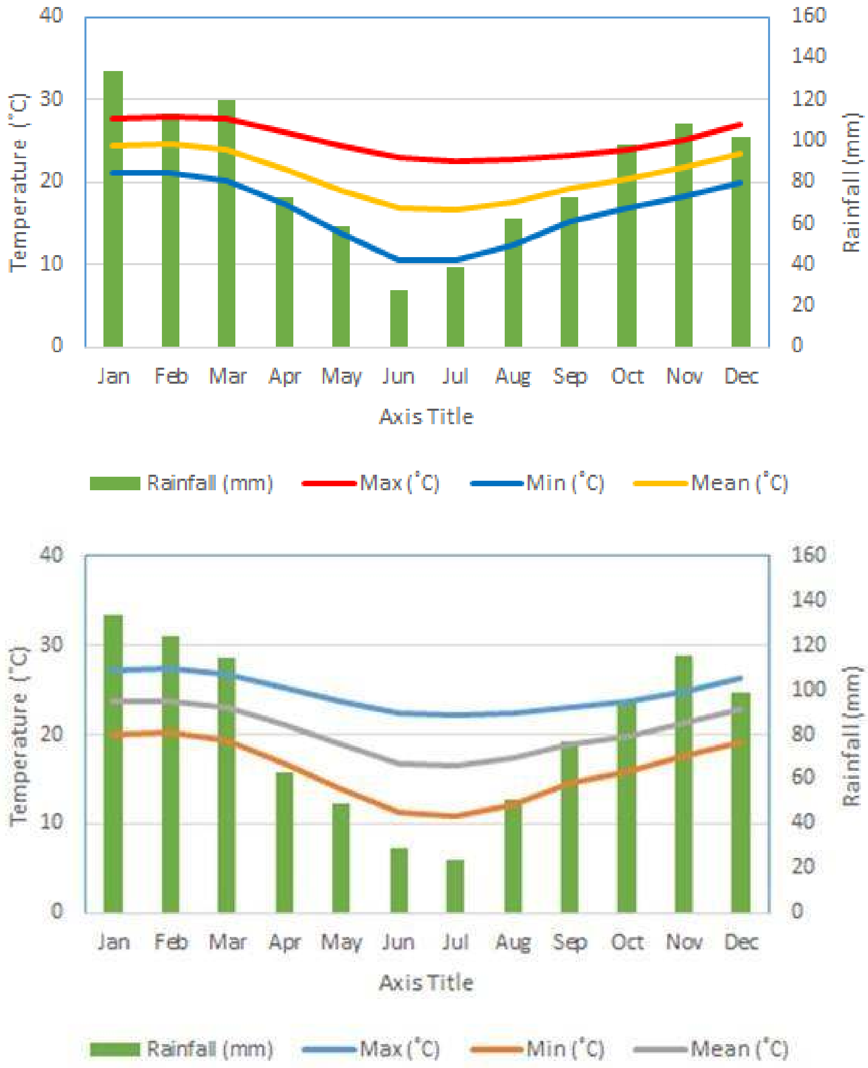


Figure 2-4: Average monthly maximum, minimum and daily temperatures and average monthly rainfall for the 30-year period 1961 to 1990 at the old Durban International Airport (top) and Mount Edgecombe (bottom)(SAWB, 1998)

Wind patterns in eThekwini DM are described by windroses for the 3-year period 2010 to 2012 at the old Durban International Airport (Figure 2-5). This monitoring station is suitably positioned to provide representative wind climatology for the eastern parts of eThekwini. The annual, daytime (06:00 to 17:00) and night time (18:00 to 05:00) windroses are shown. Windroses simultaneously depict the frequency of occurrence of hourly winds from the 16 cardinal wind directions and in different wind speed classes. Wind direction is given as the direction from which the wind blows, i.e., southwesterly winds blow from the southwest. Wind speed is given in m/s, and each arc in the windrose represents a percentage frequency of occurrence.

The dominant winds in eThekwini are from the north to north-northeast (21%) or from the south to southwest (29%), where the winds are typically light to moderate, but can exceed 11 m/s at times (Figure 2-5). These winds are mostly a result of the dominant synoptic-scale circulation. Light north-northwest to east-southeast winds result mostly from regional scale topographical drainage and land breezes and occur 24% of the time, mostly in winter and at night. The higher frequency of light off-shore winds at night is clearly seen in Figure 2-5. Easterly on-shore winds are less infrequent and occur on 17% of the time. Calm conditions occur for 9% of the time.

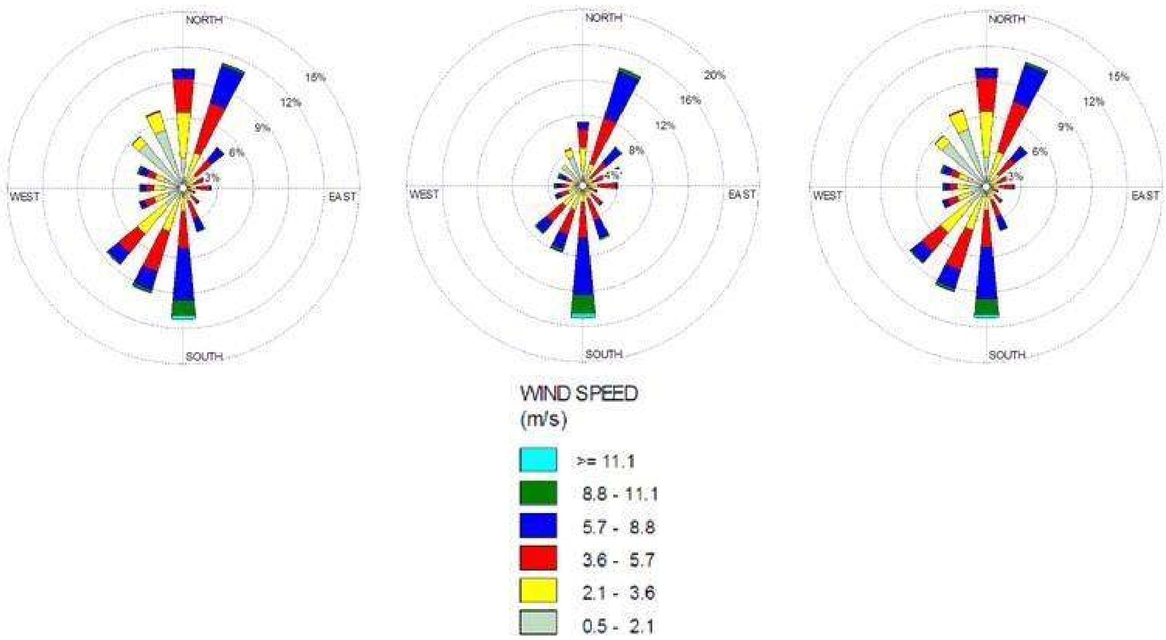


Figure 2-5: Annual windrose (left), day time (centre) and night time (right) at the old Durban International Airport for the 3-year period 2010 to 2012

2.4 Climate and air quality in eThekwini

The air pollution dispersion of an area refers to the ability of atmospheric processes, or meteorological mechanisms, to disperse and remove pollutants from the atmosphere. Dispersion comprises both vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines the rate of downwind transport and wind direction and the variability in wind direction determines the general path of a pollutant. Atmospheric stability, or instability, determines the ability of the atmosphere to mix and dilute pollutants. Stability is a function of solar radiation (thermal turbulence), wind speed and surface roughness which induces mechanical turbulence. Therefore, the dispersion potential of an area experiences diurnal and seasonal changes.

By day, with strong insolation (in coming solar radiation) and stronger winds, the dispersion potential is generally efficient due to vertical dilution and horizontal dispersion. The dispersion potential is better on summer days than winter days. At night as the surface temperature inversion develops, the lowest layer of the atmosphere becomes more and more stable, reaching a maximum at sunrise. As a result, the dispersion potential typically becomes less efficient during the night and the poorest conditions generally occur at sunrise. Thermal turbulence disappears when the sun sets, and mechanical turbulence decreases as the wind speeds drops at night. Pollutants tend to accumulate near the point of release under these conditions, particularly if these are released close to ground level. The dispersion potential is generally poorer on winter nights than summer nights.

In eThekwini the dispersion potential is relatively good during the day in both winter and summer as a result of hot daytime temperatures and a relatively high frequency of moderate winds, particularly along the coast. It is be better on summer days than winter days. This is attributed to stronger thermal mixing and night-time temperature inversions which are weaker, break up earlier and establish later in the day. Secondly, there is a higher frequency of stronger winds in summer than in winter. At night the dispersion potential is poorer and this effect is more pronounced in the winter. Surface temperature inversions are stronger and exist for longer than in summer, particularly over the central and western parts of the municipality.

Long range transport is associated with synoptic-scale circulation and affects air quality in eThekwini. Freiman and Piketh (2003) showed that 39% of all atmospheric transport from the Highveld is controlled by the IOA and the semi-permanent high over the interior and exits the sub-continent over KZN (Figure 2-6). At its origin this air is influenced by air pollution sources from industry, mining, domestic coal burning and biomass burning. Tyson and Preston-Whyte (2000) show that the horizontal atmospheric transport over southern Africa is dominated by anticyclonic transport. Transport to the Indian Ocean is in a massive plume accounting for more than 75% of all atmospheric transport out of southern Africa. The vertical structure is also distinctive and 3 to 4 km deep above the atmospheric boundary layer with distinctive cores above Durban and south of St Lucia. This long-range transport of atmospheric aerosols increases the background concentrations of particulate matter along the entire east coast.

Regional-scale atmospheric circulation over KZN also affects eThekwini's air quality. Tyson and Preston-Whyte (2000) describe the establishment of a mountain-plain, originating at the Drakensberg escarpment and moving towards the coast in a relatively shallow layer. This northwesterly flow transports pollutants that originate from biomass burning and other sources in the KZN interior to the coast.

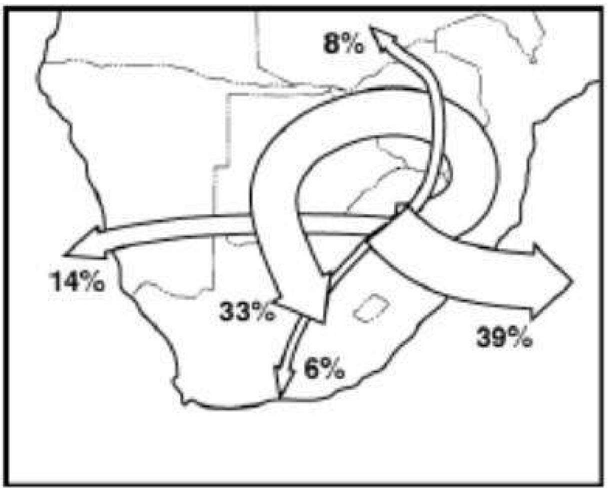


Figure 2-6: Transport from the Highveld region showing percentage of transport occurring (Freiman and Piketh, 2003)

Points for consideration in the AQMP regarding topography and meteorology

a) eThekwini Municipality is generally well ventilated by a high frequency of moderate to strong winds that effectively disperse air pollutants
b) The topography of the South Industrial Basin and the prevailing winds restrict dispersion of air pollutants to the northeast and the southwest
c) Inversions in winter inhibit the dispersion of air pollutants, particularly in valleys of the central and western parts
d) Regional scale transport of air pollutants increases background concentrations of pollutants in eThekwini Municipality

2.5 Health status

As part of the Multipoint Plan, the Centre for Occupational and Environmental Health at the University of KwaZulu-Natal and the Department of Environmental Health Sciences at the University of Michigan conducted an epidemiological study and health risk assessment in the south of Durban in 2004 and 2006 (University of KwaZulu-Natal, 2006). Emphasis was placed on respiratory health and other chronic diseases, and the relationship between health and ambient air pollution. The health risk assessment examined the potential for health problems from exposures to a range of ambient air pollutants.

The study participants included 423 children in grades 3 to 5 attending seven primary schools. Four of the schools were in South Durban, namely Assegai in Austerville, Dirkie Uys on the Bluff, Nizam in Merebank and Entuthukweni in Lamontville. Three schools in the north selected as comparison sites, namely Briardale in Newlands West, Ferndale in Newlands East, and Ngazana in KwaMashu. In addition, study participants included 379 primary child caregivers, the head of the children's household, and other adult members of the children's households.

Ambient air pollutants were monitored at the seven schools as well as at 16 other sites. In addition, indoor and outdoor air pollutants were monitored at 140 households of the participating learners, and at the seven schools. Pollutants that were monitored included, amongst others, sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), volatile organic compounds (VOCs, including benzene and 90 other compounds), particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), trace metals including lead, semi-volatile organic compounds (SVOCs, including dioxins, furans, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and pesticides.

The health of participating students was assessed through interviews with the child, the child's caregiver, head of the child's household, and through testing of baseline lung function, allergy sensitisation, lead and manganese exposure, and profiling of genes suspected to contribute to pollution-related worsening of respiratory health. Additionally, each child recorded symptoms and blew into handheld devices to measure lung function four times each day during 15 schooldays in each of four seasons. The 1 391 participating adults were interviewed about their health status.

Sulphur dioxide concentrations varied widely across the study area, averaging from 1 - 3 ppb at northern sites to 12 - 20 ppb in the south. There were frequent exceedances of the then South African limit values in Durban South (SANS 1929). Concentrations of particulate matter (PM_{10}) averaged 38 to 52 $\mu g/m^3$ across the area, and both PM_{10} and $PM_{2.5}$ at the northern and southern sites exceeding the eThekwini target concentrations. Benzene concentrations were elevated and exceeded international norms at several of the monitoring sites in the south. Concentrations of dioxins, furans and several other SVOCs were found to be relatively uniform across Durban, and also exceeded international norms.

The most prevalent health problem among children, as reported by their caregivers, was asthma (14% of the children studied were diagnosed by a doctor). Based on reported symptoms, 12% had persistent asthma, and this was somewhat higher in the south than the north. Marked airway hyper-responsiveness is a marker of significant asthma and was 3-fold higher in the south than in the north. In statistical models which adjusted for the effects of other characteristics which might be associated with health outcomes (age, gender, race/ethnicity, care-giver smokes, caregiver education, annual family income), persistent asthma and marked airway hyper-reactivity were significantly more common among children in the south as compared to children in the north. Based on models adjusting for other causes of poorer health, the study results strongly suggest that exposure to the air pollutants SO_2, PM_{10}, and NO_2 and NO cause many students to have poorer lung function on following days. These effects are more frequent and worse among those children who already have persistent asthma or have a genetic profile for asthma.

Rates of disease among the adults in Durban generally reflected the South African population. Diseases found in 10% or more of the sample included high blood pressure (20%), arthritis (17%), symptoms of lung problems (11-18%), and diabetes (10%).

Reported cancer rates were below 1%. Most outcomes were somewhat more common among adults living in the south compared to those in the North. Statistical models that adjusted for factors potentially associated with health outcomes, indicate that hay fever was significantly (more than 3 times) more common among adults living in the south compared to those in the north. In these models, chronic bronchitis, wheezing with shortness of breath, and hypertension also were somewhat higher in the south.

The health risk assessment identified a number of contaminants that pose potential health risks, including cancer. These compounds were found to be present at elevated levels based on risk calculations and compared to other urban areas. They include benzene and several other VOCs, dioxins, furans, PAHs, naphthalene, chromium, nickel, lead, and manganese.

Points for consideration in the AQMP regarding human health

a) The most prevalent health problem is among children
b) 12% of children in the south were shown to have persistent asthma, and this was somewhat higher in the south than the north
c) Marked airway hyper-responsiveness is a marker of significant asthma and was shown to be 3-fold higher in the south than in the north
d) The health status in eThekwini Municipality has not been updated since the 2006 Health Study

2.6 Socio-economy

The management of activities that produce air pollution requires an understanding of the developmental context. eThekwini Municipality is a region of rapid development. It is home to the busiest port in Africa and serves as the primary gateway for South Africa's imported crude oil and exported petrochemical products. Communities continue to negotiate environmental risks that originated during the apartheid era. It is a challenge to the municipality to safeguard air quality by managing these issues in addition to potential threats to human health that could arise as further developments take place. In order to meet this challenge an understanding of the underlying socio-economy of the municipality is essential to gauge residents' experiences of environmental risk and their vulnerability to air pollution risks, in particular. This section describes demographics, infrastructure and service delivery trends in the province based largely on the findings of Census 2011 (Statistics SA, 2014), the eThekwini 2013-2014 IDP review and the eThekwini Spatial Development Plan.

Census 2011 states that the population of the eThekwini Municipality is 3 442 361 people. The eThekwini population comprises 33% of KZN's total population and 7% of South Africa's total population. The municipality's population has grown at an annual average of 1.13% per annum since 2001 to reach 3.44 million in 2011. Population growth has largely been attributed to rising fertility rates, migration and increased access to retro-viral drugs (eThekwini, 2013). The population is relatively young with 66% of residents below the age of 35 years old and 67% of the population categorised as economically active (15-59 years old). The residents of eThekwini Municipality have diverse ethnic backgrounds, as seen in Table 2-2. Zulu, Afrikaans, English and Xhosa is spoken in the municipality, however Zulu is the predominant language.

Table 2-2: Ethnic composition of eThekwini Municipality's population

Ethnic group	Percentage of population
Black African	51.1
Indian	24.0
White	15.3
Coloured	8.6
Other	0.9

In terms of population distribution, the north (1.15 million people) and the central regions (1.18 million people) are more densely populated when compared to the southern (758 000 people) and outer west regions (338 000 people).

There are 956 713 households in the municipality, with an average household size of 3 - 4 occupants. Approximately 40% of these households are female headed and 79% are formal dwellings, with 54.5% of these owned by the residents. In terms of household services the majority of households in the municipality have access to water, sanitation and electricity (Table 2-3).

Table 2-3: Household services in eThekwini Municipality as a percentage of the total number of households

Household Services	% of Households
Flush toilet connected to sewerage	63.4%
Weekly refuse removal	86.1%
Piped water inside dwelling	60.2%
Electricity for lighting	89.9%

Source: Census 2011 Municipal Fact Sheet, published by Statistics South Africa.

Points for consideration in the AQMP regarding socioeconomics

a) eThekwini Municipality is an area of economic growth, and in turn increasing population
b) Most areas in eThekwini Municipality enjoy the provision of basic service such as refuse removal and access to electricity

3 AIR QUALITY STATUS QUO

Chapter 3 presents the air quality status quo in eThekwini Municipality and examines available data on emissions and ambient air quality using monitoring and dispersion modelling data. The capacity for air quality management is also assessed. It builds on information from the 2007 AQMP review

3.1 Emission sources

An emission inventory of air pollution sources is a fundamentally important component of any air quality management system. It provides key information on the types of sources in an area and important characteristics about the pollutants being emitted. These include the volume of emissions, where and when a pollutant is emitted, etc. In turn, an emission inventory may be used for assessment, planning, reporting and policy formulation. The assessment of existing emission inventories in the municipality allows for the identification of information gaps, priority sources and pollutants.

An emission inventory distinguishes between sources related to the combustion of fossil fuels and those that are not combustion related. They are characterised by the following aspects:

- The types of activities that result in emissions;
- The chemical or physical identity of the pollutants or greenhouse gases;
- The geographic area of concern;
- The time period over which emissions are estimated;
- The methodology used to determine the emissions.

Emissions data serves as the primary input for air dispersion modelling in providing spatially referenced emission rates from sources such as industries. Emission inventories are the starting point in the development of air quality management systems and provide data for:

- Establishing a baseline for future planning;
- Setting emission limits and reduction targets for industries through permitting;
- Tracking environmental performance of industries (and regulators);
- Identifying sources and problem areas;
- Generating public interest in air quality.

Emissions from the following source sectors in eThekwini are discussed:

- Industrial facilities (Listed Activities and Controlled Emitters);
- Motor vehicles;
- The Port of Durban;
- King Shaka International Airport (KSIA);

- Waste management (landfill sites and wastewater treatment works);
- Biomass burning (sugarcane);
- Residential fuel burning;
- Quarries;
- Biogenic emissions.

3.1.1 Listed Activities

Listed Activities are defined in Section 21(1) (a) of the eThekwini Municipality: AQA as activities which result in atmospheric emissions and which the Minister or MEC reasonably believes have or may have a significant detrimental effect on the environment including health, social conditions, economic conditions, ecological conditions or cultural heritage. On 31 March 2010 the Minister published the first list of such activities (DEA, 2010), followed by a revised list on 22 November 2013 (DEA, 2013a). Listed Activities may not be conducted without an Atmospheric Emission License (AEL). They are classed into 10 categories, and 74 sub-categories. Minimum Emission Standards and/or special conditions are set for each sub-category (DEA, 2013a).

The eThekwini Municipality is the Atmospheric Emission License Authority (AELA) in terms of Section 36 (1) of the NEM: AQA (See Section 3.3 on Capacity). To date AELs have been issued to 85 industrial facilities in eThekwini. Submitted applications for AELs on a few facilities are in progress. The number of AELs issued in the different Listed Activity categories is show in Table 3-1. The relative location of these facilities in eThekwini is shown in Figure 3-1.

Table 3-1: Industrial facilities in eThekwini by Listed Activity Category

Category	Definition	Number
1	Combustion Installations	
1.1	Solid fuel combustion installations	3
1.2	Liquid fuel combustion installations	2
1.3	Solid biomass combustion installations	2
1.4	Gas combustion installations	4
2	Petroleum industry, production of gaseous and liquid fuels and petrochemical products from crude oil	
2.1	Combustion installations	2
2.2	Catalytic cracking units	2
2.4	Storage and handling of petroleum products	24
2.5	Industrial fuel recycling	1
4	Metallurgical industry	
4.1	Drying and calcinating	2
4.2	Combustion installations	4
4.4	Secondary aluminium production	2
4.9	Ferro-alloy production	1
4.11	Agglomeration operations	1
4.13	Lead smelting	1
4.17	Precious and base metal production and refining	1
4.22	Hot dip galvanising	3
5	Mineral processing, storage and handling	
5.1	Storage and handling of ore and coal	3
5.4	Cement production (conventional fuels)	1
5.9	Ceramic production	1
5.1	Macadam production	4
6	Organic chemical industry	13
7	Inorganic chemical industry	
7.2	Production of acids	2
7.4	Production, use in production or recovery of metals	1
7.6	Production or use of phosphates or phosphorous salts	1
8	Thermal treatment of hazardous and general waste	
8.1	Thermal treatment of hazardous and general waste	1
8.2	Crematoria and veterinary waste incineration	1
8.4	Drum recycling processes	1
9	Pulp and paper manufacturing plants	
9.4	Chloride dioxide plants	1
TOTAL		85

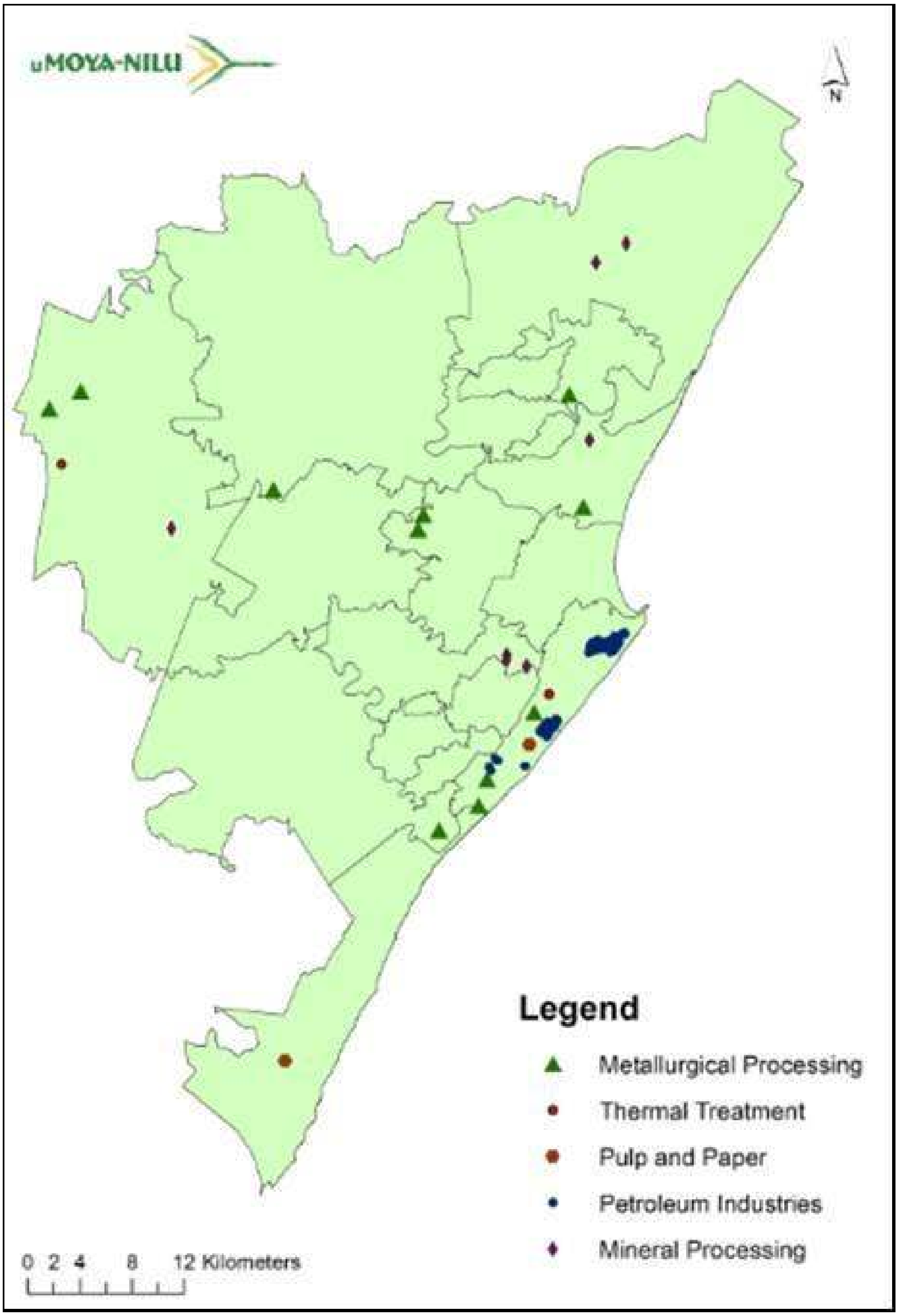


Figure 3-1: Location of Listed Activities in eThekwini

Annual emission rates of pollutants resulting from the different Listed Activity categories in eThekwini in 2012 is shown in Table 3-2. The estimation includes the 85 Listed Activities with issued AELs and is based on the results of emission testing on stacks where these are available, emission modelling for bulk storage and handling, otherwise emission factors and fuel consumption have been used. The emission estimation methodology is described in more detail in Appendix 2.

As might be expected, SO_2 is the pollutant with the highest emission rate with 13 197 tons emitted in 2012 (Table 3-2). The main contributors to the SO_2 emission are crude oil processing (50%), metallurgical processes such as ferro-alloy production and agglomeration (18%), combustion for sugar milling and refining (13%) and combustion for the pulp and paper manufacturing (9%).

The annual emission rate for total VOC in 2012 is estimated to be 5 307 tons per annum, resulting mostly from the storage and handling of petroleum and chemical products. Crude oil processing contributes 45% of the total VOC emissions in eThekwini, with the remaining 55% resulting from relatively small emissions VOC from most industries and from the petrochemical storage facilities. Of the total VOC emission, 68 tons per annum is benzene (Table 3-2). Of this emission, 48% is attributed to crude oil refining and the remaining 52% is attributed to bulk chemical storage facilities.

The total annual NO_X emission from Listed Activities in 2012 is estimated to be 5 090 tons (Table 3-2). The main contributors to the NO_X emission are metallurgical processes such as ferro-alloy production, agglomeration combustion and secondary aluminium processing (33%), combustion for crude oil processing (31%) and combustion for the pulp and paper manufacturing (23%).

The total annual emission of PM_{10} from Listed Activities is estimated to be 2 026 tons. The main contributors to the PM_{10} emission in eThekwini are metallurgical processes such as ferro-alloy production and agglomeration (27%) and combustion for sugar milling and refining (28%). Emission from crude oil processing account for 19% of the total PM_{10} emission and 19% is attributed to combustion for pulp and paper manufacturing.

CO is emitted from combustion process and 2 482 tons were emitted in eThekwini in 2012. The main contributors to the CO emission are metallurgical processes such as ferro-alloy production, agglomeration and secondary aluminium processing (36%), crude oil processing (22%), and 15% is attributed to combustion for the pulp and paper manufacturing.

Table 3-2: Emission rates for Listed Activities in eThekwini in tons per annum

	SO_2	NO_X	CO	PM_{10}	VOC	Benzene
Combustion installations	1 745	331	218	576	3	
Chemicals Manufacture	32	95	22	12	1	
Metallurgical Industry	2 321	1 660	904	566	15	
Mineral processing, storage and handling	882	133	401	109	177	
Petroleum Industries	6 997	1 699	562	389	5 087	68
Pulp and Paper	1 214	1 170	375	384	23	0
Thermal treatment of hazardous and general waste	7	1	0	1	1	0
TOTAL	**13 197**	**5 090**	**2 482**	**2 036**	**5 307**	**68**

Points for consideration in the AQMP regarding Listed Activities

a) Emissions for 2012 have been estimated for 85 industrial facilities, which hold AELs
b) AELs have not been issued to all facilities operating as Listed Activities in eThekwini
c) Emissions were determined from emission testing reports and emission modelling for storage tanks where these were available. Otherwise, emission factors and fuel consumption were used
d) The Listed Activities that contribute the most to the emission of air pollutants are crude oil refining, metallurgical facilities, pulp and paper manufacturing and sugar milling and refining
e) Maintenance of the emission inventory should be ongoing

3.1.2 Controlled Emitters

A Controlled Emitter is any appliance or activity declared by the Minister or MEC in terms of Section 23(1) of the NEM: AQA, that results in atmospheric emissions and which through ambient concentrations, bioaccumulation, deposition or any other way, presents a threat to health or environment, or which the Minister or MEC reasonably believes presents such a threat. On 1 November 2013 the Minister declared small boilers as the first Controlled Emitters (DEA, 2013d). On 29 November 2013, the Minister published her intention to declare asphalt plants as Controlled Emitters (DEA, 2013d).

The regulation of Controlled Emitters in eThekwini, i.e., boilers greater than 10 MW, but less than 50 MW, is through the municipal by-law. The law provides for, amongst others, the control of black smoke from boilers, measured emissions and compliance with emission standards for boilers using different fuels, and for reporting of emissions. eThekwini Municipality has established a database of Controlled Emitters. There are 13 in the various sub-districts operating 33 boilers with a heat output between 10 and 46 MW (Table 3-3). They use coal, heavy furnace oil (HFO), cooking liquor, low sulphur gas and electricity.

Table 3-3: Summary of Controlled Emitters in eThekwini Municipality

Sub-district	Number of facilities	Number of Controlled Emitters	Heat input (MW)	Fuel	Area
South 1	1	5	26 to 46	Coal, HFO, Cooking Liquor	Umkomaas
South 2	2	4	18 to 28	Gas, Coal	Umbogintwini
South 3	6	17	14 to 42	Coal, HFO, Gas, Electricity	Jacobs Wentworth Prospection Island View Congella Maydon Wharf
South 7	2	3	18 to 20	Oil, Gas	Merebank Mobeni
West 3	1	1	11.5	Coal	Pinetown
North 1	1	3	21	Gas	Sea Cow Lake
Total	13	33			

Fuel consumption and emission factors are typically used to estimate emissions from boilers (see Appendix 2). Unfortunately fuel consumption is not included in the Controlled Emitters database. However, for the purposes of the baseline assessment, emissions for the five largest Controlled Emitters were estimated using fuel consumption data. For these facilities a total of 43 092 tons of gas, 27 960 tons of coal and 39 402 tons of HFO are combusted annually. Gas is a clean fuel and results in some NO_X and CO emissions. Coal and HFO are dirty fuels that contain sulphur, and emit SO_2 and particulates when combusted. The estimated annual emission of pollutants resulting from Controlled Emitters are shown in Table 3-4.

Table 3-4: Emission rates for Controlled Emitters in eThekwini

SO_2	NO_X	CO	PM_{10}	VOC
5 845	895	425	1 055	2.4

Points for consideration in the AQMP regarding Controlled Emitters

a) The database includes 13 facilities that operate 33 Controlled Emitters
b) Fuel consumption data is not included in the database, inhibiting the estimation of emissions
c) Emissions for pollutants have been estimated for the 5 largest Controlled Emitters
d) Emission from Controlled Emitters are relatively small, but have the potential to impact locally due to the relatively low release height
e) The Controlled Emitter data base must be updated to include fuel consumption and physical stack data
f) Emissions should be estimated for all facilities operating Controlled Emitters

3.1.3 Fuel Burning Devices

Fuel Burning Devices refer to boilers with a heat capacity of less than 10 MW, i.e. below the minimum threshold for Controlled Emitters. Fuel Burning Devices are regulated in terms of the municipal by-law. eThekwini Municipality has developed a register for Fuel Burning Devices. There are 98 facilities in the various sub-districts that collectively operate 135 Fuel Burning Devices (Table 3-5). The fuels used include coal, HFO, LFO, diesel, kerosene, paraffin, wood and gas. Some facilities use electricity. Fuel Burning Devices are regulated in terms of the municipal by-law.

Fuel consumption and emission factors are typically used to estimate the emissions from small boilers (see Appendix 2). Unfortunately fuel consumption is not included in the database for Fuel Burning Devices. For the purposes of this baseline assessment emissions have not been estimated.

Table 3-5: Emissions from Fuel Burning Devices in eThekwini Municipality

Sub-district	Number of facilities	Number of Fuel Burning Devices	Heat input (MW)	Fuel	Area
South 2	1	1	< 1	LFO	Umbogintwini
South 3	11	17	10 to < 1	Coal, HFO, LFO, Gas, Diesel	Jacobs Wentworth Prospecton
South 4	2	5	5.8 to 2.3	Low sulphur oil	Cato Manor South Beach
South 5 & 6	3	7	< 10 to 5.6	Coal, oil	South Coast Rd Umlazi
South 7	4	5	9 to 1.7	Coal, HFO, Gas	Mobeni
South 8	12	3	7.8 to 1.8	Coal, HFO	Rossburgh
West 2	29	42	6.7 to < 1	Coal, HFO, paraffin, kerosene, diesel	Cato Ridge Hammersdale
West 3	5	5	< 10 to < 1	Coal, HFO, paraffin	Pinetown Marian Industrial
West 4	7	15	< 10 to < 1	Coal, HFO, paraffin, wood	New Germany Queensburgh Westville Claremont
North 1	2	3	2 to < 1	Paraffin	Mt Edgecombe Redhill
North 5	10	14	6.3 to < 1	Coal, HFO, paraffin, kerosene, diesel	Phoenix Industrial KwaMashu
North 6	12	18	10 to < 1	Coal, HFO, paraffin, kerosene, diesel	Tongaat Riverview Verulam
Total	98	135			

Points for consideration in the AQMP regarding Fuel Burning Devices

a) The database includes 98 facilities that operate 124 Fuel Burning Devices
b) Fuel consumption data is not included in the database, inhibiting the estimation of emissions
c) Emission from Fuel Burning Devices are expected to be relatively small, but have the potential to impact locally due to the low release height
d) The Fuel Burning Devices database must be updated to include fuel consumption data
e) Emissions should be estimated for all facilities operating Fuel Burning Devices

3.1.4 Motor vehicles

Vehicular pollutants occur as by-products of the combustion process emitted via the exhaust system, from the evaporation of fuel from fuel tanks and from brakes and tyre wear. Various types of pollutants are produced in the combustion process. A range of VOCs are produced because the fuel is not completely burnt (oxidised) during combustion. Nitrous oxide (NO) results from the oxidation of nitrogen at high temperatures and pressures in the combustion chamber. CO is generated when carbon in fuel is partially oxidised rather than fully oxidised to CO_2. Sulphur dioxide is derived from the sulphur in fuels. Particulate matter is produced from the incomplete combustion of fuels, additives in fuels and lubricants, and worn material that accumulates in the engine lubricant. These additives and worn materials also contain trace amounts of various metals and their compounds that may be released as exhaust emissions. Particulates result from brake and tyre wear. Another type of emission that arises from the use of motor vehicles is dust emissions from roads. As the vehicle's tyres turn, particles on the road are crushed and re-suspended into the atmosphere.

The National Motor Vehicle Emissions Strategy for South Africa estimated motor vehicle emissions for the country, based on fuel sales data for 2009, for gasoline, low sulphur and ultra-low sulphur diesel, from the Department of Energy (DoE) (DEA, 2013_b). The emission of NO_X, SO_2, CO, PM_{10}, benzene and CO were estimated for four vehicle classes, i.e. motorcycles, passenger, light duty vehicles (LDVs), and busses and heavy duty vehicles (HDVs). These estimates were updated using 2014 registered vehicle numbers from the electronic national administration traffic information system (eNATIS) (supplied by Preeta Hirjee, eThekwini Transport Authority).

As might be expected CO and NO_X are emitted in the greatest quantity by motor vehicles, with 147 372 and 68 292 tons emitted per annum, respectively (Table 3-6). PM_{10} and SO_2 emissions are relatively low from motor vehicles. Motor vehicles emit 38 tons of benzene per annum. The highest emissions of all pollutants occur in Durban, accounting for 60% of the total NO_X emission, followed by Pinetown (Table 3-6).

Table 3-6: Vehicle emission rates (ton/year) in 2014 based on registered vehicle number

Region	NO_X	SO_2	CO	PM_{10}	NMVOC	Benzene
Amanzimtoti	4 752	108	9 460	159	1 261	1
Camperdown	1 306	29	2 623	43	514	2
Durban	41 501	976	94 328	1 556	16 828	24
Ndwedwe	43	1	87	1	12	0
Pinetown	11 199	254	22 373	370	3 316	6
Umbumbulu	85	2	165	3	23	0
Umhlanga	4 194	96	8 276	138	1 241	2
Umlazi	1 490	34	2 850	48	412	1
Verulam	3 722	85	7 165	121	1 034	2
Total	**68 292**	**1 585**	**147 327**	**2 439**	**24 642**	**38**

Emissions per vehicle category in eThekwini Municipality illustrate the significant contribution from heavy duty vehicles (HDVs) and busses to the total emissions of NO_X, SO_2 and PM_{10} from vehicles (Table 3-7). HDVs and busses contribute 81% of the NO_X emission, 95% of the SO_2 emission and 74% of the PM_{10} emission from vehicles as a result of diesel combustion. Together passenger cars and motorcycles contribute 81% of the total NMVOC emission in eThekwini Municipality, primarily due to the combustion of petrol. Passenger cars contribute 74% of the total benzene emission.

Table 3-7: Vehicle emission rates (ton/year) in 2014 per vehicle category

	NOx	SO_2	CO	PM_{10}	NMVOC	Benzene
Motorcycles	639	13	32 944	231	7 794	1
Passenger cars	9 847	67	87 030	314	12 142	28
LDVs	2 379	7	15 369	79	2 309	9
HDVs & Buses	55 427	1,498	11 984	1 815	2 397	0
Total	**68 292**	**1 585**	**147 327**	**2 439**	**24 642**	**38**

Points for consideration in the AQMP regarding Motor Vehicles

a) Motor vehicles are significant sources of CO and NO_X in eThekwini
b) They are also a relatively large source of PM_{10}
c) Emissions from motor vehicles are concentrated in Durban and Pinetown, with lesser emissions elsewhere
d) HDVs and busses contribute 81% of the NO_X emission, 95% of the SO_2 emission and 74% of the PM_{10} emission from vehicles as a result of diesel combustion
e) Passenger cars contribute 74% of the total benzene emission primarily due to the combustion of petrol
f) Motor vehicle emissions are estimated using a top-down approach for 9 areas in eThekwini, providing a coarse estimation

3.1.5 The Port of Durban

The Port of Durban, also known as Durban Harbour, is the largest and busiest shipping terminal on the African continent. The Durban Container Terminal is the largest in the southern hemisphere. 44% of South Africa's break-bulk cargo and 61% of all containerised cargo flows through the Port of Durban with an average of 83 000 containers handled monthly. The Port of Durban employs 6 000 people, with approximately 30 000 people directly dependent on the port and its activities.

The distance around Durban Harbour is approximately 21 km and includes a total land and water area of 1 854 ha. The port has 57 berths and over 4 000 commercial vessels call at the port each year. There are 302 km of railway tracks at the port. Durban Harbour is immediately adjacent to the CDB to the north, with commercial and light industry to the west and southwest, and residential areas to the south, bordering on the ports chemical cluster.

Ship generated emissions are the main source of pollutants resulting from harbours. When docked ships have to keep systems such as air conditioning, lighting and communications running they operate their auxiliary engines to do so, producing emissions. Other sources of emissions from ports include commercial and recreational boats, motor vehicles, locomotives and cargo handling equipment, fuel storage and handling facilities, boilers and stockpiles. The pollutants that result are mainly from combustion, i.e. SO_2, NO_X and particulates, as well as VOCs.

An emission inventory was compiled for the Port of Durban as a component of their Air Quality Management System, based on 2008 data (uMoya-NILU, 2010). It included 11 different air pollution source types and emissions of criteria and toxic air pollutants. The estimation of emissions from the various sources was based on a range of methods including emission factors and emissions models.

The estimated annual emission rates of the criteria pollutants emitted from all sources at the Port of Durban were 5 490 ton of SO_2, 7 588 tons of NO_X, 1 898 tons of CO and 827 tons of PM. Emissions from ships moving in the port channel and at berth constitute 86% of total criteria pollutant emissions, followed by motor vehicles at 8.8%, boilers at 2.4% and locomotives at 1.4%. The annual emission per sources category is shown in Table 3-8. The high emissions from ships is due to the use of dirty fuels such marine diesel oil (MDO) and bunker fuel oil (BFO) in the main and auxiliary engines of ships, respectively. With respect to motor vehicles, it is noteworthy that 92% of the SO_2, 78% of the NO_X and 92% of the PM is attributed to truck emissions.

The estimated emission rates of toxic air pollutants are relatively low (Table 3-9) due to correct tank selection and the use of emission reduction measures. It noteworthy that 90% of the benzene emission result from the storage and handling of petrochemical products. The estimated emissions of toxic pollutants are likely to be underestimated as data from a number of tenants was not available for inclusion in the 2008 inventory (uMoya-NILU, 2010).

Table 3-8: Emissions per source type at the Port of Durban in tons per annum

Source	SO_2	NO_x	CO	PM	PM_{10}	Total	% of Total
Ships	5 187	6 520	1 160	733	-	13 600	85.9
Commercial boats	7.6	115	46.8	12.6	-	182	1.1
Motor vehicles	24.7	746	589	33.1	-	1393	8.8
Locomotives	2.5	177	31.3		4.8	216	1.4
Boilers	268	30.1	70.5		15.7	384	2.4
Storage piles	-	-	-	4.1	-	4.1	0.0
Grain elevators	-	-	-	44.4	12.4	56.8	0.4
Total	**5 490**	**7 588**	**1 898**	**827**	**32.9**	**15 836**	**100**

Table 3-9: Emissions of VOCs per source type at the Port of Durban in tons per annum

Source	VOC	Benzene	Toluene	Ethyl benzene	Xylene	Acrylo-nitrile	Butyl Acrylate	Ethyl Acrylate	Total
Ships	425								425
Commercial boats	21.6								21.6
Motor vehicles		1.8							1.8
Locomotives	17.8	0.31							18.15
Storage tanks	1822	18.8	52.0	9.5	47.3	0.19	0.60	1.05	1 952
Total	**2287**	**20.9**	**52.0**	**9.5**	**47.3**	**0.19**	**0.60**	**1.05**	**2 418**

Points for consideration in the AQMP regarding the Port of Durban

a) The Port of Durban is a major source of SO_2 and NO_X in eThekwini
b) The emission inventory for the Port of Durban is relatively outdated, i.e. based on 2009 data
c) Ship emissions are based on general engine sizes rather than actual data
d) Information from a number of key tenants were omitted in the 2009 inventory, but have been accounted for in the Listed Activity inventory

3.1.6 Airports

There are three active airports in eThekwini, the King Shaka International Airport, the Virginia Airport and Airforce Base Durban. KSIA is the major airport in KZN and forms part of the Dube Tradeport. It is located approximately 30 km north of the Durban CBD. KSIA recorded 4.47 million passengers in 2013–2014, with nearly 94% being domestic passengers. In the same period 49 559 aircraft traffic movements were recorded by Airports Company South Africa (ACSA) (ACSA, 2014). Based on these statistics KSIA is the third busiest airport in South Africa, after OR Tambo International Airport in Johannesburg and Cape Town International Airport.

Virginia Airport is home to a number of fixed wing and rotor wing flight schools and charter companies. It is located approximately 10 km north of the city. Airforce Base Durban is located approximately 13 km southwest of the Durban CBD at the northern end of the old Durban Airport. It is home to 15 Squadron which currently operates BK 117 helicopters. Their primary role is maritime and landward search and rescue.

Emissions of air pollutants from airports result from a range of activities including aircraft operations, ground support equipment, vehicular traffic at the airport's roadways, parking lot, electrical generators and fuel storage facilities. The main pollutants include CO, NO_X, SO_2, PM and hydrocarbons such as benzene, toluene, ethylbenzene and xylene. It is therefore important that emissions from major airports are characterised when assessing air quality in a region. Emissions from KSIA are therefore included in the baseline emission inventory for eThekwini Municipality.

Emissions for KSIA were estimated by WSP in 2012 (KSIA, 2012). Emissions from aircraft considered large aircraft only, using monthly aircraft movement data, engine data from the International Civil Aviation Organisation (ICAO) and specifications for Jet 1A fuel. The total estimate emission of 528.2 tons per annum for CO and 453.6 tons per annum for NO_x are the highest, followed by hydrocarbons, SO_2 and PM (Table 3-9). The estimation of emissions from vehicles at KSIA considered ground support vehicles, passenger and staff vehicles and delivery vehicles. CO and PM are the most significant pollutants from vehicles, accounting for 171.4 tons per annum and 57.9 tons per annum respectively (Table 3-10). Diesel and petrol are stored and handled at the forward fuel storage depot and at the car hire facilities. Evaporative emissions of hydrocarbons were estimated as 10.9 tons per annum (Table 3-10). Emissions were also estimated from the diesel generations. These all relatively low, but again NO_X is the most significant at 3.5 tons per annum (Table 3-10). Relatively low emissions rates of ammonia (NH_3) and hydrogen sulphide (H_2S) were calculated from the KSIA wastewater treatment works (WWTW), resulting from the digesters (KSIA, 2012).

No emission information is available for Virginia Airport. It has not been included in the baseline assessment.

Table 3-10: Estimated emission in tons per annum from the different sources at KSIA (from WSP, 2012)

	HC	CO	NO_X	SO_2	PM	NH_3	H_2S
Aircraft	78.1	528.2	453.6	59.4	20.2	N/A	N/A
Vehicles	22.8	171.4	11.5	0.005	57.9	N/A	N/A
Fuel Storage	10.9	N/A	N/A	N/A	N/A	N/A	N/A
Generators	0.57	2	3.5	0.03	0.16	N/A	N/A
WWTW	N/A	N/A	N/A	N/A	N/A	27.3	9.1
Total	**112.4**	**701.6**	**468.6**	**59.4**	**78.3**	**27.3**	**9.1**

Points for consideration in the AQMP regarding airports

a) KSIA is not a major source of emission in eThekwini
b) The emission estimates for KSIA uses limited data on aircraft type, considering only two commercial jet aircraft types
c) Emissions information for Virginia Airport and Airforce Base Durban have not been included in the baseline assessment

3.1.7 Residential fuel burning

Electricity usage in eThekwini has increased, but many households are still reliant on paraffin, candles, wood and other sources of energy for domestic needs. The choice of fuel for household needs has an impact on both ambient and indoor air quality. Electricity, paraffin, gas and candles are considered clean fuels with respect to air pollution. However, wood and coal burning are associated with human health impacts in indoor and ambient environments. Smoke resulting from incomplete combustion of wood contains many harmful chemical substances, such as NO_2 and CO, hazardous air pollutants (HAPs), fine particulate matter and volatile organic compounds (VOCs).

The estimation of emissions from domestic burning in eThekwini is based on energy use data contained in the 2011 census (StatsSA, 2014). This data delineates the number of households utilising fuels for domestic purposes (i.e. cooking, lighting, and space heating). Electricity is the main energy source in the municipality, but paraffin, wood and coal is used in cooking and space heating (Figure 3-2). Candles are used to a limited extent for lighting and the use of paraffin is high, especially for cooking (Figure 3-3).

The estimation of domestic fuel burning emissions is challenging given that the amount of fuel consumed per household and the fuel type is uncertain. The quantity of fuels consumed varies with geographical areas due to climate (more fuels are consumed in colder areas) and the extent of development (more fuels are consumed in rural areas). The total annual fuel consumption for eThekwini is based on household-level fuel consumption for wood, coal, paraffin and LPG~~s~~ shown in Table 3-11. Emission factors for the criteria pollutants from domestic burning are from the FRIDGE report (FRIDGE, 2006). The emission estimation methodology for domestic fuel burning is included in Appendix 2.

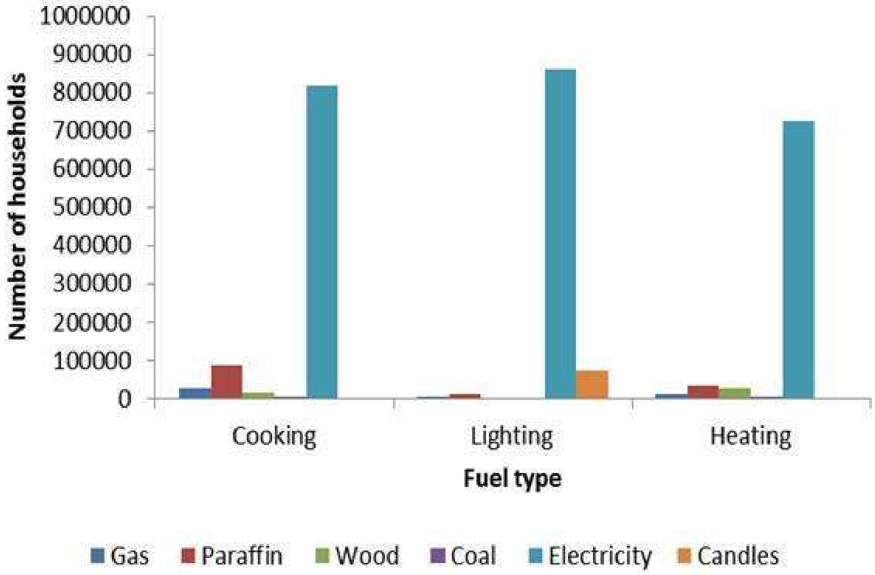


Figure 3-2: Fuel use profile for the eThekwini Municipality (from StatSA, 2014)

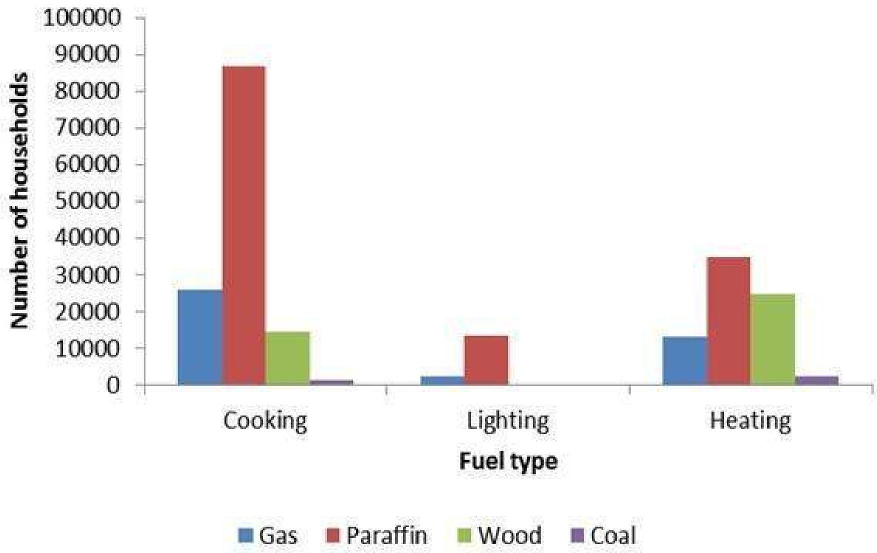


Figure 3-3: Fuel use profile for the eThekwini Municipality excluding electricity (from StatsSA, 2014)

Table 3-11: Residential fuel consumption in eThekwini in tons per annum

LPG	COAL	PARAFFIN	WOOD
13.3	86.0	2373.6	2226.0

The highest emissions from residential burning in eThekwini is 437.3 tons of CO annually, largely attributed to the burning of wood for cooking and space heating (Table 3.12). PM_{10} from wood burning is relatively high at 56.5 tons per annum. The annual NO_x emission of 29.2 tons per annum is a consequence of paraffin use for cooking. The emission of SO_2 from residential fuel burning is very low, estimated at 14 tons per annum.

Table 3-12: Emission distribution across fuel types in tons per annum

Fuel Type	Pollutant			
	SO_2	**NO_x**	**CO**	**PM_{10}**
Gas	0.0	0.1	0.02	0.0
Paraffin	9.3	23.5	6.5	1.4
Wood	0.7	5.0	412.8	54.7
Coal	4.0	0.6	17.9	0.4
Total	**14.0**	**29.2**	**437.3**	**56.5**

The distribution of emissions from residential fuel burning in the 103 municipal wards are included in Appendix 3. The spatial distribution of emissions is shown for SO_2, NO_X, PM_{10} and CO in Figure 3-4 to Figure 3-7 in tons per annum. While the emissions are relatively low, noteworthy is relatively high emissions of SO_2 in wards where coal is the preferred fuel, and the relatively high emissions of PM_{10} in the more rural areas of the outer west and the south where wood is the preferred fuel (see Appendix 3).

Points for consideration in the AQMP regarding residential fuel burning

a) Emissions from residential fuel burning are relatively small in eThekwini
b) The highest emission from residential fuel burning is CO, estimated at 473 tons per annum resulting mostly from wood burning
c) Emission of PM_{10} and NO_2 from residential fuel burning are comparatively small at 56.5 tons and 29.2 tons respectively, resulting from wood and paraffin burning

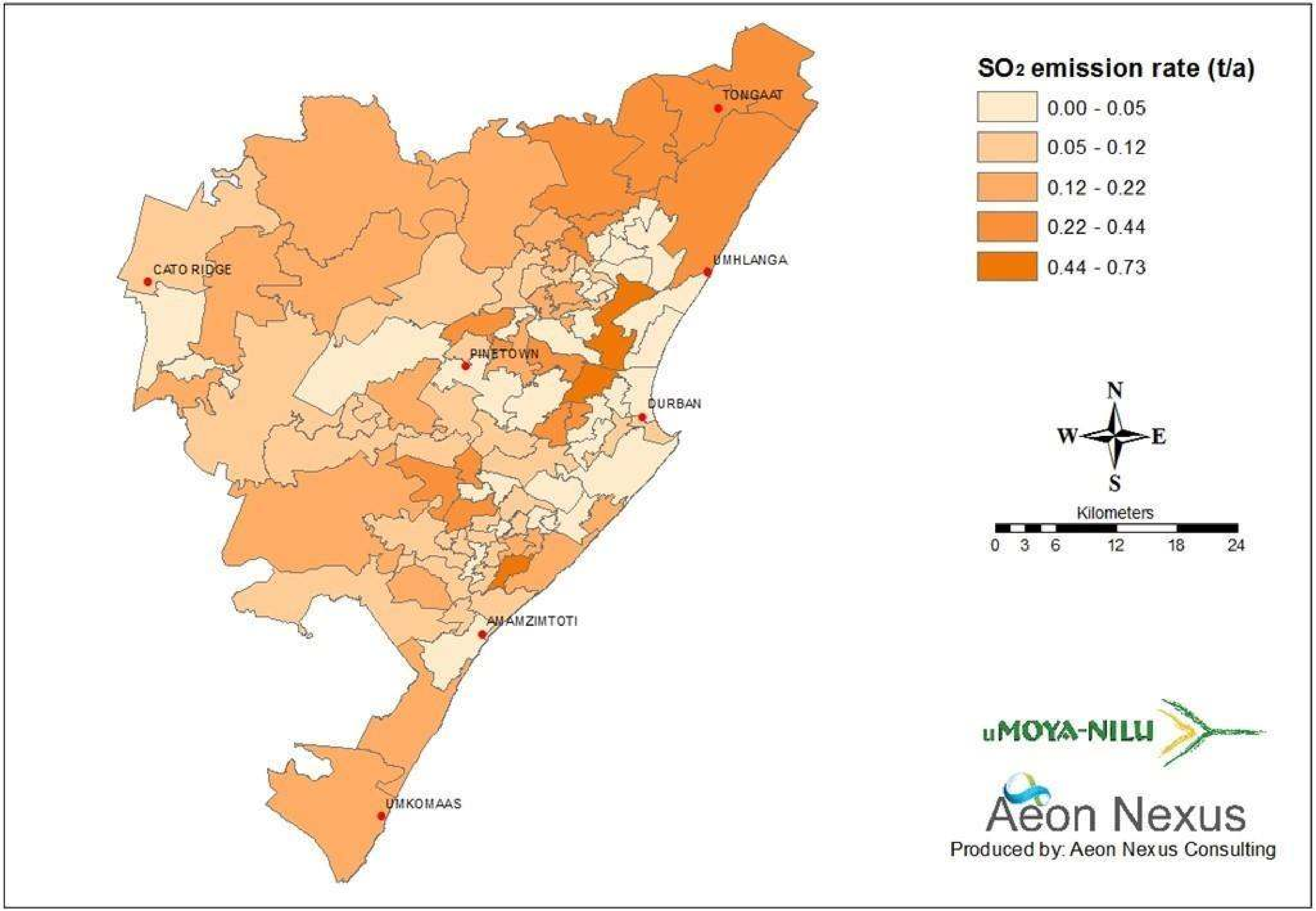


Figure 3-4: Emissions of SO_2 from residential fuel burning in the municipal wards in eThekwini in tons per annum

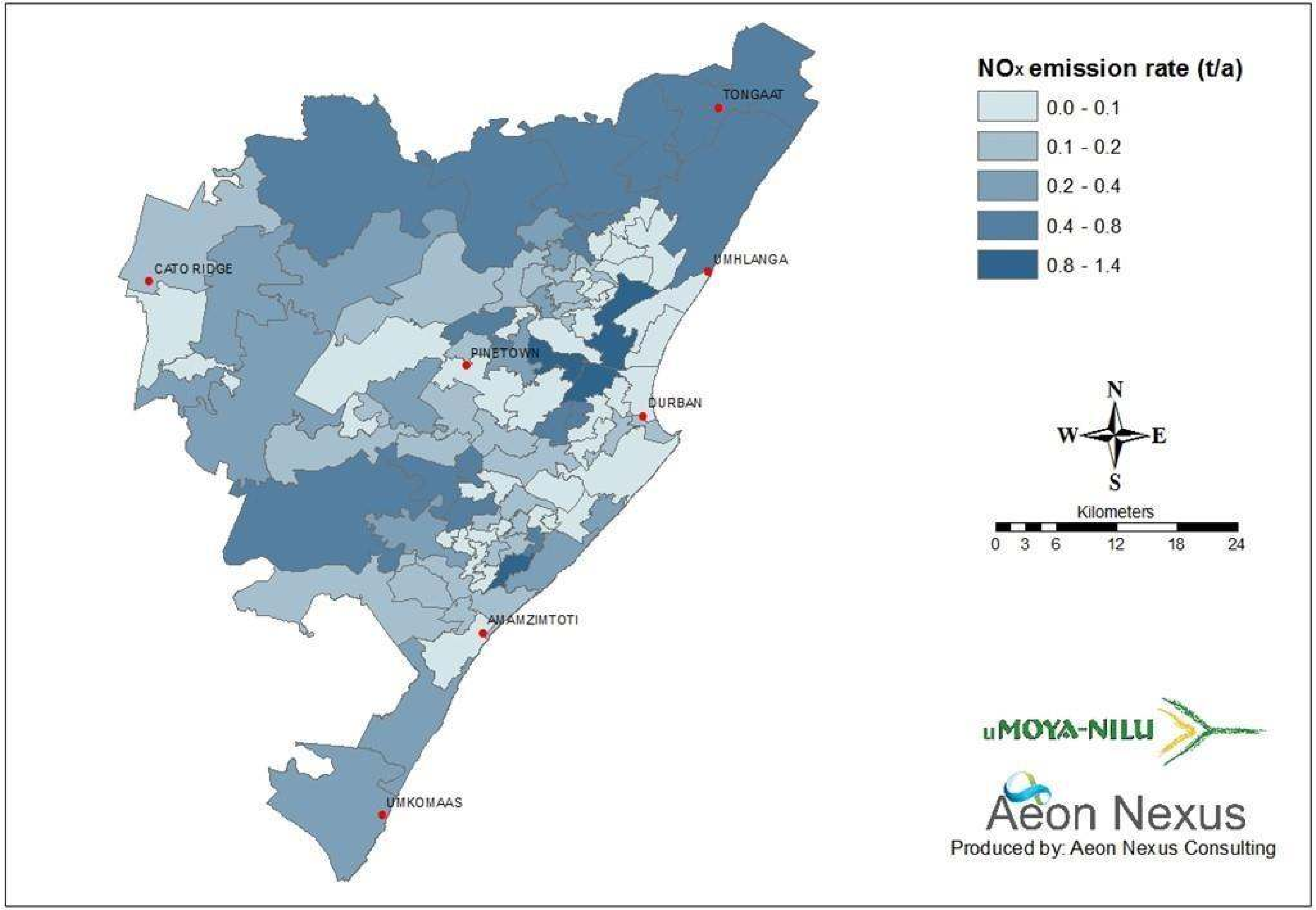


Figure 3-5: Emissions of NO_X from residential fuel burning in the municipal wards in eThekwini in tons per annum

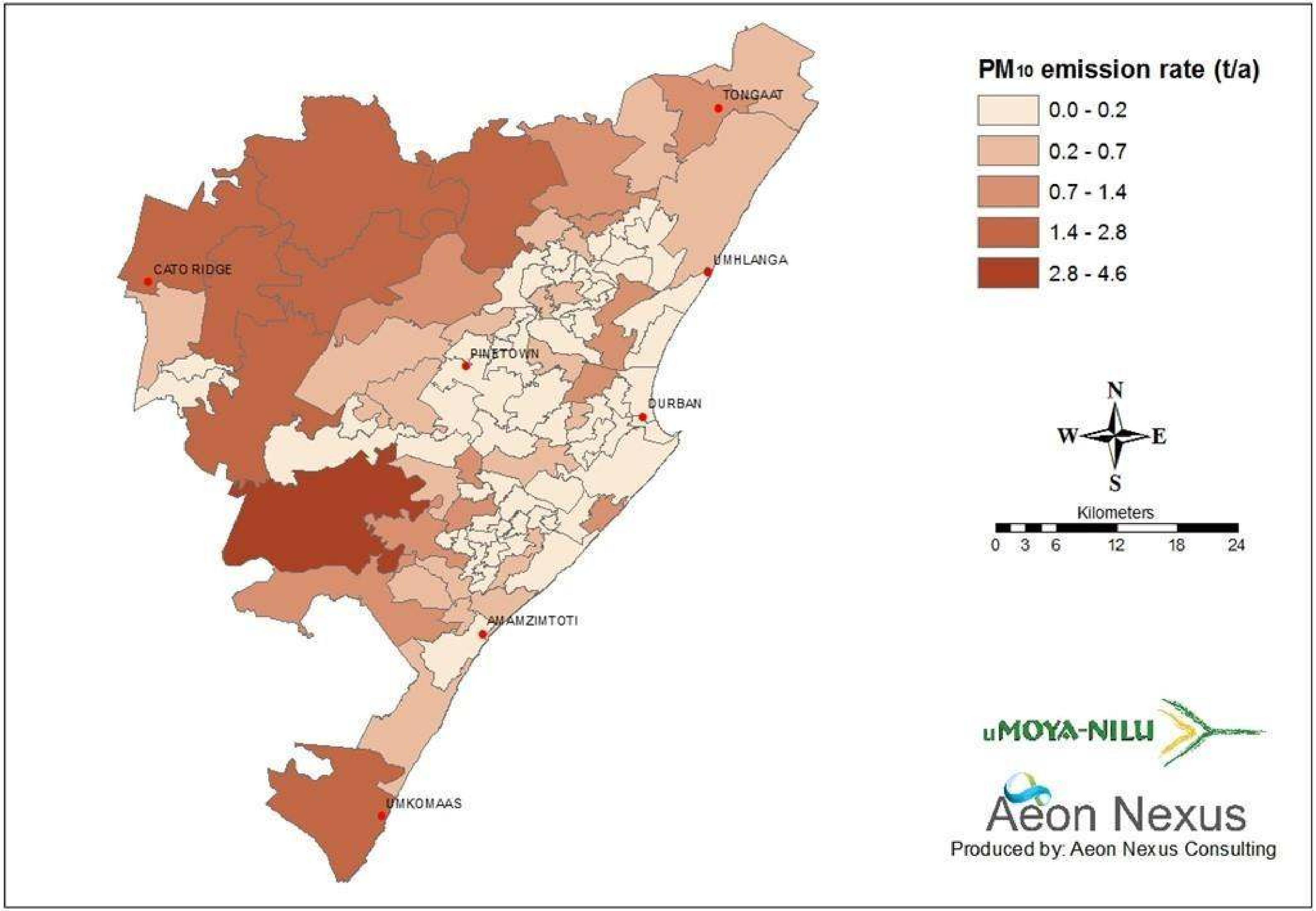


Figure 3-6: Emissions of PM_{10} from residential fuel burning in the municipal wards in eThekwini in tons per annum

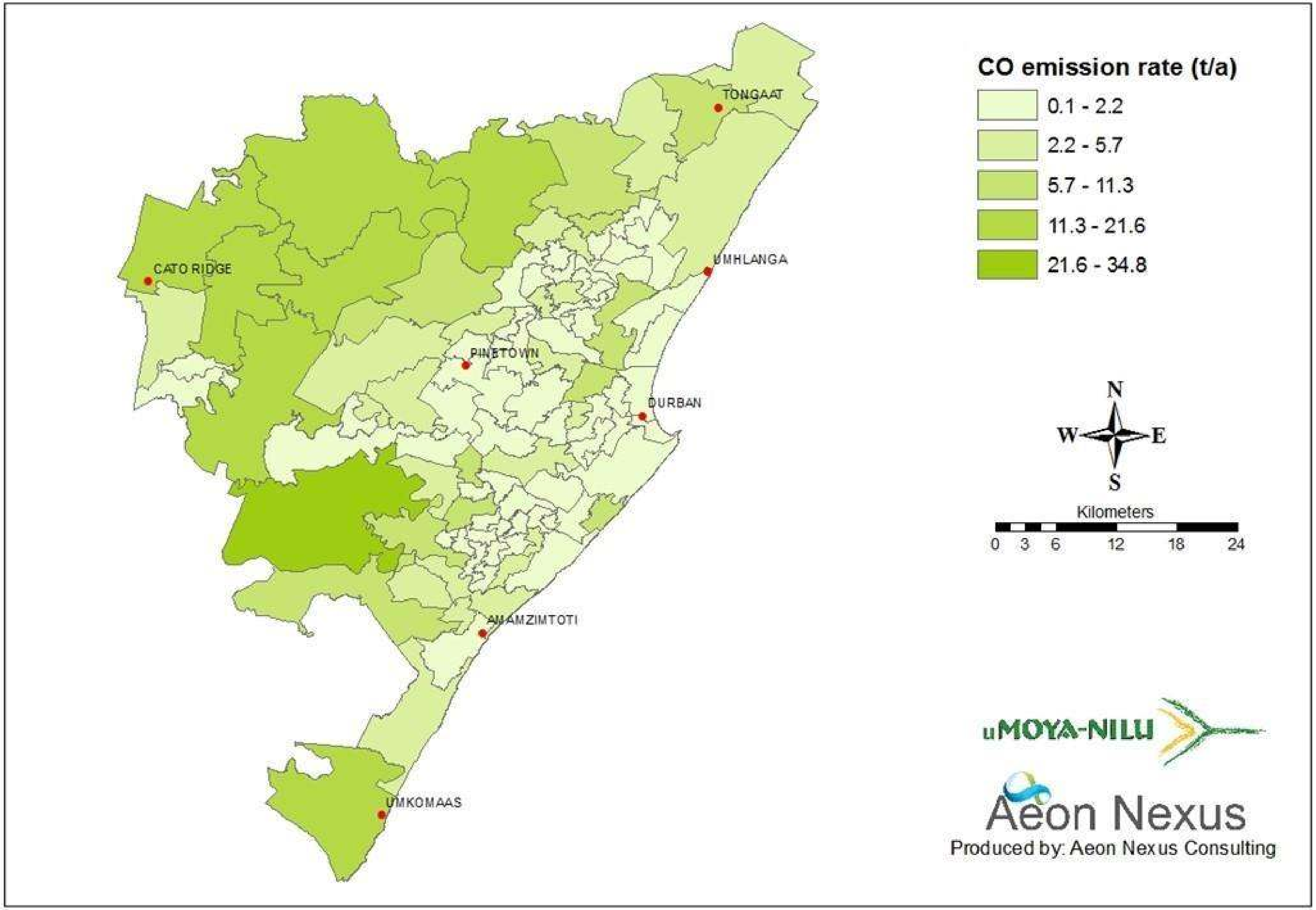


Figure 3-7: Emissions of CO from residential fuel burning in the municipal wards in eThekwini in tons per annum

3.1.8 Quarries

Quarry operations are inherently dusty processes with all aspects of the operation having the potential to generate dust. The potential dust emissions are associated with the following:

- Mechanical handling operations, including crushing and grading processes where in general, the more powerful the machinery and the greater the volume of material handled, the greater the potential for dust emission;
- Haulage, where the weight of vehicles, their speed of passage and number of wheels in contact with the ground, and the nature and condition of road surfaces or haul routes all affect the amount of dust emitted;
- Blasting, crushing and screening;
- Wind entrainment from paved and unpaved areas, from stockpiles etc.; and
- The consistency and nature of dust control measures that are employed on the site.

The subsequent dispersion of dust is a function of the particle size, shape and density, as well as wind speed and other climatic effects. Smaller dust particles remain airborne for longer, dispersing widely and depositing more slowly compared with coarse particles. Typically concentrations of dust decrease rapidly with increasing distance from the source.

There are five active quarries in the eThekwini Municipality (Figure 3-8). Each of the quarries is licensed by the Department of Mineral Resources. Dust control and fallout dust monitoring is a requirement of the respective license conditions. In addition, each quarry is required to maintain a complaints register and to resolve complaints. Other than the Stockville Quarry, residential areas are located relatively close to the respective quarries. Complaints generally refer to the nuisance effects of dust fallout.

Neither of the quarries have estimated their dust emissions. For small mines such as these, it is expected that the emission of particulates from the quarries will be less than 34 tons per annum (DEA, 2014), and considerably less for the Stockville Quarry which is very small and where there is no drilling and blasting. The total emission of particulates from quarrying in eThekwini is therefore likely to be less than 120 tons per annum.

Points for consideration in the AQMP regarding residential fuel burning

a) Quarries are regulated by the Department of Mineral Resources
b) Emissions of particulates from quarries have not been quantified
c) The quarries are relatively small and emissions of particulates are likely to be relatively low
d) Impacts of emissions from quarries are localised and of a nuisance nature

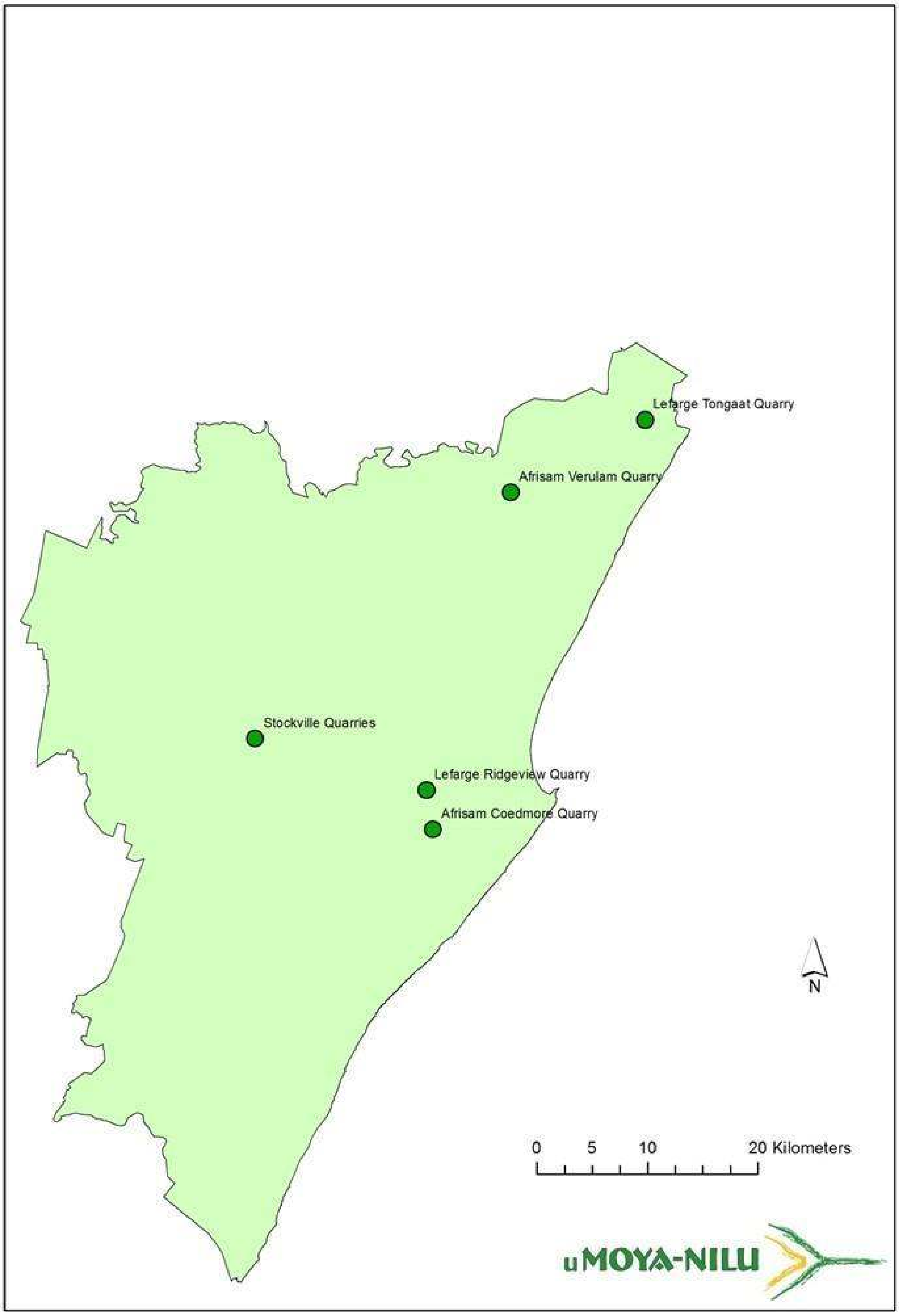


Figure 3-8: Relative location of the quarries in eThekwini

3.1.9 Waste management

Landfill

The nature of airborne emissions from a landfill site is dependent on site specific factors such as the type and quantity of waste and the age of the waste (Richardson *et al*., 2010). The impact on air quality that ensues is dependent on local meteorological conditions and proximity to the site. Wind speed and direction is of particular importance as it affects odour and pollutant dispersion characteristics (Richardson *et al*., 2010). Landfill gas consists mostly of CH_4, CO_2 and particulates, which are emitted during waste handling, vehicle movement and wind entrained dust.

The Cleansing and Solid Waste Unit of eThekwini Municipality are tasked with the waste management service for 3.1 million residential, commercial and industrial customers. Industrial and hazardous waste sites are operated by private corporations. Where no landfills and waste management services exist household and general waste is burnt or taken to illegal dumpsites where it is burned together with harmful and hazardous materials. The pollutants released will depend on the type of waste being burnt and may include particulates, CO, NO_X and toxic pollutants, if waste including plastics and other hazardous material is burnt.

There are six landfill sites for general waste in the municipality (Table 3-13). There are two hazardous waste sites. Their relative locations are shown in Figure 3-9. The La Mercy, Inanda and Ntuzama landfills are now closed and have been rehabilitated, monitoring has continued during the rehabilitation process. Odour, dust and landfill gas are audited on a regular basis at all the municipal landfill sites. These parameters are explored in further detail below and audit reports from January 2015 are discussed (Lombard and Associates, 2015a-f).

Table 3-13: Landfill sites in eThekwini (eThekwini, 2004)

Hazardous Waste	General Waste
Shongweni (Hh)	La Mercy
Bulbul Drive (Hh)	Bisasar Road
	Marianhill

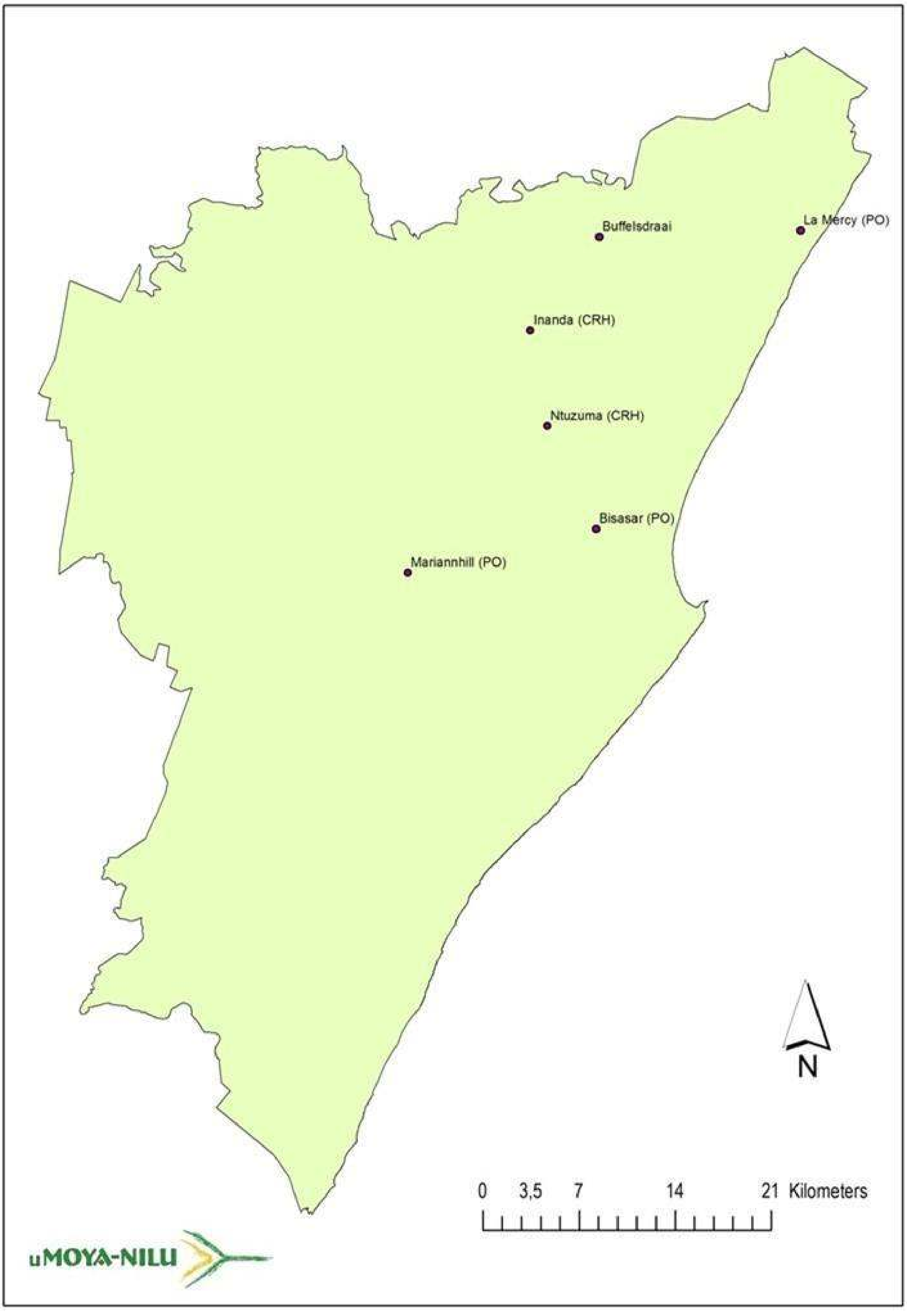


Figure 3-9: Relative location of the landfill sites in eThekwini

Landfill Gas

Decomposition of organic material is the largest source of gas in landfills (Durmusoglu *et al*., 2010). Landfill gas comprises several gases such as methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H), oxygen (O_2), nitrogen (N), and hydrogen sulphide (H_2S). CH_4 and CO are the principal gases. Trace amounts of other organic compounds are also found in landfill gas, of which VOC's are thought to comprise 40% (Durmusoglu *et al*., 2010). BTEX are common in landfill gas. There are gas to electricity projects running at Marianhill and the Bisasar Road Site. Landfill gas monitoring is regularly undertaken at municipal landfill sites. Allowed concentrations of CH_4 are not to exceed 1% and CO_2 to not exceed 0.5%. However, levels of 2-4% CO_2 are common in well vegetated soils. In January 2015, permit limits were exceeded at 9 sampling points at the Bisasar road site. Exceedances were detected at the Bufflesrdraai site at 3 points for CO_2, however this could be attributed to the dense vegetation surrounding the site. One exceedance of CO_2 was recorded at the Marianhill Site in the same month which was attributed to dense vegetation around the site. Gas monitoring at the now closed Inanda landfill site is not possible because of blocked boreholes. Permits for landfill gas at the now closed La Mercy and Ntuzuma landfill sites were not exceeded. However, slightly elevated levels of CO_2 were measured at the latter and attributed to dense vegetation surrounding the site and well ventilated soils.

Odour

Many of the complaints around the landfill sites relate to the persistence of odour, particularly the Bisasar road site. The occurrence of H_2S in landfill gas is usually attributed to substantial quantities of sulphate bearing waste material and results in perceptible odour issues. At the Bisasar road site, this is managed through the use of perfume rods. There are no complaints of odour at the rehabilitated sites.

Fugitive dust emissions

Fugitive dust emissions are also a source of complaints at some of the landfill sites. Landfilling activities have the potential to produce both fine and coarse particulates (Stretch *et al*., 2001). Particulate matter composition is dependent on the nature of activities undertaken on-site and the types of waste being handled. There are various activities that contribute to fugitive dust emission, these include but are not limited to the transportation of waste on and off site; the handling, storage and processing of waste and if a plant is used to burn landfill gas, including gas flare or engines (Mine *et al*., 2013). Dust is also generated through erosion of the surface of the landfill. The movement of airborne particulate matter from landfill sites is facilitated through a number of mechanisms (Mine *et* *al*., 2013). The quantity of dust transported is dependent on wind speed, the surface gradient and particle size. Dispersion of dust is dependent on particle size and wind; smaller particles have a longer residence time although stronger winds will keep larger particles airborne for longer periods (Okuda *et al*., 2008). Particulates from landfills may comprise metals like arsenic, cadmium, chromium, cobalt, copper, lead and manganese (Al-Ansari, 2013). Fugitive dust emissions from landfill sites are supressed with water to some degree.

Wastewater treatment works (WWTW)

The nature of emissions from wastewater treatment works (WWTW) is dependent on the composition of effluent streams. Air pollutants associated with WWTW include hydrogen sulphide (H_2S), mercaptans and ammonia. Volatile organic compounds (VOCs) form by the volatilization of organic compounds in the treatment process, often found in industrial waste. Wastewater treatment works are also sources of greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4) and nitric oxide (N_2O). CO_2 production is associated with the anaerobic treatment process through the breakdown of organic matter in the activated sludge. Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system. The rate of CH_4 production increases with increasing temperature. This is especially important in uncontrolled systems and in warm climates. N_2O is associated with the degradation of nitrogen components in the wastewater, e.g., urea, nitrate and protein.

The eThekwini Municipality deals with 435 million litres of industrial and domestic sewage on a daily basis. There are 35 sewage treatment works in the municipality, operating 365 days of the year and 24 hours a day. The Southern and Central works discharge sewage effluent into the sea through ocean outfall pipes and the other works discharge final effluent into river systems. The relative locations of WWTW for industrial waste and sewage in eThekwini are shown in Figure 3-10.

Points for consideration in the AQMP regarding waste management

a) Illegal dumping remains a problem at informal and formal waste sites
b) Indiscriminate burning of waste where waste removal services are lacking impacts negatively on ambient air quality
c) Most ambient air quality issues at landfill sites are attributed to dust and odour
d) More information on air emissions from wastewater treatment works is required to understand the contribution of this sector to the emission in the municipality

Figure 3-10: Relative location of the WWTW in eThekwini

3.1.10 Biomass burning

Sugarcane plantations cover 19 604 ha in eThekwini Municipality, mostly in the north, some in the west and at a very small scale in the south (Figure 3-11).

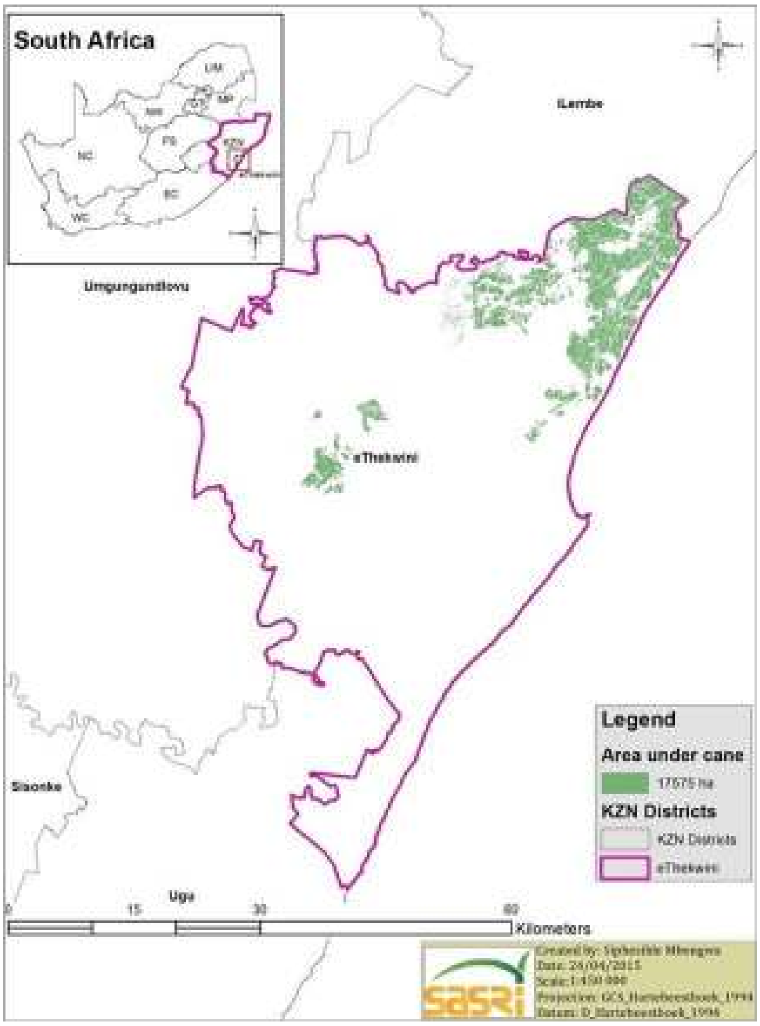


Figure 3-11: Area under sugarcane cultivation in eThekwini Municipality and the surrounding district municipalities (SASRI,2015)

The practice of burning sugarcane prior to harvesting is a recognised farming practice in the South African sugarcane industry, and occurs predominantly in the late winter and early summer months. It is worthy to note that not all sugarcane is burnt prior to harvesting. Green cane harvesting has agricultural and economic benefits for the farmer and the miller and is practiced by the industry (SASA, 2015). It is also worth noting that not all sugarcane fires are intentionally lit for harvesting. Arson in the industry is common for a number of social reasons. Sugarcane fires emit large volumes of particulate matter, ranging from coarse smut that deposit on surfaces and is a nuisance, to fine inhalable particulate matter (PM_{10}) and CO, NO_X and VOCs.

In 2013 nearly 400 ha of vegetation was burnt in either controlled or uncontrolled fires. Data on burnt areas was obtained from the CSIR's Meraka Institute using Moderate Resolution Imaging Spectroradiometer (MODIS) data. MODIS is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites.

Emissions of particulates, CO, NO_2 and VOC may be estimated by assuming that all biomass burnt in eThekwini Municipality is sugarcane. Estimated emissions are shown in Table 3-14 for a fuel load of 0.502 kg/m^2 and a combustion factor of 0.63. As may be expected from biomass burning the emission of CO is most abundant followed by VOCs, including benzene, toluene, ethylbenzene and xylenes. Nearly 68 tons of particulate matter and more than 25 tons of NO_X were emitted from sugarcane burning in 2013. SO_2 is not emitted from vegetation burning. The emission estimation methodology is presented in Appendix 2.

Table 3-14: Estimated emissions of particulate matter, CO, NO_X and total VOCs from sugarcane burning in eThekwini Municipality in 2013 in tons per annum

PM	CO	NO_X	VOCs
67.9	817.5	25.2	150.9

Points for consideration in the AQMP regarding biomass burning

a) Sugarcane farming neighbours commercial and residential property in parts of eThekwini
b) Pre-harvest burning of sugarcane is an accepted farming practice in the industry, so is green cane harvesting
c) Sugarcane burning is seasonal from late winter to early summer
d) Sugarcane burning results in nuisance impacts and adds to the ambient concentrations of criteria pollutants
e) Arson is a problem in the sugarcane industry resulting in unscheduled burning

3.1.11 Biogenic emissions

While anthropogenic VOC emissions results from fossil fuel burning in industrial processes, transportation, biomass burning, wastewater treatment, etc., natural sources of VOCs include wild fires and biogenic volatile organic compound (BVOC) emissions from plants and animals. The primary role BVOC emissions in plants is to protect them against biotic and abiotic stresses and to attract pollinators. The direct and indirect effects of BVOC emissions on atmospheric chemistry, particularly ozone formation, and the magnitude of their contribution makes an understanding of BVOC emission important for air quality management and atmospheric chemistry modelling at all scales (Zunckel *et al*., 2007).

BVOC emissions show isoprene and monoterpenes to vary widely as a function of plant species, temperature, foliar density and photosynthetically active radiation; and vary diurnally and seasonally. The BVOC emissions modelling study conducted by Otter *et al.* (2003) provides the most comprehensive assessment of emissions from southern Africa to date and it includes either total VOC or isoprene emission estimates for approximately 400 African plant species and monoterpenes emissions for about 90 of these. On the east coast of South Africa the isoprene emission rates are relatively high compared with the rest of South Africa due to greater vegetation density. They are however low and vary from around 0.5 gC/m^2 in January (summer) to less than 0.2 gC/m^2 in winter (Otter, 2003).

Points for consideration in the AQMP regarding biogenic emissions

a) BVOC emissions are species specific and emission factors are not readily available for all vegetation species in eThekwini
b) BVOC emissions contribute to the formation of O_3 on a regional scale

3.1.12 Emission summary

Emissions of priority pollutants from Listed Activities, Controlled Emitters, transportation, residential fuel burning, mining and agricultural burning have been estimated for eThekwini Municipality using the best available information.

The greatest emission of any pollutant is CO, totalling 154 089 tons per annum, with 97% attributed to emissions from transportation, dominated by motor vehicle emissions (Table 3-15). The total NO_X emission was 82 388 tons per annum, resulting primarily from transportation (motor vehicles and shipping) and Listed Activities (Table 3-15 and Figure 3-12). The total SO_2 emission in eThekwini was 26 191 tons per annum. As expected, 73% of the SO_2 emission is attributed to industrial sources (Listed Activities and Controlled Emitters). The Port of Durban is also a major SO_2 source.

By comparison with other pollutants, the total emission of PM_{10} is relatively low at 5 865 tons per annum. Collectively industrial sources account for 53% of the total PM_{10} emissions with motor vehicles accounting for 41% of the total emissions.

The emission of total VOCs is 32 635 tons per annum with 75% from motor vehicles and 16% from Listed Activities. Benzene constitutes 3.3% of the total VOC emission. Of the

VOCs, benzene emissions account for 108 tons per annum with Listed Activities accounting for 63% of the total emission, followed by motor vehicles accounting for 35% of the emission.

Table 3-15: Total emissions of air pollutants from the different source sectors in eThekwini in tons per annum

Sectors	SO_2	NO_x	CO	PM_{10}	VOC	Benzene
Listed Activities	13 197	5 090	2 482	2 036	5 307	68
Controlled Emitters	5 845	895	425	1 055	2	
Residential fuels	14	29	437	56		
Motor vehicles	1 585	68 292	147 327	2 439	24 642	38
Port of Durban	5 490	7588	1 898	33	2 421	2[1]
King Shaka IA	60	469	702	78[2]	112	
Biomass burning		25	818	68[2]	151	
Quarries				120[2]		
Total	**26 191**	**82 388**	**154 089**	**5 885**	**32 635**	**108**

1: Benzene from storage tanks included in Listed Activities
2: Total particulates

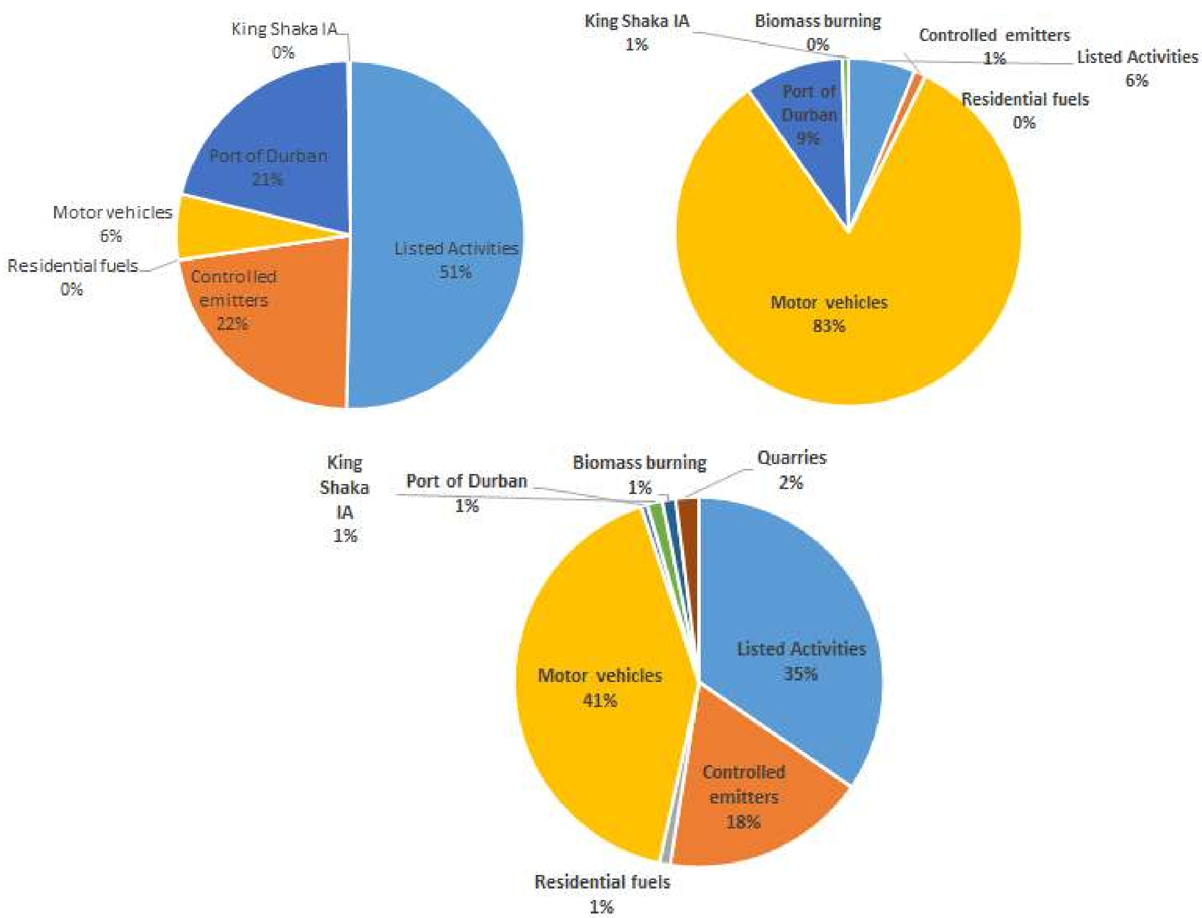


Figure 3-12: Relative contribution of different source sectors to the total emission of SO_2 (top left), NO_X (top right) and PM_{10} (bottom) in eThekwini Municipality

3.2 Ambient air quality

Ambient air quality is informed by measured and predicted data. Monitoring data, where available in the eThekwini Municipality is presented. Using the emission inventory developed for the AQMP, dispersion modelling outputs have also been processed to present a complementary picture of air quality in the region.

Ambient air quality monitoring started in eThekwini in 1985 at Wentworth measuring SO_2 concentrations using the so-called bubbler method and smoke using a soiling index which provided a proxy for PM_{10} (DEA, 2009b). The bubbler network consistently expanded and by 1995 monitoring was done at 18 monitoring stations in the municipality (Table 3-16 and Figure 3-13). eThekwini Municipality still operate this network. Ambient monitoring for lead started at City Hall in 1995 and continued up until 2012.

In December 2003 ambient monitoring in eThekwini increased significantly with the implementation of the MPP and the installation of 10 fully automated air quality monitoring stations, measuring a range of air pollutants in real time. The network expanded again in

2012 and 2013 with the addition of 4 monitoring stations. Ambient monitoring of benzene is conducted by eThekwini at a number of sites. Information on the monitoring sites is listed in Table 3-17, and their relative location of the stations is shown in Figure 3-13.

Ambient air quality monitoring is also done by industry and other facilities in the municipality. This monitoring includes, *inter alia*, fenceline monitoring of benzene and other VOCs by SAPREF, Engen Refinery and FFS Refiners using passive sampling, continuous monitoring of a number of pollutants by the National Ports Authority TNP at the Port of Durban and by the Airports Company South Africa, at the King Shaka International Airport. SO_2 monitoring is done by Sappi Saiccor and Assmang; and dust fall at the quarries in the municipality. Ambient monitoring is also done at the landfill sites.

Table 3-16: eThekwini municipality SO_2 bubbler and lead monitoring stations

Station name	
New Germany	Pinetown Civic
Chatsworth	Riverside
City Hall	South Bluff
Cato Manor	Southern Works
Congella	Wentworth
Cowies Hill	Alverstone
Gillitts	King Edward
Hollesley Road	Tongaat
Isipingo	Montclair
Palmfield	

Table 3-17: eThekwini Municipality continuous monitoring stations

Station name	Monitoring period	Siting rationale	Parameters measured
Prospection	2004 -	Industrial background	SO_2
Southern Works	2004 -	Urban industrial	SO_2, NO_X, PM_{10}, TRS, met
Settlers	2004 -	Residential	SO_2, TRS
Ganges	2004 -	Suburban traffic	SO_2, NO_X, PM_{10}
Grosvenor	2004 -	Residential	SO_2, met
King Edward	2004 - 2006	Urban background	NO_X, PM_{10}
Warwick	2004 -	Traffic	NO_X, CO
Wentworth	2004 -	Industrial	SO_2, PM_{10}, O_3, $PM_{2.5}$, met
City Hall	2004 -	CBD traffic	NO_X, PM_{10}
Alverstone	2004 -	Urban background	O_3
Ferndale	2005 - 2013	Urban background	SO_2, PM_{10}, $PM_{2.5}$
Jacobs	2004 -	Industrial	Met, SO_2, NO_X
Sapref	2004 - 2008		Met
Harbour	2004 - 2009		Met
Edgewood	2004 -		Met
Tongaat	2004 -		Met
	2014 -	Network expansion	SO_2, NO_X, PM_{10}, O_3, met
Amanzimtoti	2014 -	Network expansion	SO_2, NO_X, PM_{10}, O_3, met
New Germany	2014 -	Network expansion	SO_2, NO_X, PM_{10}, O_3, met
Cato Ridge	2014 -	Network expansion	SO_2, NO_X, PM_{10}, O_3, met

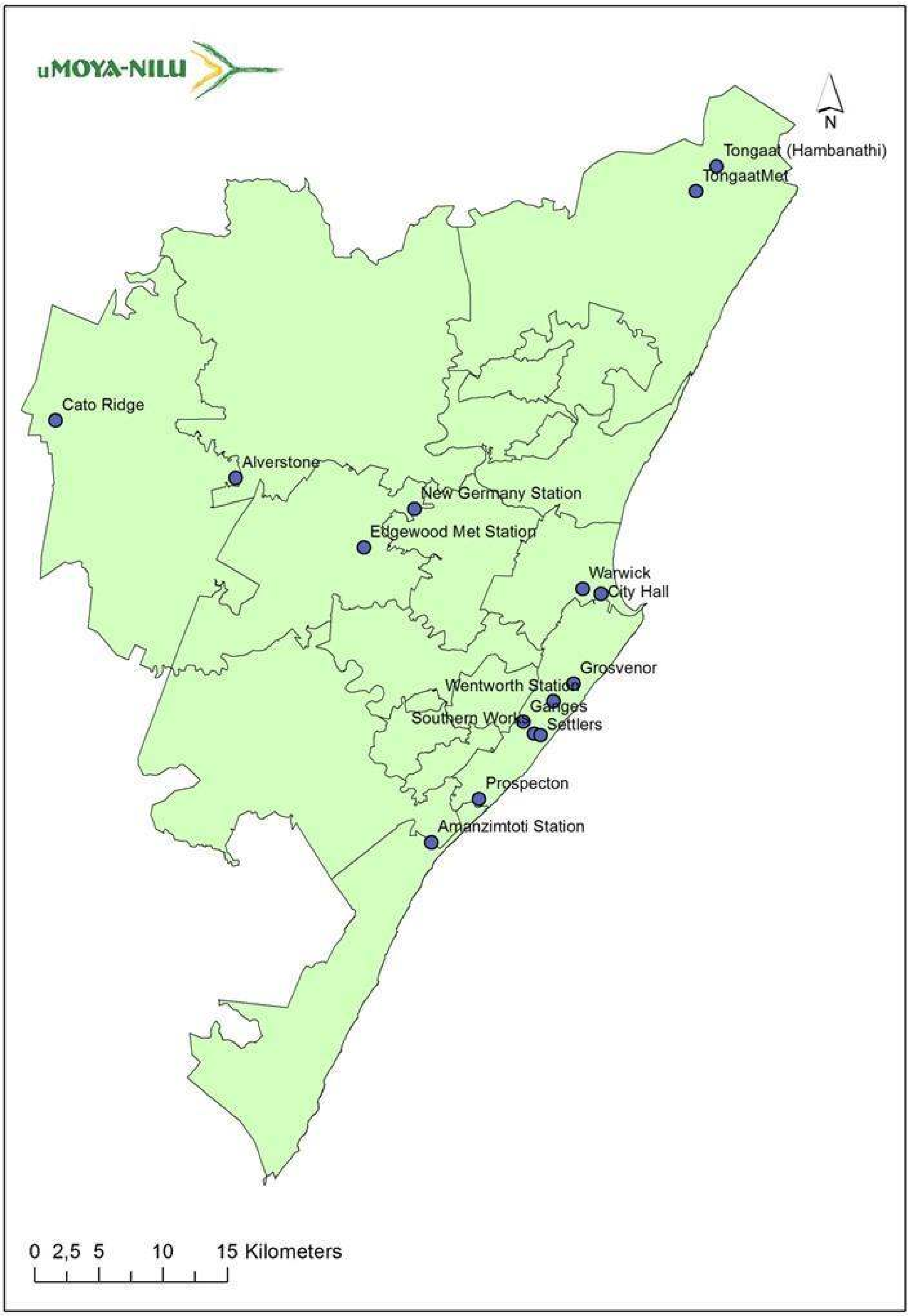


Figure 3-13: Location of eThekwini's ambient monitoring stations

The percentage data capture provides insights into operational aspects of ambient monitoring. These include, amongst others, the technical wellbeing of the monitoring equipment, the technical ability of personnel to perform maintenance and repair, and the availability of financial resources to ensure equipment are serviced routinely and replaced when necessary. The annual data capture record at the eThekwini Municipality monitoring stations is listed in Table 3-18.

SO_2 has been monitored at 9 stations since 2004, with the City Hall monitor being moved to Ferndale in 2005. The annual average data capture record was above 90% for the 6-year period up to the end of 2009. NO_X has been measured at 8 monitoring station and PM_{10} at 6 monitoring station since 2004 with the King Edward station moved to Ferndale in 2006. Similar to SO_2, the annual average data capture for NO_X and PM_{10} was satisfactorily high up to the end of 2009. CO has been monitored at the traffic station at Warwick since 2004 with a good return of data except in 2011. Initially O_3 was monitored at Wentworth and Alverstone, but discontinued at Wentworth at the end of 2008. As for the other pollutants the O_3 data capture record was satisfactorily high up to the end of 2009.

From 2010 data capture declines at a number of monitoring stations. This is attributed to eThekwini Municipality's inability to resource spares and effect repairs to aging monitoring and essential support equipment. It also reflects their inability in cases to replace these where needed.

Table 3-18: Annual data capture record for SO_2, NO_2, PM_{10}, CO and O_3 from 2004 to 2014

SO_2	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Prospecton	94	78	88	81	96	91	50	96	63	95	88
Southern Works	98	97	94	92	89	88	91	34	42	59	49
Settlers	96	90	98	97	91	98	95	91	80	96	46
Ganges	99	98	99	92	83	95	50	93	48	48	49
Grosvenor	97	84	97	84	91	87	71	98	53	0	27
Wentworth	95	98	94	93	93	92	96	97	78	76	35
City Hall	93	-	-	-	89	-	-	-	-	-	-
Ferndale	-	93	80	77	85	74	89	74	32	29	-
Jacobs	90	99	88	80	90	91	54	39	81	75	-
Cato Ridge	-	-	-	-	-	-	-	-	-	-	47
New Germany	-	-	-	-	-	-	-	-	-	-	83
Average	95	92	92	87	90	90	74	78	60	60	56

NOx	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Southern Works	98	89	93	96	91	91	97	33	0	62	92
Ganges	99	95	96	96	92	91	65	96	55	19	83
King Edward	74	89	-	-	-	-	-	-	-	-	-
Warwick	98	92	96	97	93	94	86	82	54	79	82
Wentworth	98	95	88	98	87	95	96	98	60	0	45
City Hall	89	95	72	90	76	75	96	0	36	73	64
Ferndale	-	91	76	86	87	79	72	54	0	0	-

Jacobs	97	91	95	82	85	93	0	51	20	73	-
Cato Ridge	-	-	-	-	-	-	-	-	-	-	59
New Germany	-	-	-	-	-	-	-	-	-	-	79
Average	93	92	88	92	87	88	73	59	32	44	72

PM_{10}	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Southern Works	-	-	96	90	89	72	61	45	29	57	0
Ganges	99	96	99	90	90	65	81	97	66	85	82
King Edward	91	86	-	-	-	-	-	-	-	-	-
Wentworth	97	97	93	95	88	75	0	0	84	89	49
City Hall	98	90	66	85	83	95	94	0	56	69	84
Ferndale	-	89	92	90	91	82	0	89	75	65	-
Cato Ridge	-	-	-	-	-	-	-	-	-	-	72
New Germany	-	-	-	-	-	-	-	-	-	-	33
Average	96	92	89	90	88	78	47	46	62	73	64

CO	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Warwick	89	94	98	98	88	95	82	43	84	91	71

O_3	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Wentworth	89	62	96	97	80	-	-	-	-	-	
Alverstone	97	96	0	81	87	93	70	0	23	77	69
Cato Ridge	-	-	-	-	-	-	-	-	-	-	82
New Germany	-	-	-	-	-	-	-	-	-	-	33
Average	93	79	48	89	84	93	70	0	23	77	61

Dispersion modelling may be used in air quality management to compliment site specific monitoring data by providing spatially continuous concentration fields for the respective pollutants and estimates of concentrations where monitoring is not done. The emission inventory which was developed for the baseline assessment for Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport are used to model ambient concentrations of SO_2, NO_X, PM_{10} and benzene using the CALPUFF dispersion model. Dispersion modelling is done in six modelling domains (Figure 3-14) where emission sources are currently concentrated. See the Modelling Plan of Study in Appendix 4 for additional details on the modelling.

Ambient concentrations of the different pollutants that are monitored in eThekwini, trends and temporal variations are presented in the next sections. In addition, modelled ambient concentrations are presented for pollutants resulting from industrial sources (Listed Activities and Controlled Emitters), the Port of Durban and King Shaka International Airport. The monitored and modelled concentrations are assessed relative to the national ambient air quality standards (See Appendix 5). Issues and problems are noted and gaps and challenges with respect to ambient monitoring are identified.

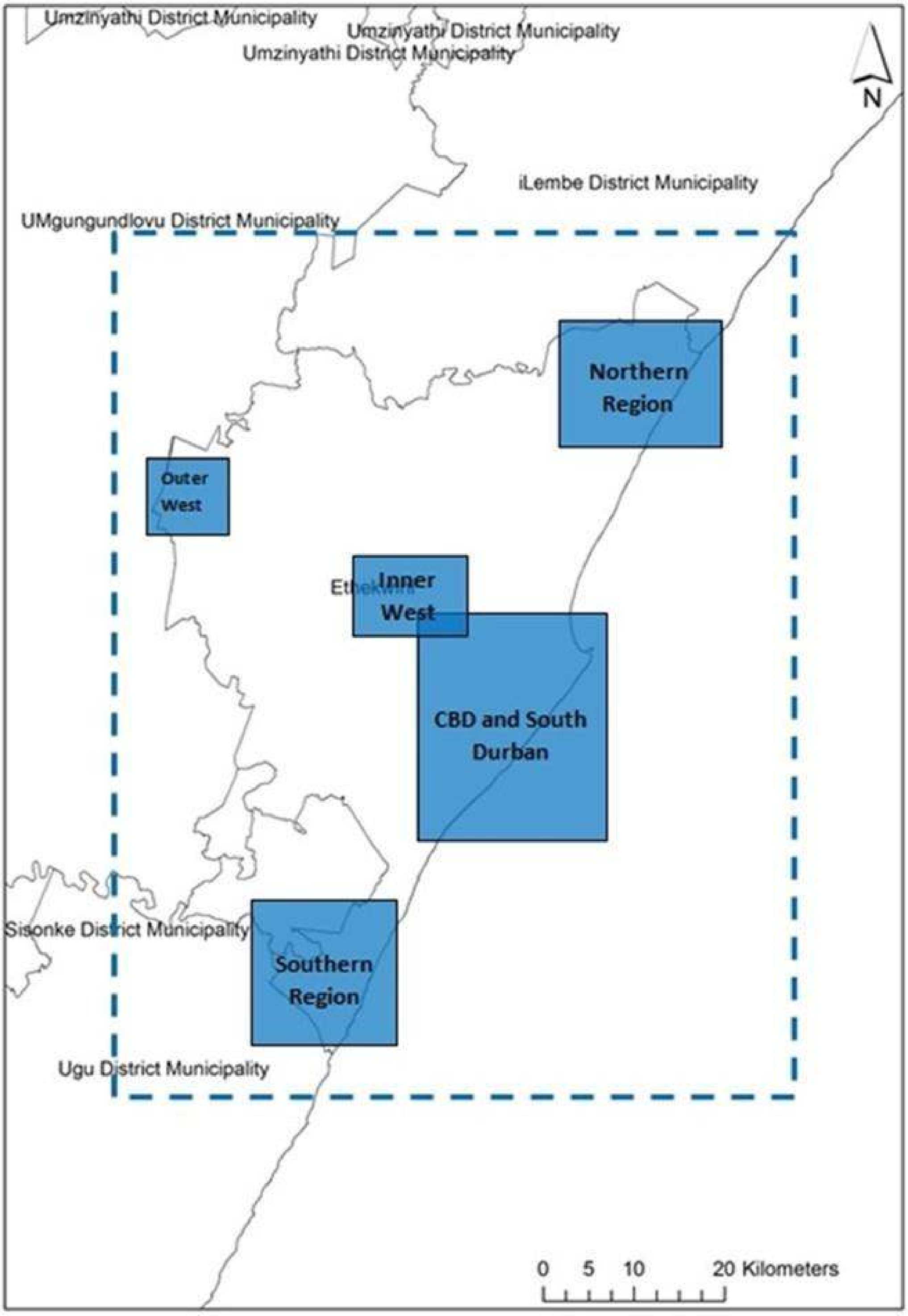


Figure 3-14: Relative location of the six modelling domains used for the CALPUFF dispersion modelling. The eThekwini modelling domain is represented by the dashed lines

3.2.1 Sulphur dioxide (SO_2)

SO_2 is a criteria pollutant and exposure through inhalation can impact negatively on human health. National ambient air quality standards have been set for SO_2. The primary source of SO_2 is the combustion of fossil fuels that contain sulphur. Sources in eThekwini include industrial boilers, crude oil refining, ship emissions and diesel vehicles. Read more about SO_2 in Appendix 5.

eThekwini Municipality has been monitoring SO_2 since the 1990's at a number of sites using the SO_2 bubbler method, providing average monthly concentrations. Data are available for 21 monitoring sites in eThekwini for different periods since 1996, showing reliable and long term trends and good spatial representation. Annual average SO_2 concentrations at 7 monitoring stations between 1996 and 2013 are shown in Figure 3-15 and compared to the NAAQS of 50 μg/m^3. Noteworthy features are firstly, the concentrations above or near the annual NAAQS at stations affected by emissions from the South Industrial Basin, prior to the switch to clean fuels and other emission reduction measures by industry. Secondly is the reduction in ambient SO_2 concentrations from 2006 with the implementation of these measures. The annual average SO_2 concentrations at the other bubbler stations in eThekwini are consistently below the annual NAAQS and mostly between 10 and 20 μg/m^3. This might be expected as elsewhere there are no major sources of SO_2. The annual average concentrations at selected bubbler stations are shown in Figure 3-16.

SO_2 is now measured at 12 continuous monitoring stations (Table 3-17). Sappi Saiccor in Umkomaas monitor SO_2 at three stations and make the data available to eThekwini, thereby extending the monitoring network to the south of the municipality. Generally annual average ambient concentrations of SO_2 are below the SAAQS limit value of 50 μg/m^3 throughout the municipality. They were high at the stations in the South Industrial Basin (Southern Works, Wentworth, Settlers) in 2004 and 2005 at the start of the MPP (Figure 3-17).

A marked decrease in concentrations is noted with the implementation of cleaner fuels, particularly at the two crude oil refineries and the control technologies in other industries (Figure 3-17). At these stations the annual average concentration is less than half of the NAAQS limit value. The annual average concentrations are lower at monitoring stations that are outside the direct influence of major sources of SO_2. At Dlambula and Ifracombe near Umkomaas the annual average SO_2 concentrations are high relative to the NAAQS and exceed the limit value in 2013 at both stations and again at Dlambula in 2014 (Figure 3-18). Although SO_2 is emitted from relatively high stacks in the Umkomaas River valley, it is effectively emitted close to ground level at the top of the valley, resulting in high ground level concentrations above the valley rather than in the valley itself.

The improvement in ambient SO_2 in the South Industrial Basin is further illustrated in Figures 3-18 and 3-19 which illustrate the number of exceedances of the limit value of the 24-hour and 10-minute NAAQS. The NAAQS permits 4 exceedances per year of the 24-hour limit value of 125 μg/m^3 and 526 exceedance of the 10-minute limit value of 500 μg/m^3. At Southern Works, 24-hour exceedances occurred in 2006 and 2007, but none have been recorded since. Similarly at Wentworth and at Settlers School, nine exceedances occurred in 2006 and four in 2010, implying non-compliance with the NAAQS at this station. The high SO_2 concentrations at Dlambula and Ifracombe are shown by the number of exceedances of the 24-hour and 1-hour limit values in Figure 3-18.

SO_2 can have acute respiratory effects for sensitive people. The NAAQS therefore provides a 10-minute standard. The highest number of exceedances of the 10-minute limit value occurred at Settlers School in 2006 when 227 exceedances occurred, less than half the number of permitted exceedance. Since then the number of exceedances has decreased dramatically with less than 50 in every year and just eight in 2013.

A seasonal variation in ambient SO_2 concentrations is shown at some of the monitoring sites in eThekwini Municipality. Higher winter concentrations occur at the stations located nearer the main sources of SO_2, i.e. Wentworth, Grosvenor and Jacobs, and to a lesser extent at Settlers and Southern Works (Figure 3-20). The higher winter concentrations are attributed to greater atmospheric stability and poorer dispersion in winter. Little seasonal variation is shown in ambient SO_2 concentrations at the other monitoring stations where SO_2 concentrations are relatively low (Figure 3-20).

Modelled annual ambient SO_2 concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-20 for the each of the 6 modelling domains. The predicted annual average concentrations are relatively low throughout eThekwini Municipality compared with the NAAQS of 50 $\mu g/m^3$, except in two areas, the CBD and South Durban domain. Exceedances of the NAAQS are shown by the red isopleths in Figure 3-20, in Clairwood and Jacobs and in Wentworth and Merewent.

The modelled 99th percentile of the 24-hour SO_2 concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-21. These are similar to the annual concentrations, being relatively low compared with the limit value of the NAAQS of 125 $\mu g/m^3$, except in the CBD and South Durban modelling domain. Here the limit value is exceeded at two areas near the Port of Durban, in an area extending from Clairwood and Jacobs to Wentworth and Merewent and in Umbogintwini. In these areas the predicted number of exceedances of the NAAQS limit value exceeds the permitted frequency of exceedance (i.e. 4 daily exceedance per year).

The monitored exceedances in the Umkomaas area are not predicted in the dispersion modelling. This is likely a result of parameterisation of the topography in the model being too coarse to adequately parameterise the river valley.

The modelled 99th percentile of the 1-hour SO_2 concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-22 in each of the 5 modelling domains and eThekwini as a whole. As with the annual and 24-hour predictions, the predicted 1-hour concentrations are relatively low compared with the limit value of the NAAQS of 350 $\mu g/m^3$ throughout the municipality, except in the CBD and South Durban modelling domain. Here the limit value is exceeded at two small areas near the Port of Durban, in Clairwood and Jacobs, Wentworth and Merewent and in Umbogintwini. The predicted number of exceedances of the NAAQS limit value exceeds the permitted frequency of exceedance (i.e. 88 daily exceedances per year) in these areas.

Again the monitored exceedances in the Umkomaas area are not predicted in the dispersion modelling.

The isopleth map for the eThekwini Municipality in Figures 3-21 to 3-23 illustrates the dispersion of SO_2 from industrial activities. The main dispersion pattern to the south-west and the north-east along the coast line is clearly evident. So too are the four zones of industrial emissions and corresponding relatively high predicted concentrations at Cato Ridge, Tongaat, Umkomaas and the South Industrial Basin including Jacobs. The limiting influence of the sharp increase in topography west of Pinetown is also evident.

The modelled annual ambient SO_2 concentrations resulting from emissions from the Port of Durban and the modelled 99^{th} percentile of the 24-hour and 99^{th} percentile of 1-hour SO_2 are presented and compared in Figure 3-24. Despite the Port of Durban and shipping in particular being a relative large source of SO_2, the predicted ambient concentrations are relatively low compared with the limit values of the NAAQS for SO_2 (Appendix 6). The highest concentrations are predicted to occur at the harbour and extend westward towards the higher elevation of the Berea under the prevailing northeasterly winds.

The modelled annual ambient SO_2 concentrations resulting from emissions from King Shaka International Airport and the modelled 99^{th} percentile of 24-hour and 99^{th} percentile of 1-hour SO_2 are presented in Figure 3-25 for the northern modelling domain. The emission of SO_2 from the airport is low, corresponding with low predicted ambient concentrations. No exceedances of the NAAQS for SO_2 are predicted.

The collective effect of emissions from industrial sources (Listed Activities and Controlled Emitters), the Port of Durban and King Shaka International Airport in eThekwini are presented in Figure 3-26. The main dispersion pattern to the south-west and the north-east along the coast line is again clearly evident. The predicted cumulative concentrations are generally well below the limit values of the NAAQS for SO_2. The four zones of relatively high concentrations at Cato Ridge, Tongaat, Umkomaas and the South Industrial Basin including Jacobs correspond with sources in the emission inventory. The areas of exceedances resulting from industrial emissions are evident in the maps for added sources (Figure 3-26).

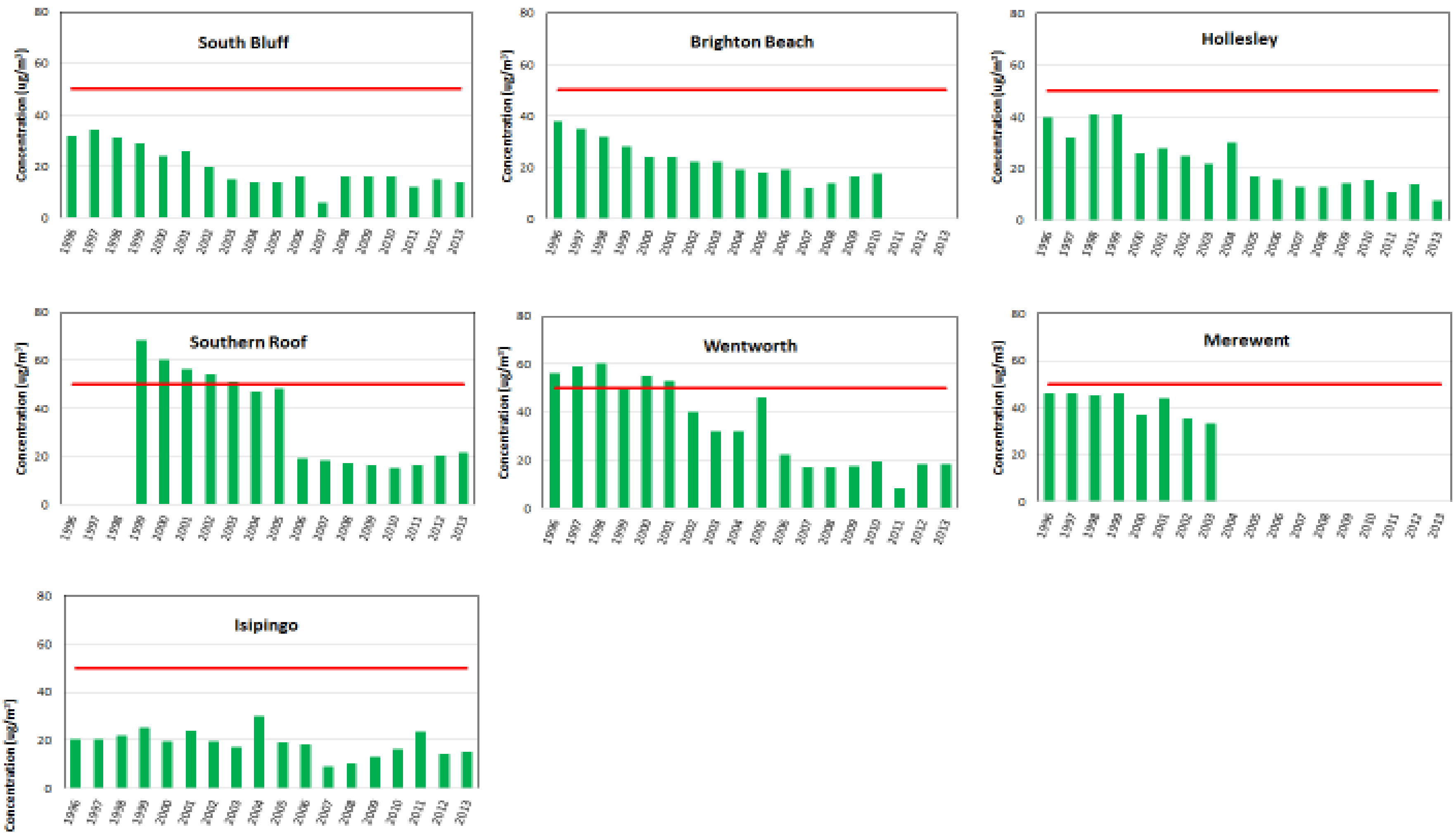


Figure 3-15: Annual average SO_2 concentration in µg/m^3 at seven long running bubbler sites in eThekwini Municipality. The NAAQS of 50 µg/m^3 is shown by the red line

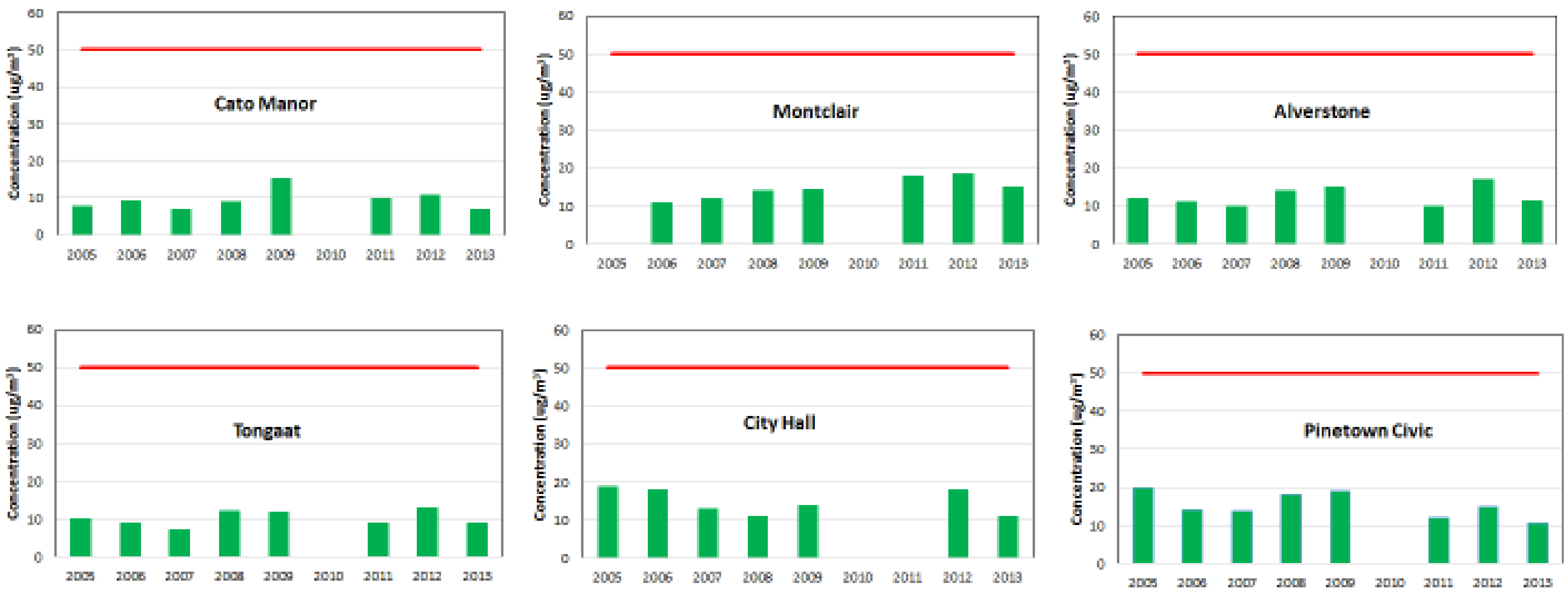


Figure 3-16: Annual average SO_2 concentration in µg/m^3 at seven long running bubbler sites in eThekwini Municipality. The NAAQS of 50 µg/m^3 is shown by the red line

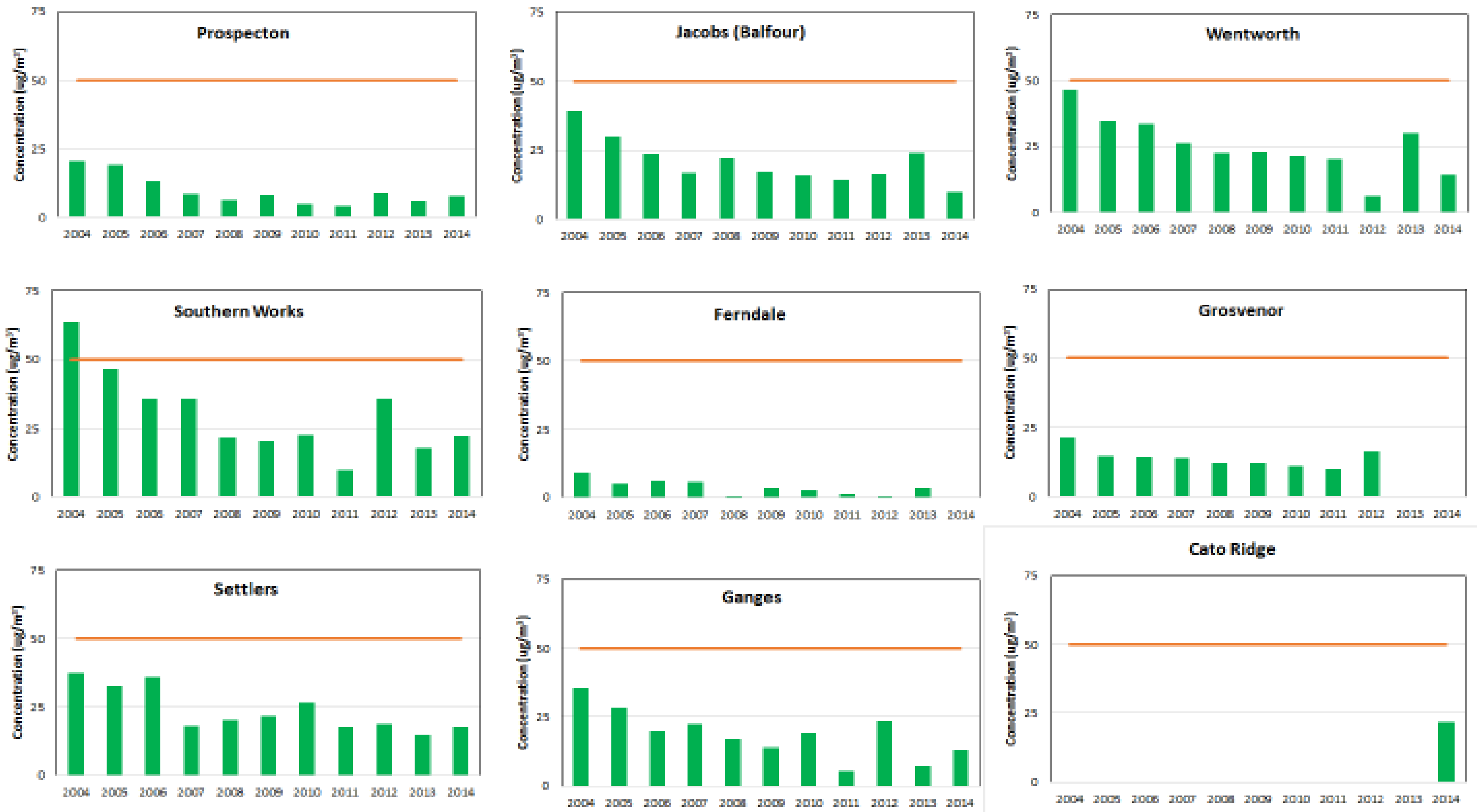


Figure 3-17: Annual average SO_2 concentrations at eThekwini monitoring stations in µg/m^3, showing the NAAQS of 50 µg/m^3

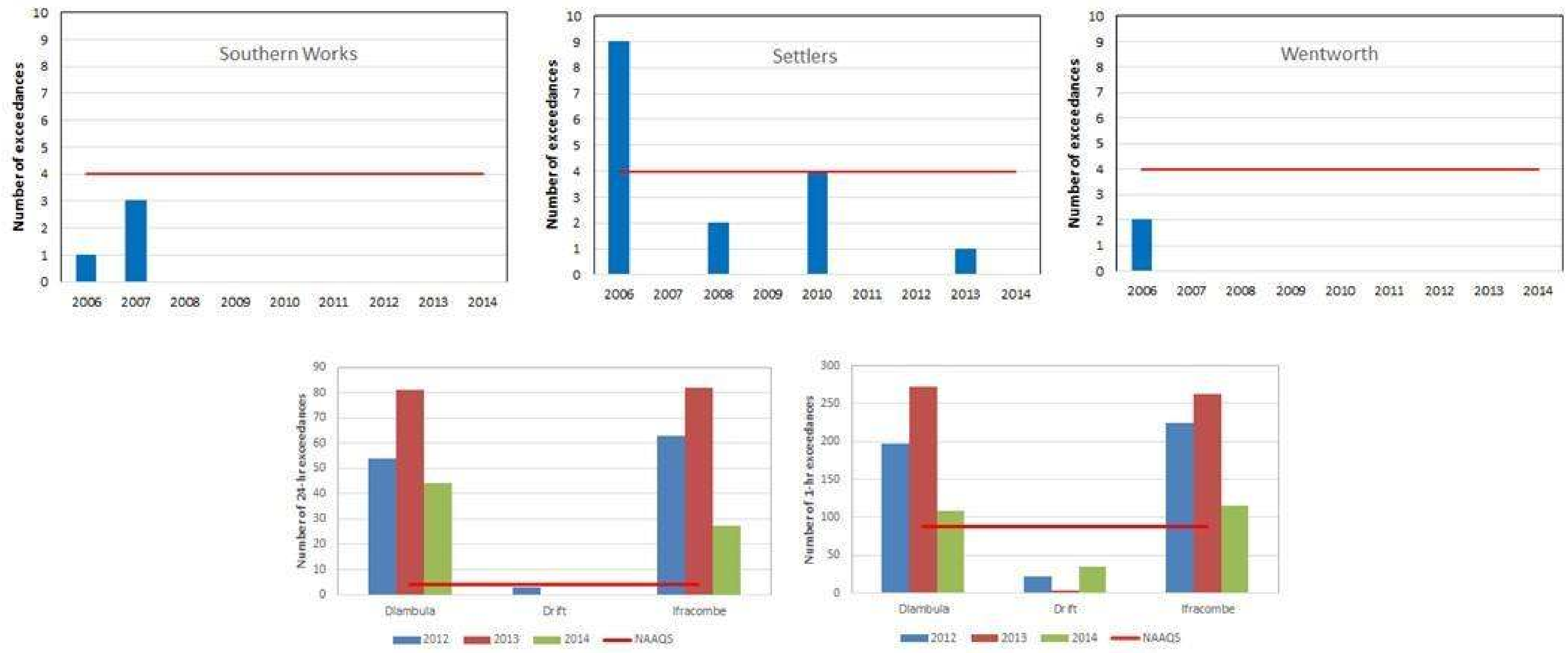


Figure 3-18: Number of exceedances of the 24-hour limit value of the NAAQS for SO_2 at eThekwini monitoring stations and the 24-hour and 1-hour limit value at the two monitoring stations near Umkomaas. The red line shows the permitted number of exceedances

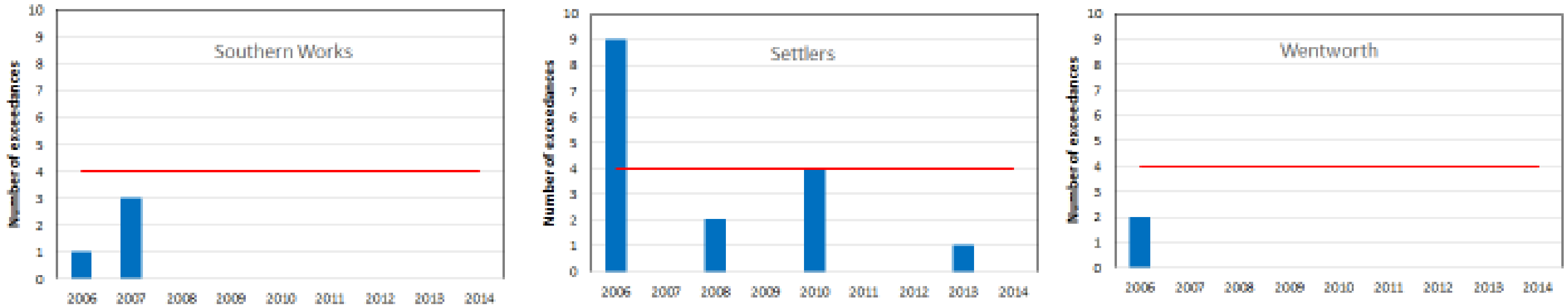


Figure 3-19: Number of exceedances of the 10 minute limit value of the NAAQS for SO_2 at eThekwini monitoring stations

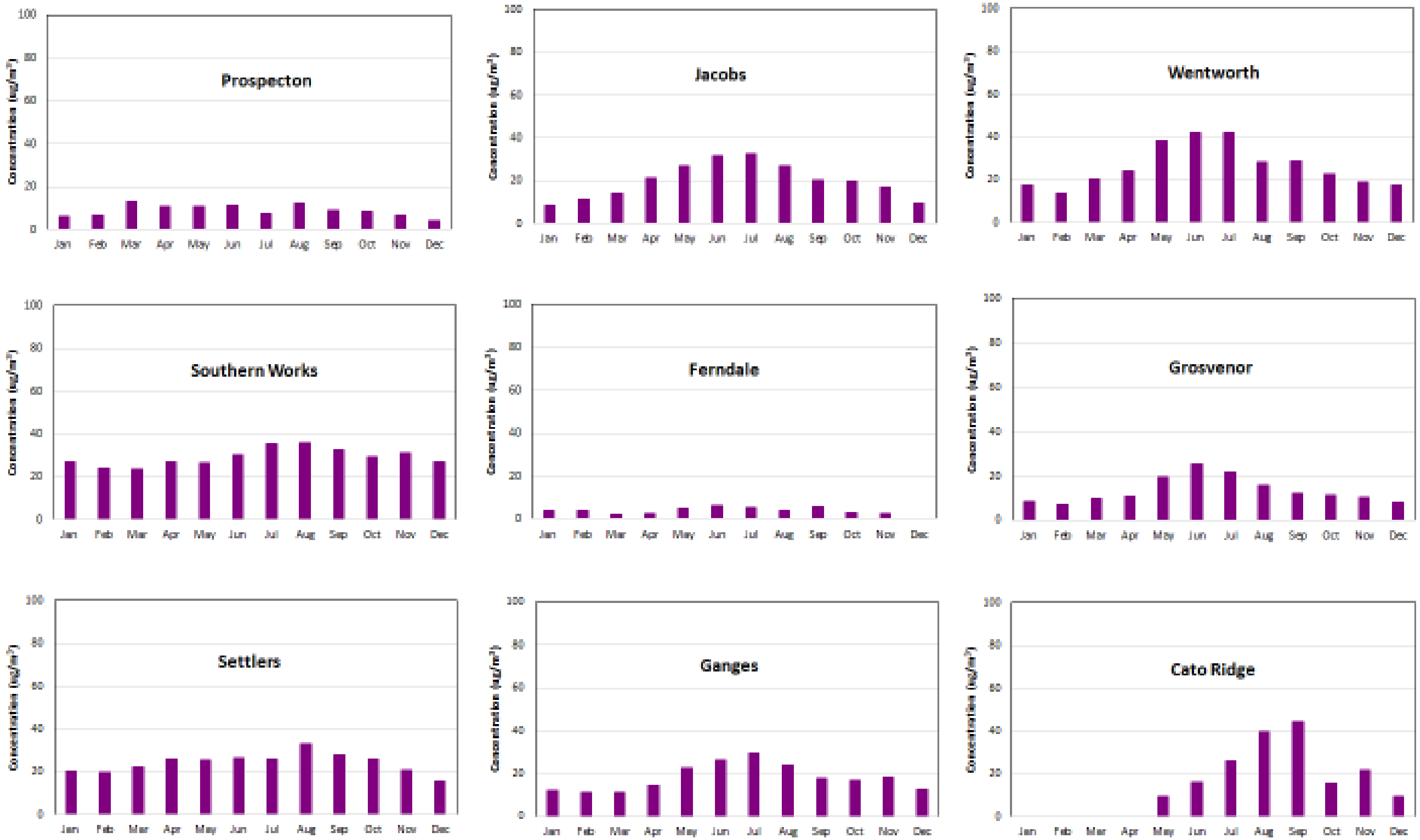


Figure 3-20: Average monthly ambient SO_2 concentration for available data from 2004 to 2014 at eThekwini monitoring stations

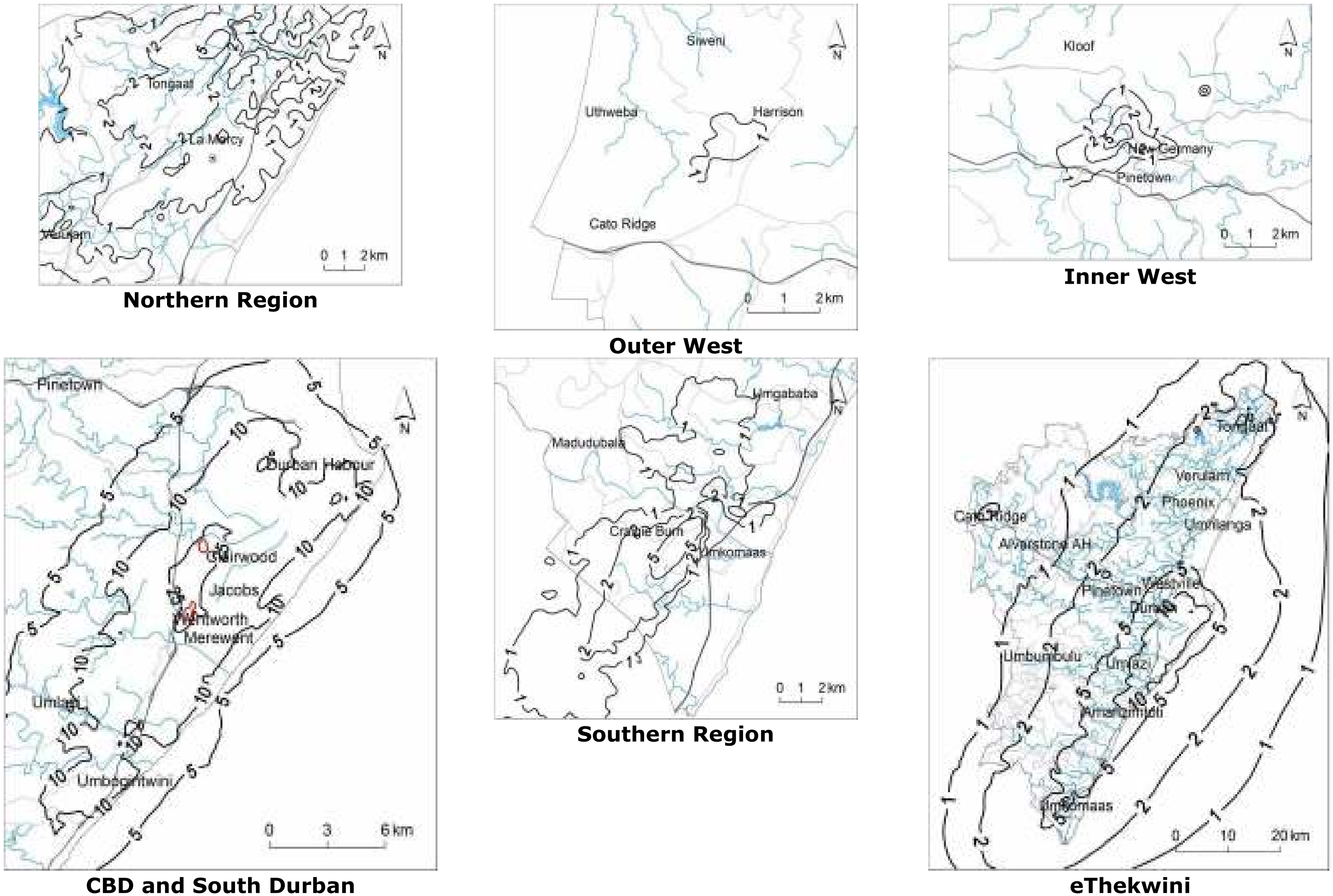


Figure 3-21: Modelled annual ambient SO_2 concentrations in µg/m^3 resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains. Exceedances of the NAAQS of 50 µg/m^3 are shown by the red isopleths.

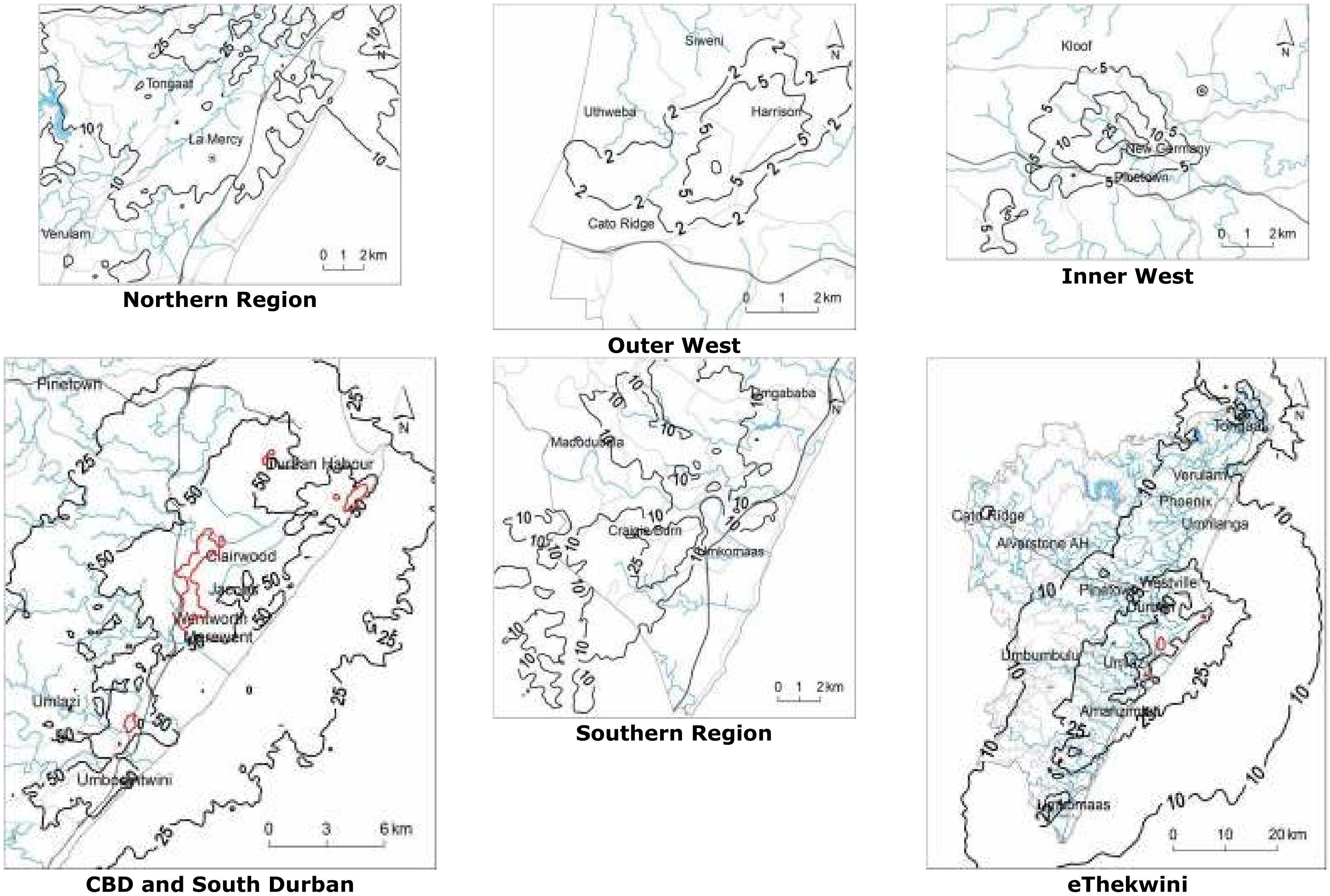


Figure 3-22: Modelled 99th percentile of 24-hour SO_2 concentrations in µg/m^3 resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains. Exceedances of the NAAQS of 125 µg/m^3 are shown by the red isopleths.

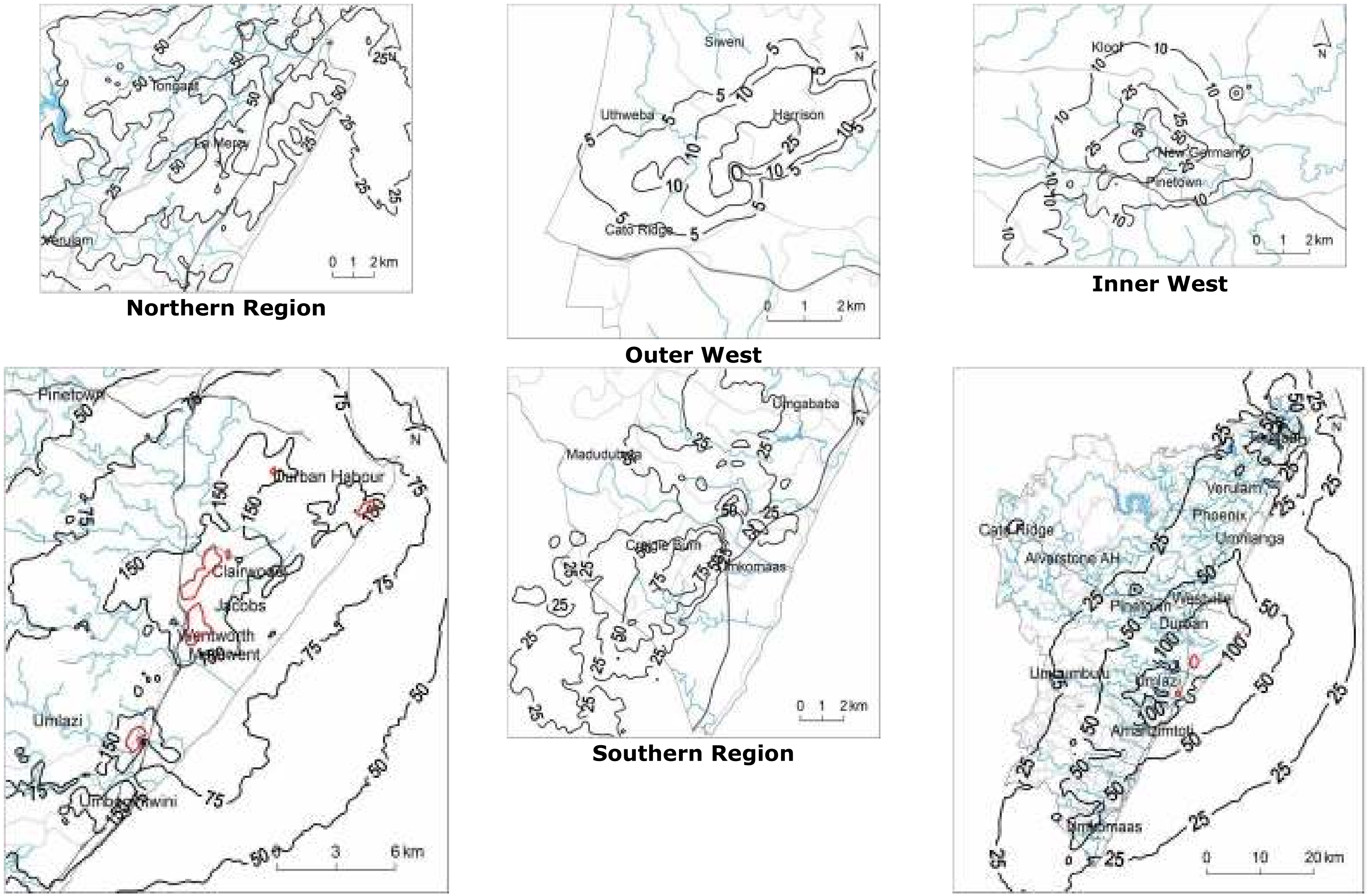
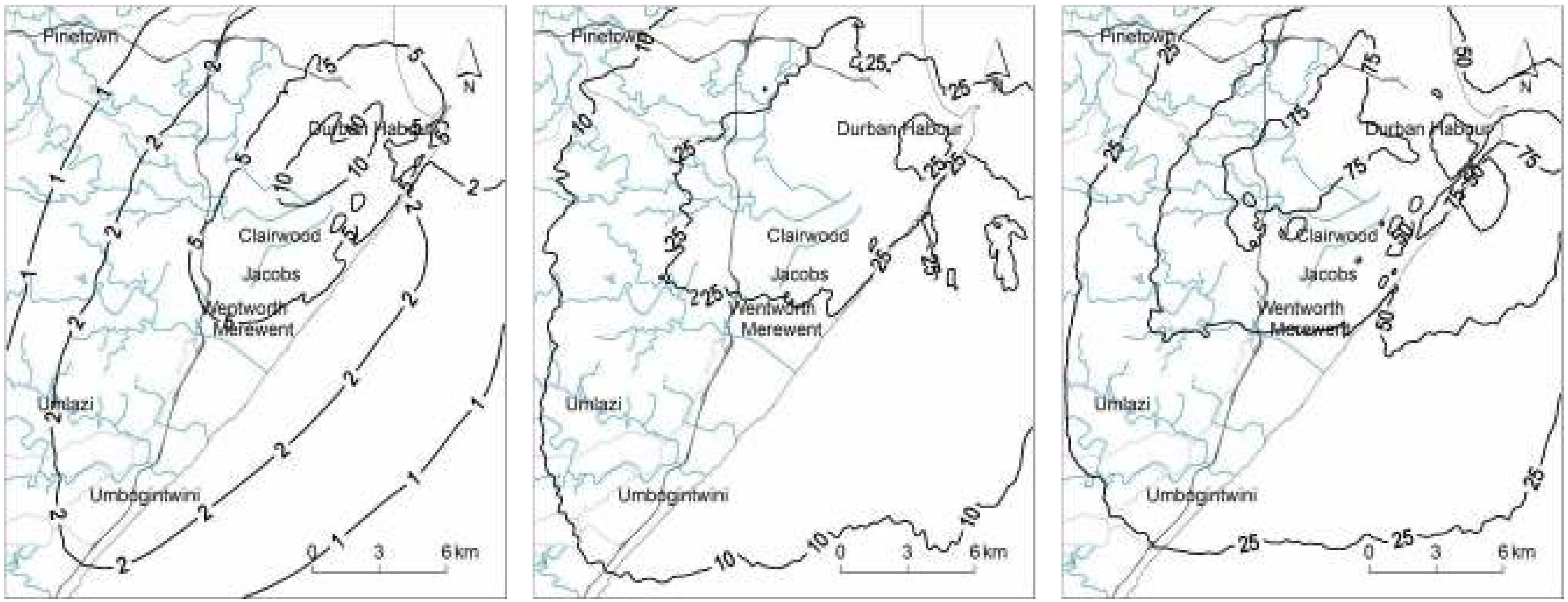


Figure 3-23: Modelled 99th percentile of 1-hour SO_2 concentrations in µg/m^3 resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains. Exceedances of the NAAQS of 350 µg/m^3 are shown by the red isopleths.

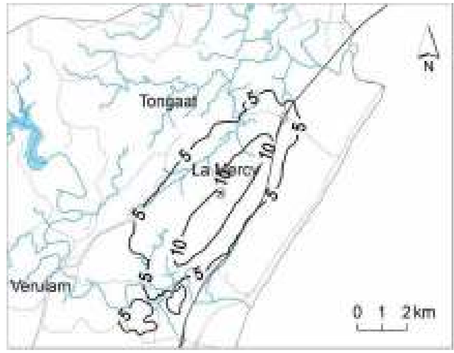


Annual **24-hour** **1-hour**

Figure 3-24: Modelled annual ambient SO_2 concentrations (left), the 99th percentile of 24-hour SO_2 concentrations (middle) and 99th percentile of 1-hour SO_2 concentrations (right) in µg/m^3 in the CBD and South Durban domain resulting from emissions from the Port of Durban

Annual

24-hour



1-hour

Figure 3-25: Modelled annual ambient SO_2 concentrations (left), the 99th percentile of 24-hour SO_2 concentrations (middle) and 99th percentile of 1-hour SO_2 concentrations (right) in µg/m^3 in the Northern domain resulting from emissions from King Shaka International Airport

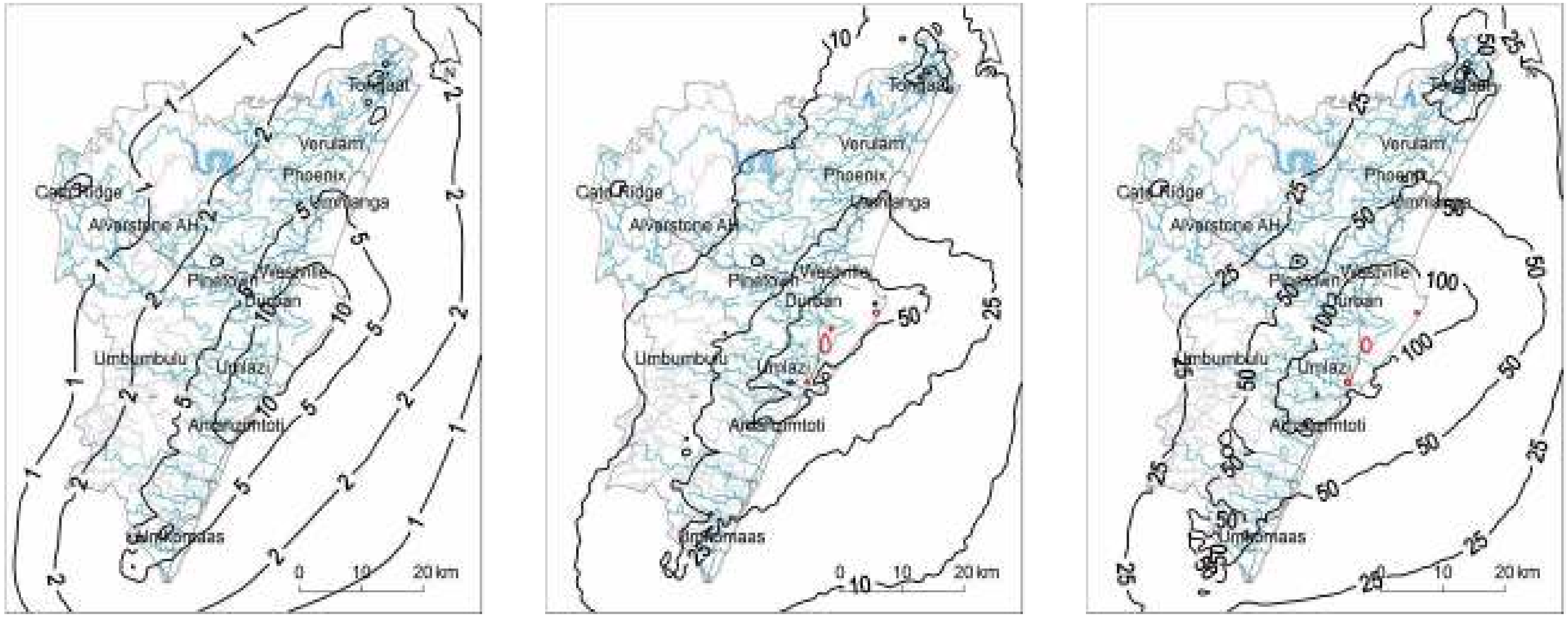


Figure 3-26: Modelled annual ambient SO_2 concentrations (left), the 99th percentile of 24-hour SO_2 concentrations (middle) and 99th percentile of 1-hour SO_2 concentrations (right) in $\mu g/m^3$ in eThekwini resulting from emissions from Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport. Exceedances of the NAAQS of 350 $\mu g/m^3$ are shown by the red isopleths.

Points for consideration in the AQMP regarding SO_2

a) SO_2 has been monitored by eThekwini since the 1990's in the smoke and SO_2 network, and using real-time network since 2004
b) SO_2 concentrations in the South Industrial Basin decreased dramatically in 2006 with emission reduction by major industry
c) Measured ambient SO_2 concentrations are relatively low, except at Umkomaas where exceedance of the NAAQS occur
d) Modelled ambient SO_2 concentrations are relatively low throughout eThekwini Municipality, except at places in the South industrial Basin, Jacobs and Clairwood and at Umbogintwini where exceedances of the NAAQS occur as a result of industrial emissions

3.2.2 Oxides of nitrogen (NO_X)

Oxides of nitrogen (NO_X) is commonly referred to as the sum of nitrous oxide (NO) and nitrogen dioxide (NO_2). NO_2 is a criteria pollutant and exposure through inhalation can impact negatively on human health. National ambient air quality standards have been set for NO_2. The primary sources of NO_X is high temperature combustion that leads to the oxidation of nitrogen in the atmosphere. Industrial boilers and motor vehicles are readily associated with NO_X emissions. Read more about NO_X in Appendix 5.

NO_2 is measured at 9 continuous monitoring stations (Table 3-17) with the intention of understanding the impact of major industrial sources and motor vehicle emissions on ambient air quality. The average annual ambient concentrations of NO_2 is relatively high at most monitoring stations compared with the NAAQS limit value of 40 µg/m^3 (Figure 3-27). At Warwick Triangle, City Hall, Ganges and Jacobs, which are important traffic stations, the annual limit value of the NAAQS has been exceeded since monitoring started in 2004, particularly at Ganges where the station is close to the M4 highway.

While the annual average NO_2 concentrations are relatively high, the number of exceedances of the 1-hour limit value are relatively low. The NAAQS permits 88 exceedances per year of the 1-hour limit value of 200 µg/m^3. At City Hall 46 exceedances occurred in 2006, otherwise few exceedances with the most at Ganges and Warwick (Figure 3-28), all likely to be related to traffic emissions. The exceedances at Southern Works in 2013 are most likely attributed to industrial emissions, but these are well below the tolerance value of 88 per year (Figure 2-28).

The seasonal variation on ambient NO_X concentrations is marked at most of eThekwini Municipality's monitoring stations (Figure 3-29). A large portion of the NO_X emission is released close to ground level by vehicles. The more stable winter conditions at the surface inhibit dispersion and NO_2 tends to accumulate, resulting in relatively higher ambient concentrations in winter.

Modelled annual ambient NO_2 concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-30 for each of the 5 modelling regions and eThekwini as a whole. The predicted annual average ambient concentrations are low and well below the NAAQS of 40 μg/m^3. Like SO_2, the dispersion is largely controlled by the prevailing north-easterly and south-westerly winds along the coast and the topography.

The modelled 99th percentile of the 1-hour NO_2 concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-31 for each of the 5 modelling regions and eThekwini as a whole. In all of the modelling domains and throughout eThekwini Municipality the predicted ambient concentrations are well below the limit value of the NAAQS of 200 μg/m^3 and no exceedances of the NAAQS are predicted as a result of industrial emissions.

The modelled annual ambient NO_2 concentrations and the 99th percentile of 1-hour NO_2 concentrations resulting from emissions from the Port of Durban are presented in Figure 3-32. Despite the harbour being a relatively large source of NO_X, the predicted ambient concentrations are relatively low and no exceedances of the NAAQS are predicted.

The modelled annual ambient NO_2 concentrations and the 99th percentile of 1-hour NO_2 concentrations resulting from emissions at King Shaka International Airport are presented in Figure 3-33. The predicted ambient concentrations are relatively low compared with the NAAQS in the surrounding environment. Exceedances of the 1-hour limit value are predicted to occur in an area that corresponds with the runway as a result of aircraft exhaust emissions. They are not predicted to extend beyond the immediate area of emission.

The collective effect of emissions from Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport in eThekwini Municipality on ambient NO_2 concentrations are presented in Figure 3-34. The predicted cumulative concentrations are below the respective annual and 1-hour limit values of the NAAQS throughout the municipality. The predicted exceedances of the 1-hour limit value at the King Shaka International Airport runway are not evident at the scale of the map in Figure 3-32.

The dispersion pattern along the coast with the prevailing north-easterly and south-westerly winds is again evident. So too are the sources of industrial emission at Tongaat, the Outer West, the Port of Durban and the South Industrial Basin, as well as Umkomaas.

Motor vehicle emissions are the largest source of NO_X in eThekwini (Table 3-15). Motor vehicle emissions were not quantified at street level and therefore could not be parameterised effectively for dispersion modelling. The relatively high measured concentrations of NO_2 at the traffic monitoring stations in eThekwini are therefore not shown in the dispersion modelling results, i.e. City Hall, Jacobs and Ganges.

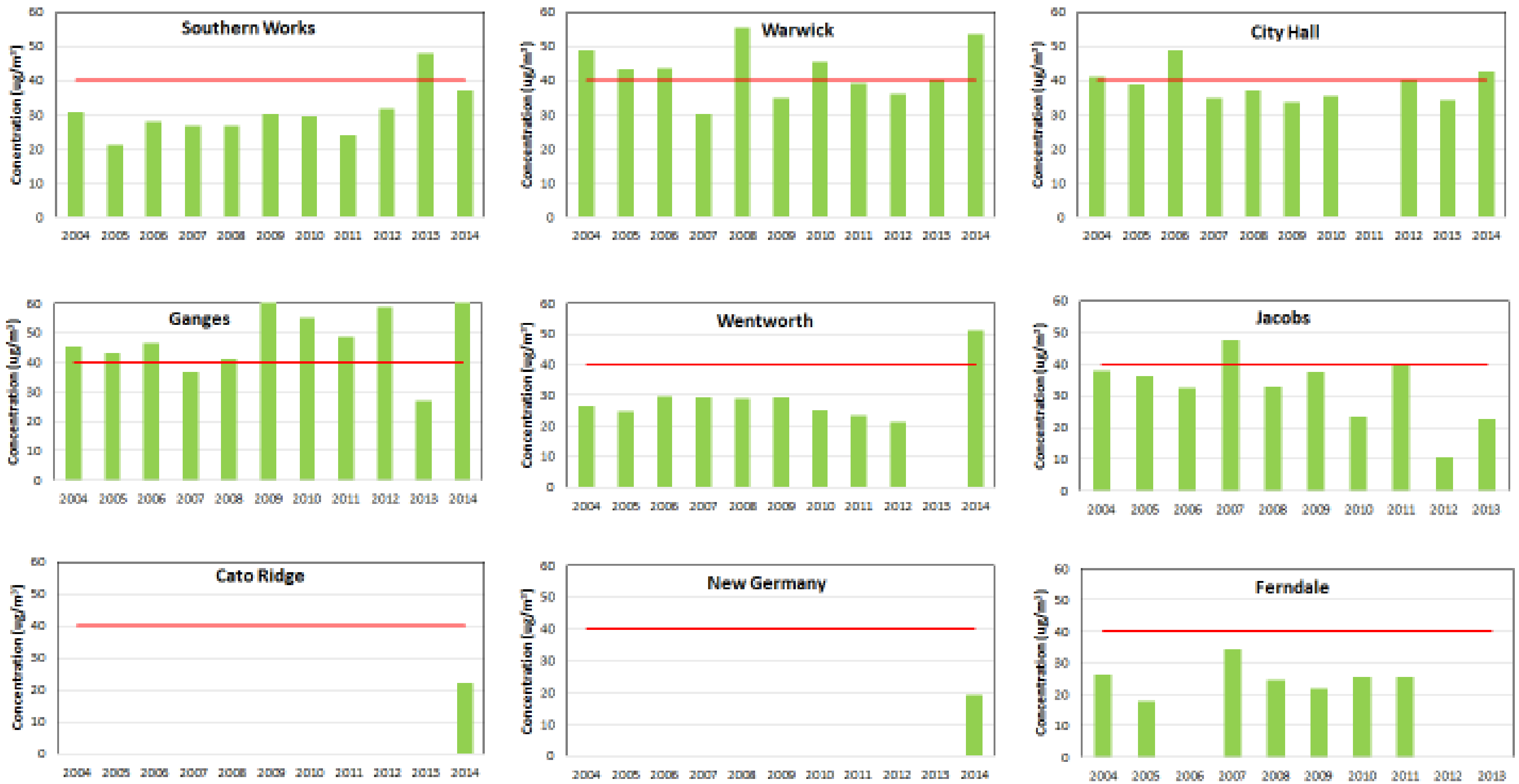


Figure 3-27: Annual average NO_2 concentrations at eThekwini monitoring stations in µg/m³, showing the NAAQS of 40 µg/m³

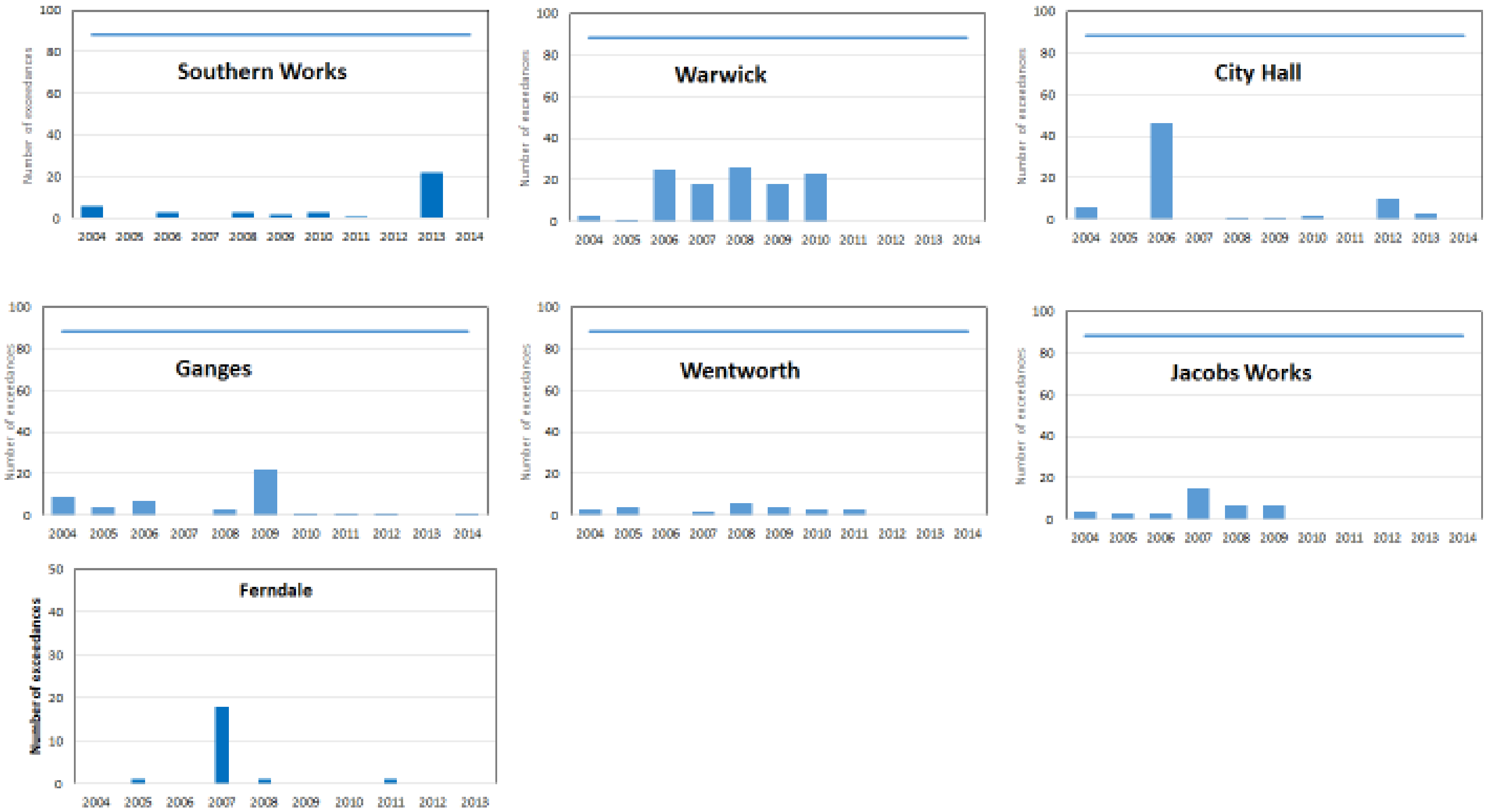


Figure 3-28: Number of exceedances of the 1-hour limit value of the NAAQS for NO_2 at eThekwini monitoring stations

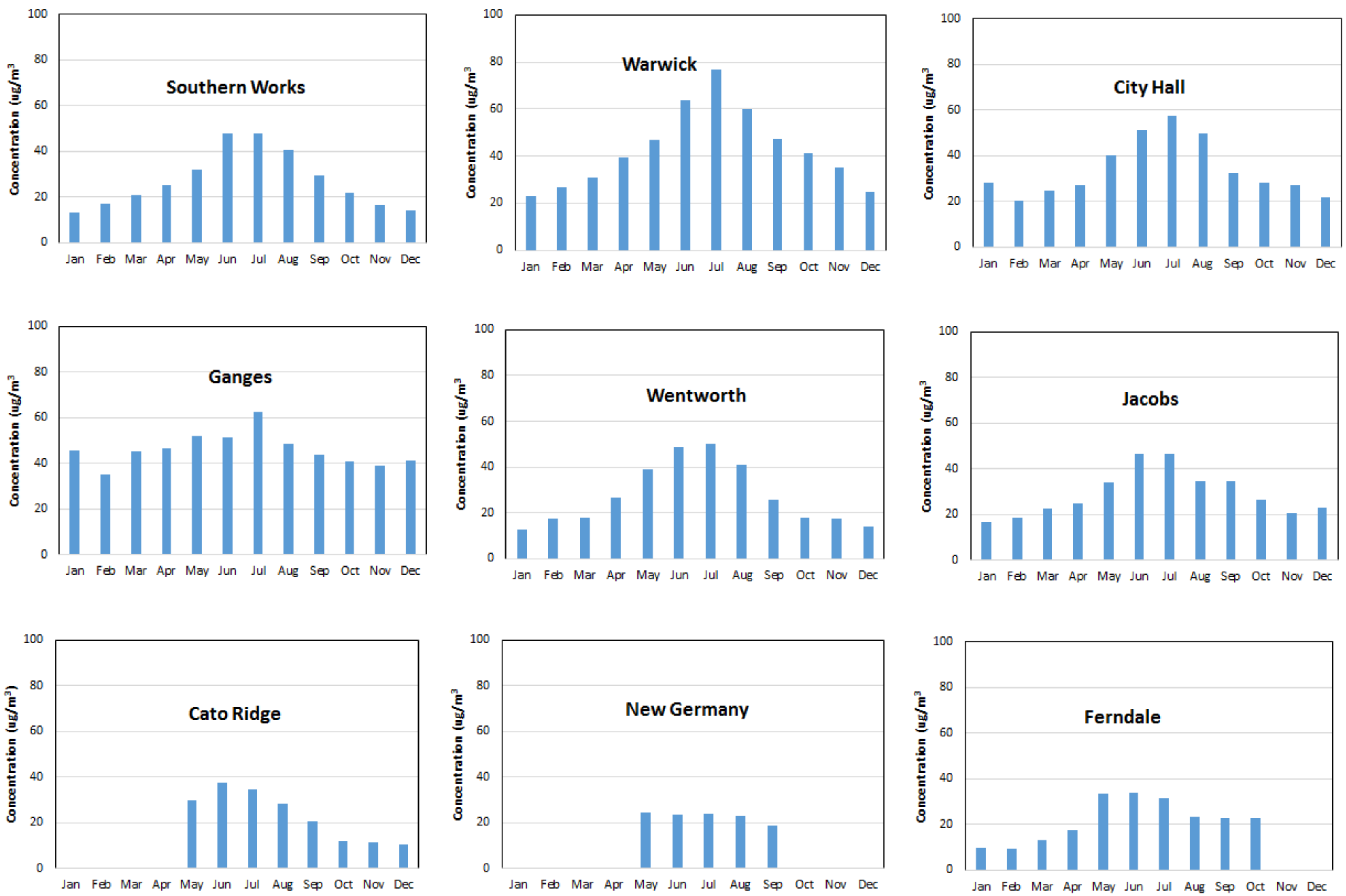


Figure 3-29: Average monthly ambient NO_2 concentration for available data from 2004 to 2014 at eThekwini monitoring stations

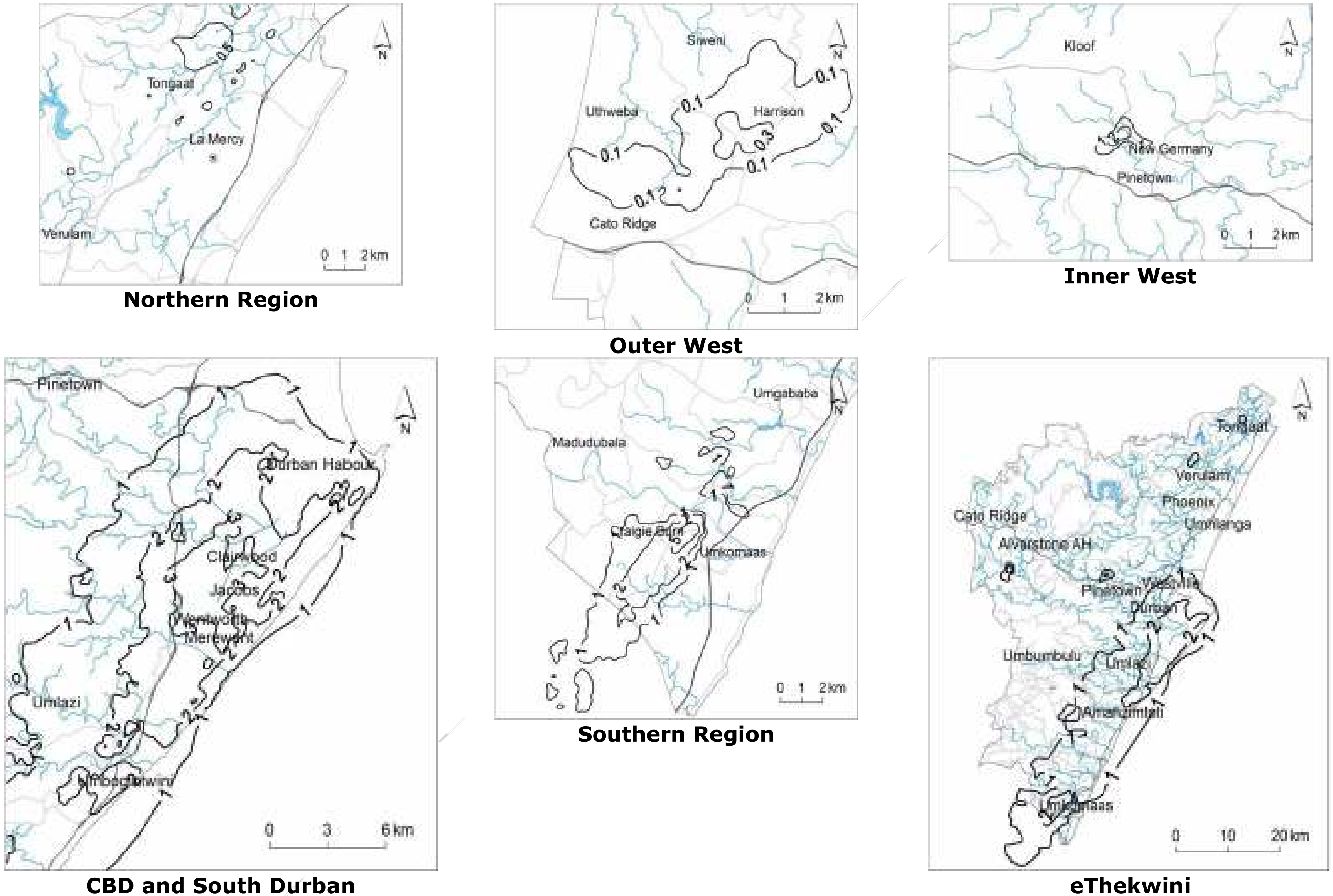


Figure 3-30: Modelled annual ambient NO_2 concentrations in µg/m^3 resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains

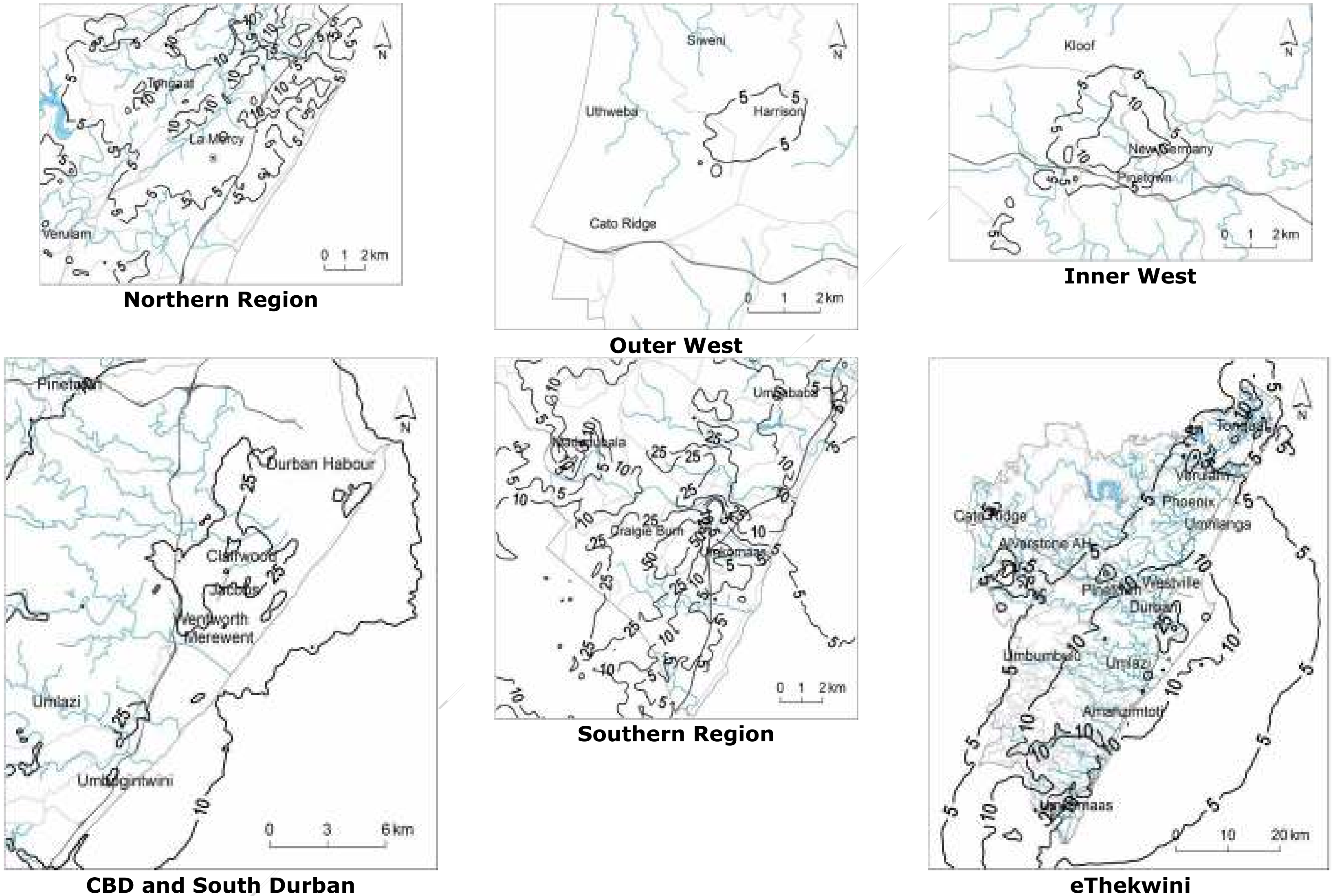
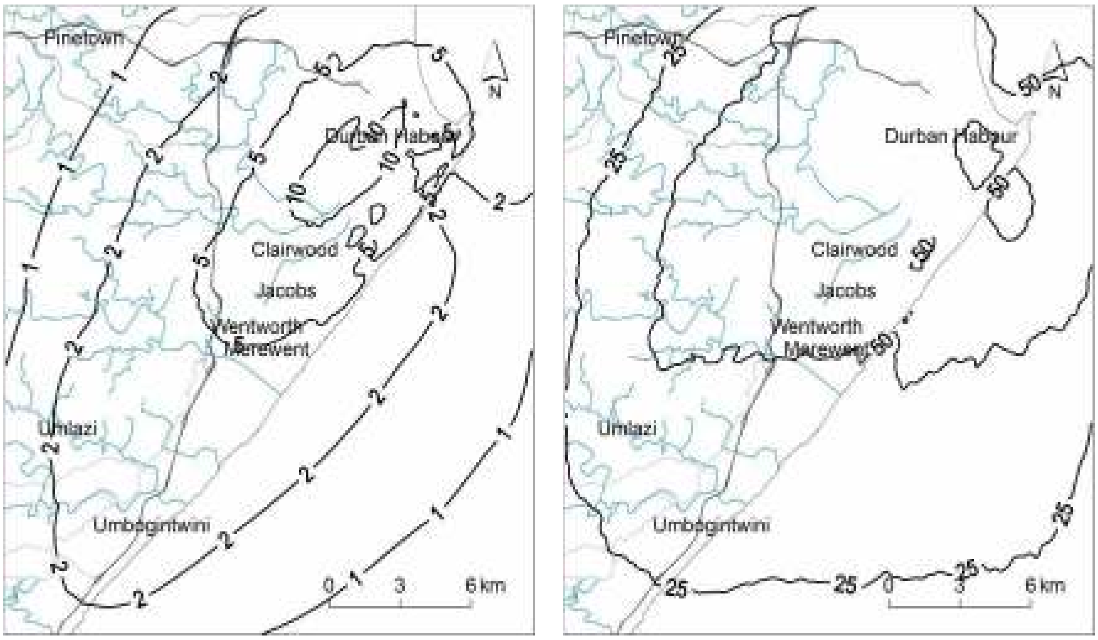
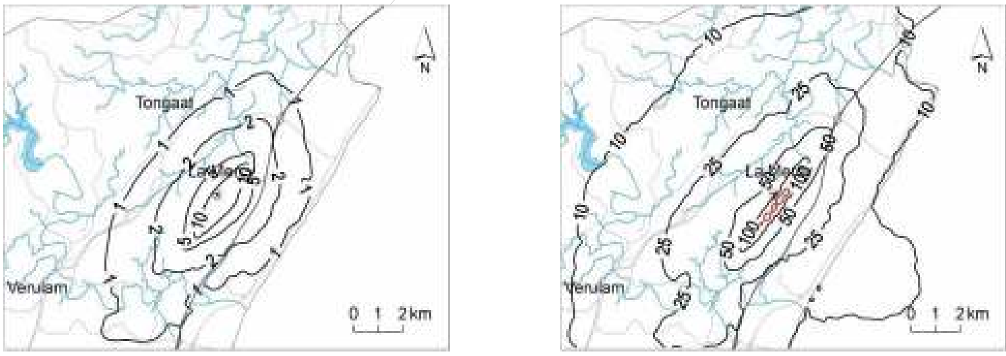


Figure 3-31: Modelled 99th percentile of 1-hour NO_2 concentrations in µg/m³ resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains



Annual ***1-hour***

Figure 3-32: Modelled annual ambient NO_2 concentrations (left), the 99th percentile of 1-hour NO_2 concentrations (right) in µg/m^3 in the CBD and South Durban domain resulting from emissions from the Port of Durban



Annual **1-hour**

Figure 3-33: Modelled annual ambient NO_2 concentrations (left), the 99th percentile of 1-hour NO_2 concentrations (right) in µg/m^3 in the Northern domain resulting from emissions from King Shaka International Airport

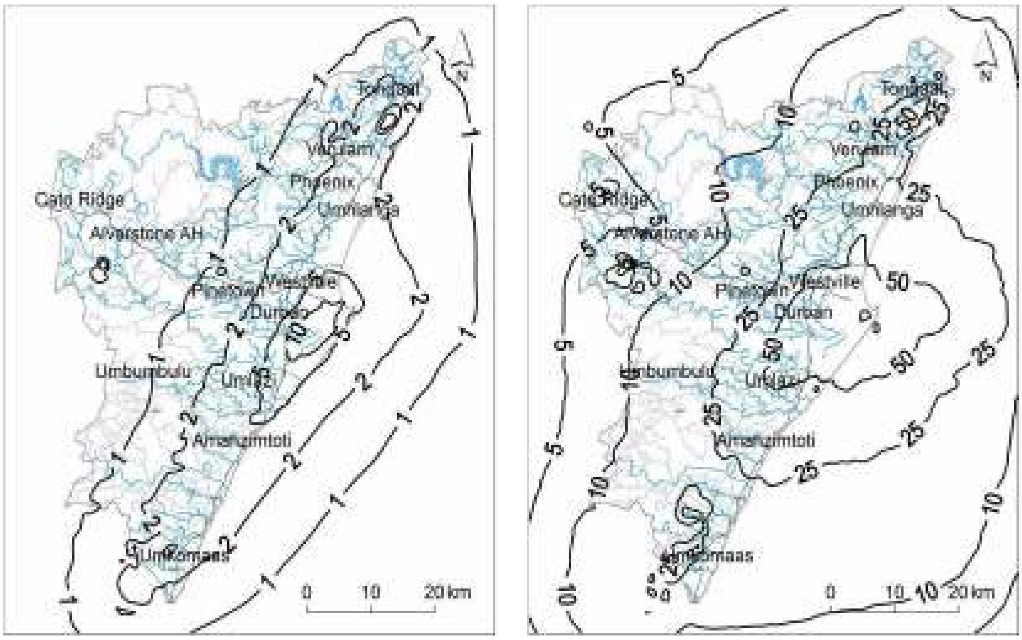


Figure 3-34: Modelled annual ambient NO_2 concentrations (left), the 99th percentile of 1-hour NO_2 concentrations (right) in µg/m³ in eThekwini resulting from emissions from Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport

Points for consideration in the AQMP regarding NO_2

a) NO_X has been monitored by using a real-time network since 2004
b) NO_2 concentrations are relatively high, the number of exceedances of the 1-hour limit value are relatively low
c) The exceedances at City Hall, Ganges and Warwick are likely to be related to traffic emissions while exceedances at Southern Works are most likely attributed to industrial emissions. The number of exceedances are well below the tolerance value of 88 per year
d) Ambient NO_2 concentrations show a seasonal variation and are relatively higher in winter

3.2.3 Particulates

Particulate matter is a broad term used to describe the fine particles found in the atmosphere, including soil dust, dirt, soot, smoke, pollen, ash, aerosols and liquid droplets. The most distinguishing characteristic of PM is the particle size and chemical composition. Particle size has the greatest influence on the behaviour of PM in the atmosphere and on human exposure through inhalation. Smaller particles tend to have longer residence times than larger ones and may penetrate deeper into the lungs. ***PM_{10}*** describes all particulate matter in the atmosphere with a diameter equal to or less than 10 µm while ***$PM_{2.5}$*** describes all particulate matter with a diameter equal to or less than 2.5 µm. They are criteria pollutants known to impact negatively on human health. National ambient air quality standards have been set for PM_{10} and $PM_{2.5.}$ More information on particulates can be found in Appendix 5.

The limit value of the NAAQS for PM_{10} is 40 µg/m^3, lowered from 50 µg/m^3 on 1 January 2015. At the same time the limit value of the 24-hour NAAQS for PM_{10} was lowered from 120 µg/m^3 to 75 µg/m^3. In this assessment of historic and current status of $PM_{10,}$ reference is made to both standards when necessary.

PM_{10} is measured at 10 of the continuous monitoring stations in eThekwini (Table 3-17) and more recently $PM_{2.5}$ at Southern Works. The intention is to understand the contribution of emissions from industrial sources and motor vehicles on ambient air quality. A further purpose of the monitoring is to develop an understanding of the background concentrations of PM_{10}.

The average annual ambient concentrations of PM_{10} are relatively high at City Hall and Ganges throughout the evaluation period, but is consistently below the previous SAAQS limit value of 50 µg/m^3 (Figure 3-35). At Wentworth the annual average concentration was relatively high until 2010, and at Southern Works until 2007, but consistently compliant with the NAAQS. Wentworth is affected by industry and traffic, while Southern Works is mostly an industrial site. The switch to cleaner fuels by industry in the South Industrial Basin has brought about decreases in ambient concentrations, observed at Southern Works (Figure 3-35). Currently the annual average ambient concentrations of NO_2 are well below the previous SAAQS limit value of 40 µg/m^3 throughout eThekwini. The average annual ambient $PM_{2.5}$ concentrations at Southern Works has been below the limit value of the NAAQS since monitoring started in 2011 (Figure 3-36).

The annual average PM_{10} concentrations are relatively high and the number of exceedances of the 24-hour limit value surpassed the tolerance provided for in the NAAQS at Wentworth, Ganges and City Hall between 2004 and 2009 (Figure 3-37). The NAAQS allowed for 4 exceedances per year of the 24-hour limit value of 50 µg/m^3, applied at the time. In 2010 a marked decrease in the number of exceedances was observed. In 2009, 105 exceedances of the 24-hour limit value were recorded in eThekwini, decreasing to 3 exceedances in 2011, 4 in 2012 and 3 in 2013. There is some evidence in the PM_{10} data which reflect the phasing-out of leaded petrol from 2006 and the availability of low-sulphur diesel with lower ambient concentrations from 2006 onward and fewer exceedances of the limit value of the NAAQS. Similarly with $PM_{2.5}$, a number of exceedances of the 24-hour limit value occurred at Southern Works, particularly in 2007 and 2010 (Figure 3-38).

Average ambient PM_{10} concentrations exhibit a marked seasonal variation at all eThekwini Municipality's monitoring sites, with relatively higher ambient concentrations in winter than in summer (Figure 3-39). This variation is expected and results from the combined effects of stable winter meteorology and the increased contribution of particulates from long-range transport from the interior. The same seasonal variation is seen in average $PM_{2.5}$ concentrations at Southern Works.

Regional scale transport of air pollutants from the industrialised interior of South Africa, and from biomass burning increases background concentrations of pollutants in eThekwini Municipality (see Section 2.3). Evaluation of data from eThekwini's new stations that are not directly influenced by local sources of PM_{10} provides an indication of the background PM_{10} concentration. These are Cato Ridge and Amanzimtoti where the annual average concentration in 2014 was 15.2 μg/m^3 and 16.5 μg/m^3 respectively. Therefore it appears that background sources of PM_{10} contribute about 16 μg/m^3 to ambient PM_{10} concentrations in eThekwini. This concentration is added in the dispersion modelling simulations so that the background contribution is included in the predictions.

Modelled annual ambient PM_{10} concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-40 for each of the 5 modelling regions and eThekwini as a whole. There are no dominant sources of PM_{10} in eThekwini Municipality and the contribution of the background value of 16 μg/m^3 is clearly evident in the predicted outputs. The incremental contribution of emissions from industrial sources is small and ranges between 1 μg/m^3 by sources in the Outer West to 4 μg/m^3 in the Clairwood and Jacobs area. The predicted annual ambient PM_{10} concentrations are well below the NAAQS of 40 μg/m^3 throughout eThekwini Municipality.

The modelled 99th percentile of the 24-hour maximum PM_{10} concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-41 for each of the 5 modelling regions and eThekwini as a whole. Again the incremental contribution by industry over the baseline of 16 μg/m^3 ranges from about 1 μg/m^3 in the Outer West to about 24 μg/m^3 in the Clairwood and Jacobs area. The predicted 24-hour ambient PM_{10} concentrations are below the NAAQS of 75 μg/m^3 throughout the eThekwini Municipality.

The modelled annual ambient PM_{10} and the 99th percentile of 24-hour PM_{10} concentrations resulting from emissions from the Port of Durban are presented in Figure 3-42 for the CBD and South Durban domain. The emissions from the Port of Durban add a little more than 1 μg/m^3 to the predicted annual concentrations and about 6 μg/m^3 to the 24-hour predictions. The predicted concentrations are well below the respective NAAQS for PM_{10}.

King Shaka International Airport is not a large source of PM_{10}. The modelled annual ambient PM_{10} concentrations and the 99th percentile of 24-hour PM_{10} concentrations resulting from emissions from KSIA are presented in Figure 3-43 for the CBD and South Durban domain. The emissions from the airport add less than 1 μg/m^3 to the predicted annual concentrations and about 2 μg/m^3 to the 24-hour predictions. The predicted concentrations are well below the respective NAAQS for PM_{10}.

Modelled annual ambient PM_{10} concentrations resulting collectively from background contributions and emissions from Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport in eThekwini are presented in Figure 3-44. These sources add about 2 µg/m^3 to the predicted annual concentrations and about 14 µg/m^3 to the 24-hour predictions. Collectively from all sources the predicted PM_{10} concentrations are well below the respective NAAQS for PM_{10}.

The dispersion pattern of PM_{10} along the coast with the prevailing north-easterly and south-westerly winds is again clearly evident. So too are the sources of industrial emission in the respective modelling domains.

Motor vehicles are the largest source of PM_{10} in eThekwini (Table 3-15). Motor vehicle emissions were not quantified at street level and therefore could not be parameterised effectively for dispersion modelling. The relatively high measured concentrations of PM_{10} at the traffic monitoring stations in eThekwini are therefore not shown in the dispersion modelling results, i.e. City Hall, Ferndale and Ganges.

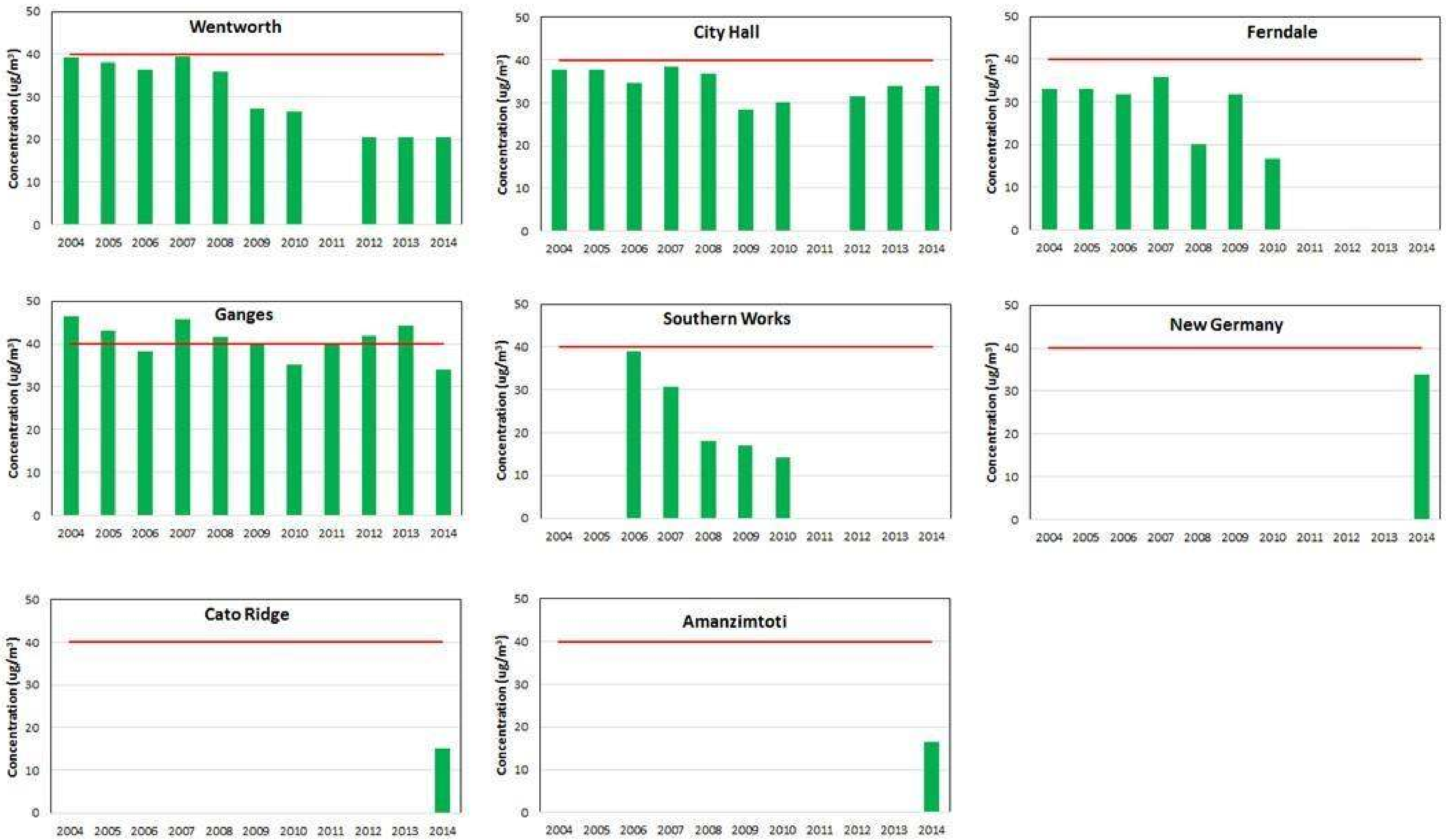


Figure 3-35: Annual average PM_{10} concentrations measured in eThekwini from 2004 to 2014 compared with the limit value of the NAAQS of 40 µg/m^3

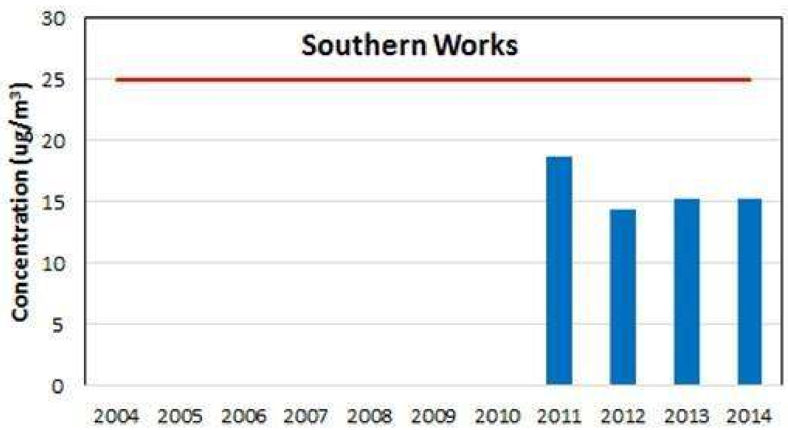


Figure 3-36: Annual average $PM_{2.5}$ concentrations measured in eThekwini from 2011 compared with the limit value of the NAAQS of 25 µg/m^3

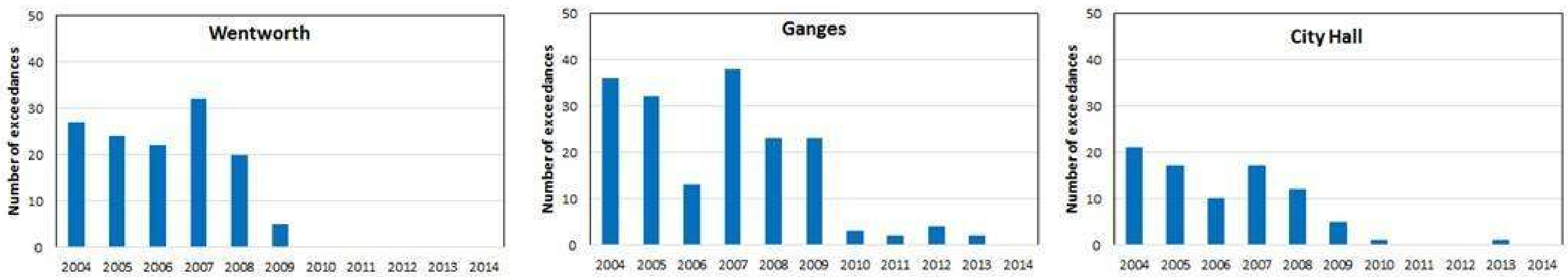


Figure 3-37: Number of exceedances of the 24-hour limit value of 75 µg/m^3 for PM_{10} at Wentworth, Ganges and City Hall from 2004 to 2014

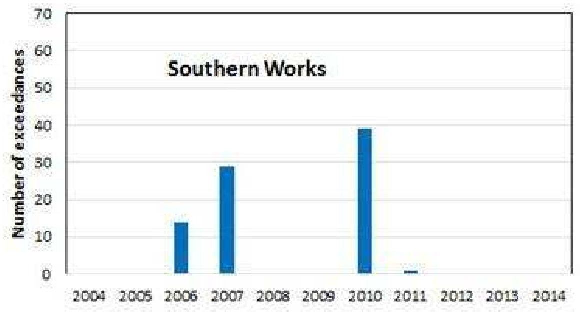


Figure 3-38: Number of exceedances of the 24-hour limit value of 65 µg/m³ for $PM_{2.5}$ at Southern Works

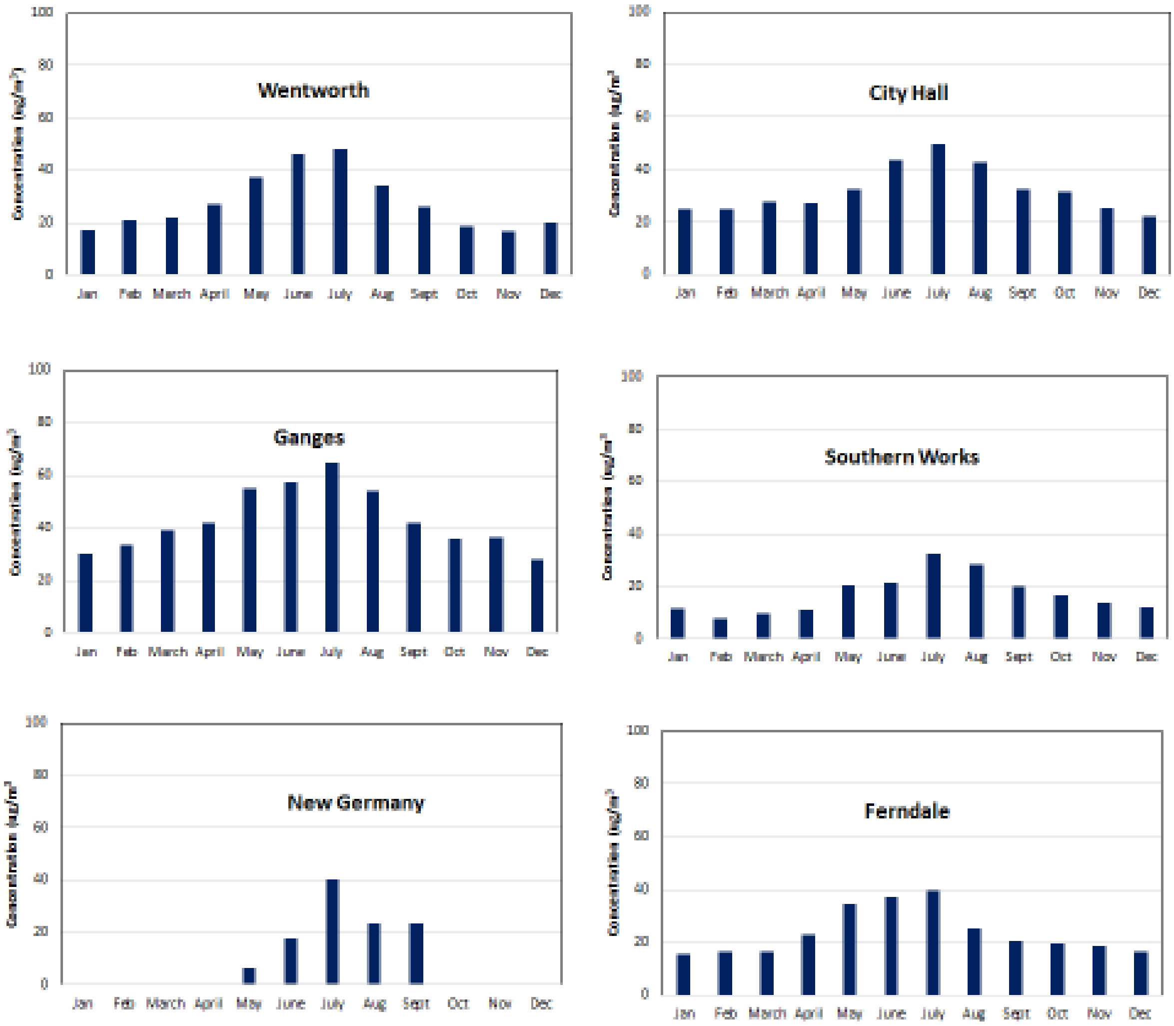
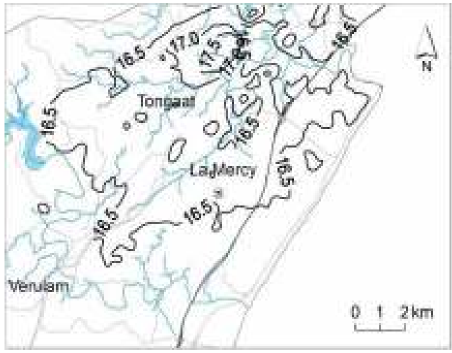
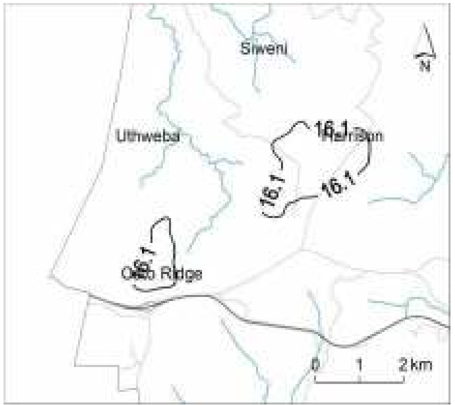


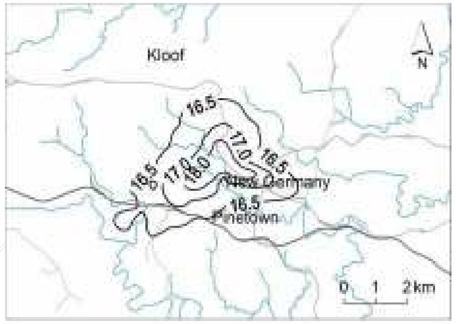
Figure 3-39: Average monthly ambient PM_{10} concentration for available data from 2004 to 2014 at eThekwini monitoring stations



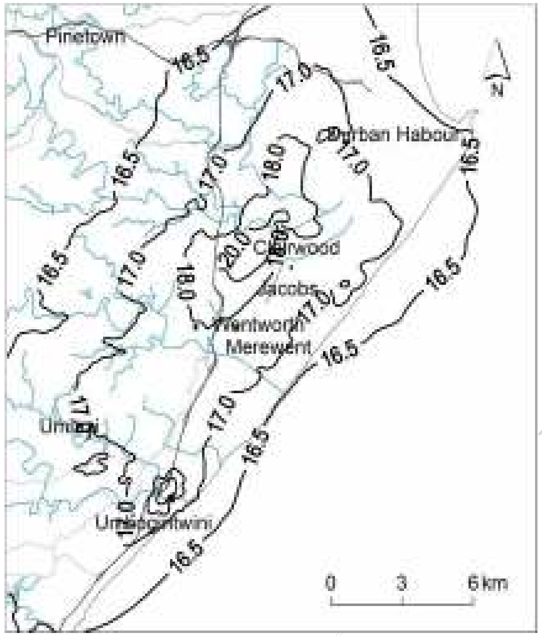
Northern Region



Outer West



Inner West



CBD and South Durban

Southern Region

eThekwini

Figure 3-40: Modelled annual ambient PM_{10} concentrations in µg/m^3 resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains

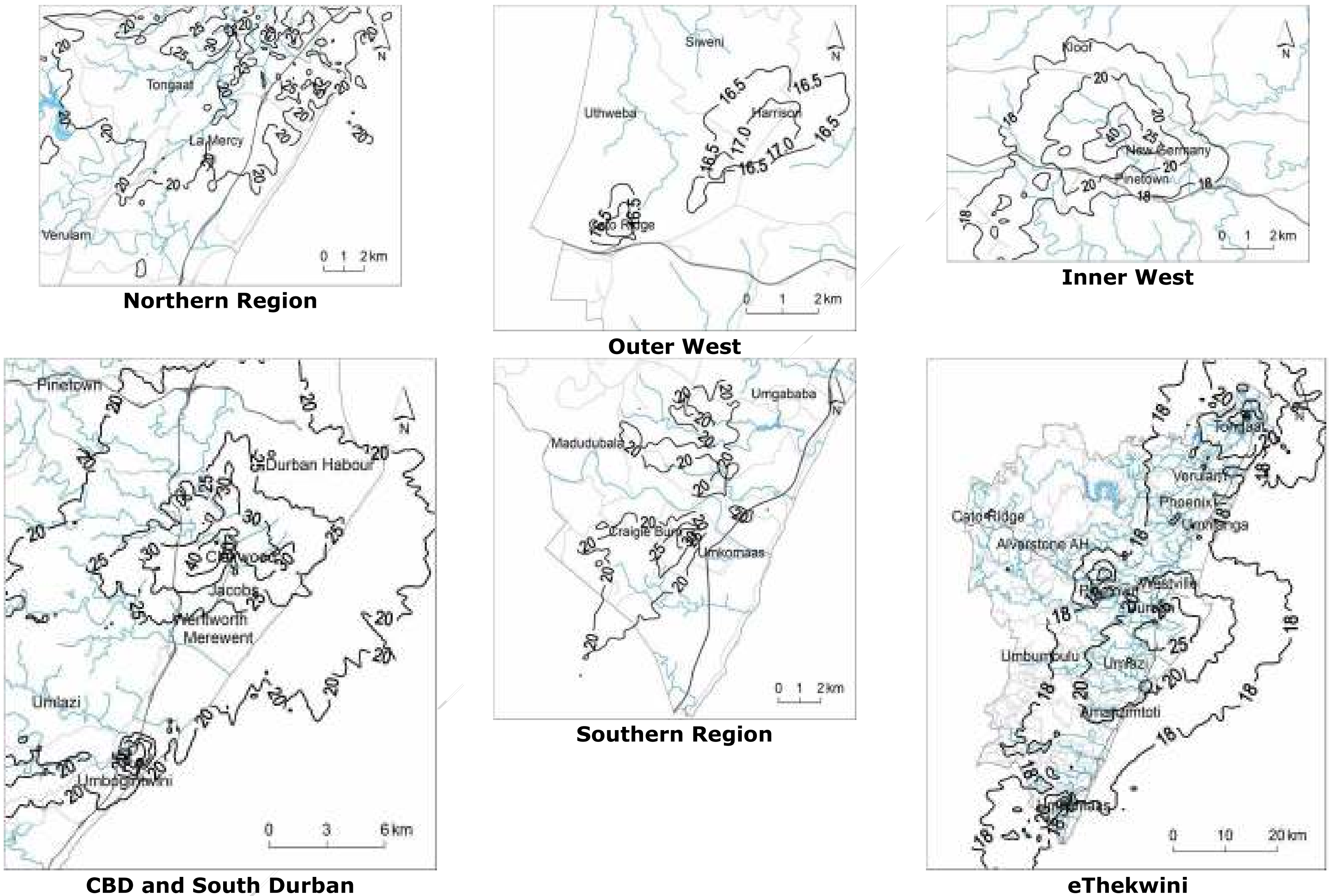
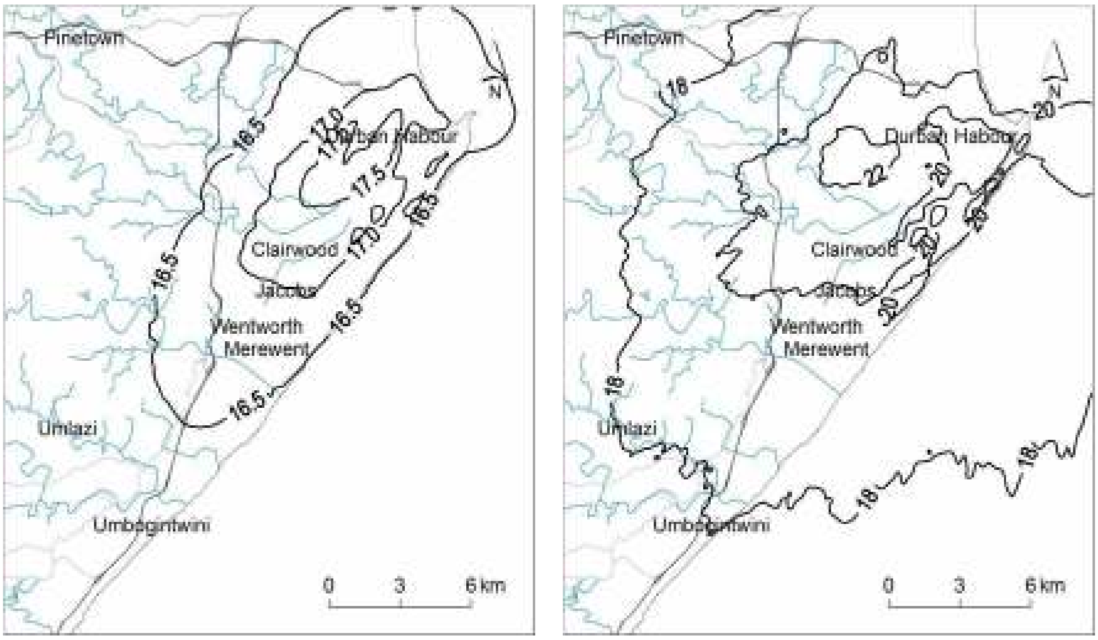
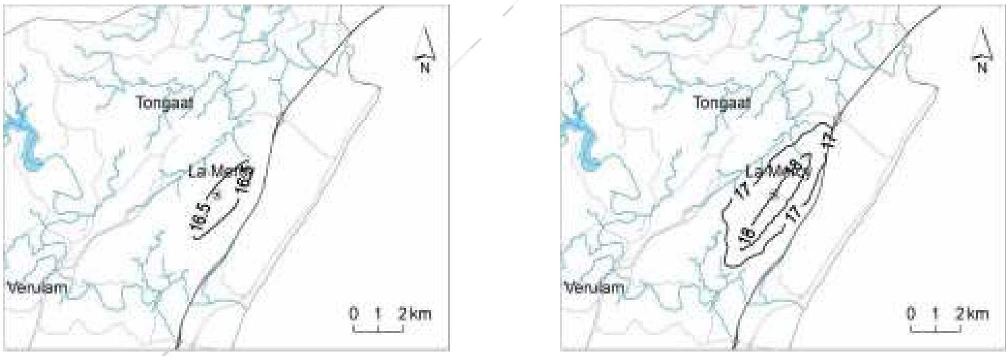


Figure 3-41: Modelled 99th percentile of 24-hour PM_{10} concentrations in µg/m^3 resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) in the six modelling domains



Annual ***1-hour***

Figure 3-42: Modelled annual ambient PM_{10} concentrations (left), the 99th percentile of 24-hour PM_{10} concentrations (right) in µg/m³ in the CBD and South Durban domain resulting from emissions from the Port of Durban



Annual **1-hour**

Figure 3-43: Modelled annual ambient PM_{10} concentrations (left), the 99th percentile of 24-hour PM_{10} concentrations (right) in µg/m³ in the Northern domain resulting from emissions from King Shaka International Airport

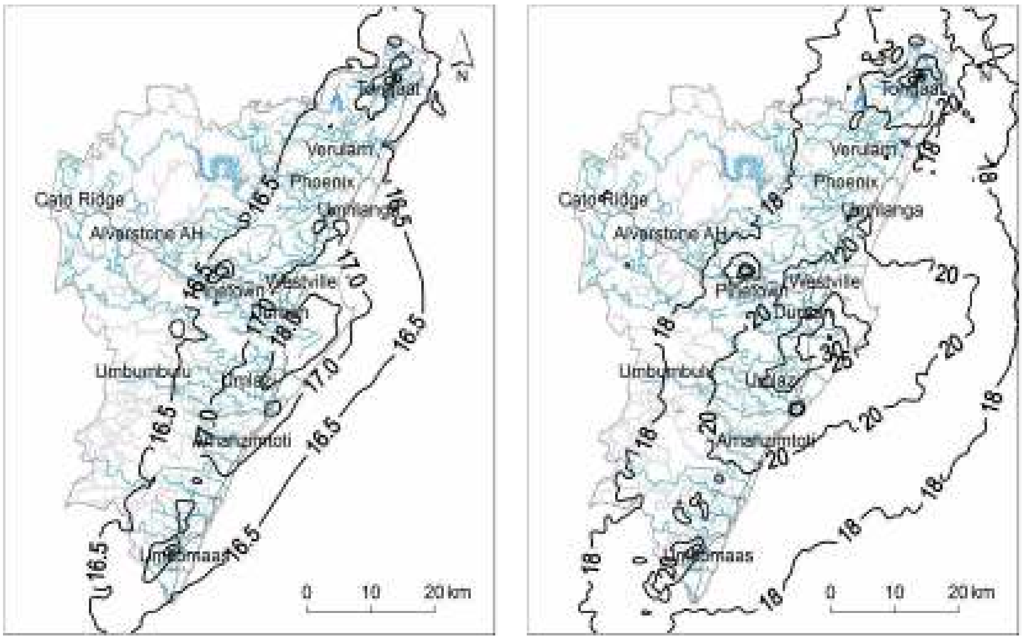


Figure 3-44: Modelled annual ambient PM_{10} concentrations (left), the 99th percentile of 1-hour PM_{10} concentrations (right) in µg/m^3 in eThekwini resulting from emissions from Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport

Points for consideration in the AQMP regarding particulates

a) PM_{10} and more recently, $PM_{2.5}$, are monitored throughout eThekwini Municipality
b) The background concentration of PM_{10} in eThekwini is approximately 16 µg/m^3
c) Monitored PM_{10} concentrations are relatively high in eThekwini, but generally comply with the NAAQS, except at the Ganges traffic monitoring site
d) The relatively high measured concentrations of PM_{10} at the traffic monitoring stations in eThekwini are not shown in the dispersion modelling results as motor vehicle emission were not quantified in sufficient detail
e) Collectively modelled concentrations from industrial, port and airport emissions add between 1 and 14 µg/m^3 to the background concentration

3.2.4 Benzene (C_6H_6)

Benzene (C_6H_6) is a natural component of crude oil, petrol, diesel and other liquid fuels and is emitted when these fuels are stored or combusted. It is one of many volatile organic compounds, is a carcinogen and is classified as a toxic pollutant. National ambient air quality standards have been set for benzene. Read more on benzene in Appendix 5. In eThekwini, crude oil refining, bulk storage and handling of petroleum products, fuel combustion by industry and motor vehicles are sources of benzene.

eThekwini Municipality has conducted monitoring campaigns using passive samplers to measure ambient benzene concentrations in high traffic zones and background sites around the city. Bissett (2004) conducted a passive sampling campaign at 17 BTEX monitoring sites in eThekwini Municipality in 2003. The Warwick Triangle Air Pollution Health Assessment Project (eThekwini, 2014) is another example. In the 2003 campaign, the highest 11 day average benzene concentration of 8.0 µg/m^3 was recorded at Turner Street, followed by 7.1 µg/m^3 at Settlers School, 6.7 µg/m^3 at Lower Bluff Road and 5.9 µg/m^3 at Warwick Avenue. Later measurements in the health assessment (eThekwini, 2014) confirm high benzene concentrations in Warwick Avenue during the 4-week sampling period.

Routine monitoring in eThekwini reveals that the annual average benzene concentration complied with the annual NAAQS of 10 µg/m^3 at all sites in eThekwini at the time (Figure 3-45). The annual average concentrations were elevated at monitoring sites in Warwick Triangle, Settlers School, Amanzimtoti and Leeds Crescent in Pinetown where the 2015 NAAQS of 5 µg/m^3 is exceeded. It is noteworthy that Settlers School is an industrial site rather than a traffic site.

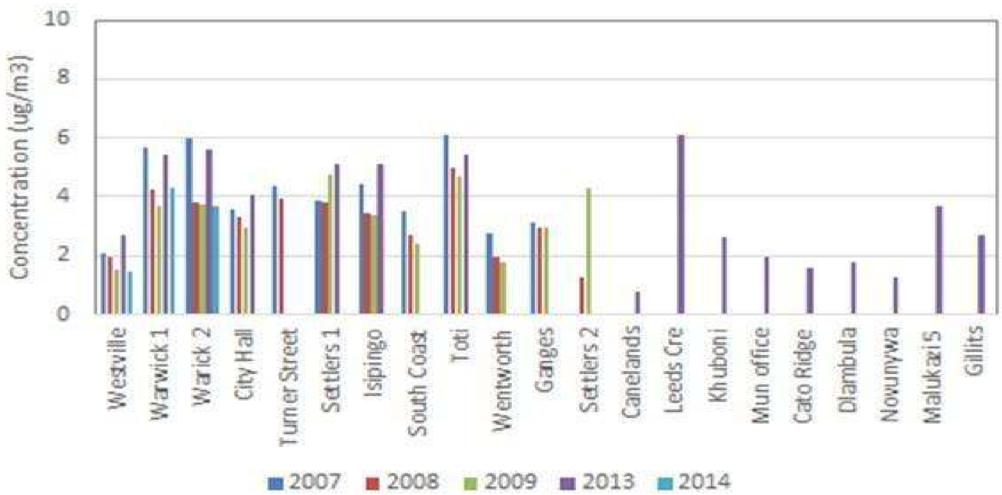


Figure 3-45: Annual average benzene concentrations in eThekwini Municipality in µg/m^3 from 2007 to 2014

eThekwini Municipality has operated a continuous monitor at Settlers School since 2011 measuring hourly ambient benzene concentrations. The annual average concentration was below the NAAQS at the time, i.e. 10 μg/m^3. It must be noted that the benzene concentrations measured at Settlers School are consistently above the NAAQS that was implemented on 1 January 2015, i.e. 5 μg/m^3 (Table 3-19).

Table 3-19: Annual average benzene concentration at Settlers School from 2011 to 2013

Year	Annual average (μg/m^3)
2011	1.85
2012	5.04
2013	5.03

Ambient benzene concentrations are also monitored at the School and in the area neighbouring the Engen Refinery, SAPREF and FFS Refiners as a requirement of their respective AELs. Engen Refinery has been operating a network of six monitoring stations since 2010. At all of the sites, the annual average concentration of benzene was below the NAAQS at the time of 10 μg/m^3 with the highest concentration at the Main Gate of the refinery and the fence on Badulla Road in 2011 (Table 3-20). Since 2012 the annual average benzene concentrations have been consistently below the current NAAQS of 5 μg/m^3, with the highest concentrations at the same two monitoring points. Similarly, annual average ambient benzene concentrations on the Sapref fenceline and in the neighbouring environment are well below the NAAQS (Table 3-21).

Table 3-20: Annual average benzene concentrations measured by Engen Refinery from 2010 to 2014 in μg/m^3 (Engen Refinery, 2015)

Monitoring point	2010	2011	2012	2013	2014
Admin block	3.2	4.5	4.1	2.8	1.8
Main gate	3.7	6.8	3.6	4.0	2.0
Mosque	3.2	5.0	2.6	2.7	1.4
Recreational Club	2.9	4.8	3.3	3.0	1.9
Badulla Road fence	5.2	9.2	4.4	3.9	2.1
Southern Works	2.8	3.5	2.0	2.5	1.3

Table 3-21: Annual average benzene concentrations measured by Sapref from 2012 to 2014 in μg/m^3 (Sapref, 2015)

	2012	2013	2014
West of Sapref	0.5	0.7	0.9
Sapref Training Centre	0.8	0.6	0.8
Athlone Park	1.1	0.4	0.6
South Westerly of SAPREF	1.5	0.5	0.7
Umlaas Canal	1.7	1.5	1.1

FFS Refiners have monitored benzene since 2009. With the exception of 2012 at the Main Gate, the annual average concentrations have been consistently below the NAAQS at the time of 10 µg/m^3 (Table 3-22). On note is the exceedance of the current NAAQS of 5 µg/m^3 at the Main Gate and at the monitoring point at The Hub in 2013.

Table 3-22: Annual average benzene concentrations measured by FFS Refiners from 2009 to 2013 in µg/m^3 (FFS Refineries, 2015)

	2009	2010	2011	2012	2013
Tanks (on site)	6.7	9.8	4.0	8.9	4.
Cooling tower (on site)	8.8	8.5	4.6	4.3	6.6
Main gate	4.5	7.1	5.7	14.2	7.0
The Hub	2.1	5.9	2.6	2.3	8.4
Defy			2.3	2.3	3.0
Precision Spring Manufacturing			6.5	3.9	4.1

Modelled annual ambient benzene concentrations resulting from emissions from industrial sources (Listed Activities and Controlled Emitters) are presented and compared in Figure 3-46 for eThekwini Municipality and the CBD and South Durban domain. The highest concentrations occur in the South Industrial Basin where the predicted annual average concentrations exceed the NAAQS of 5 µg/m^3 in the Wentworth/Merewent area and in the vicinity of the Umlaas Canal. This corresponds with the monitoring results at Southern Works. The annual average concentrations resulting from the bulk petrochemical storage facilities in the Island View area are predicted to be below the NAAQS.

Motor vehicles are a relatively large source of benzene in eThekwini (Table 3-15). Motor vehicle emissions were not quantified at street level and therefore could not be parameterised effectively for dispersion modelling. The relatively high measured concentrations of benzene at traffic sites in eThekwini are therefore not shown in the dispersion modelling results, i.e. Warwick, Isipingo and Amanzimtoti.

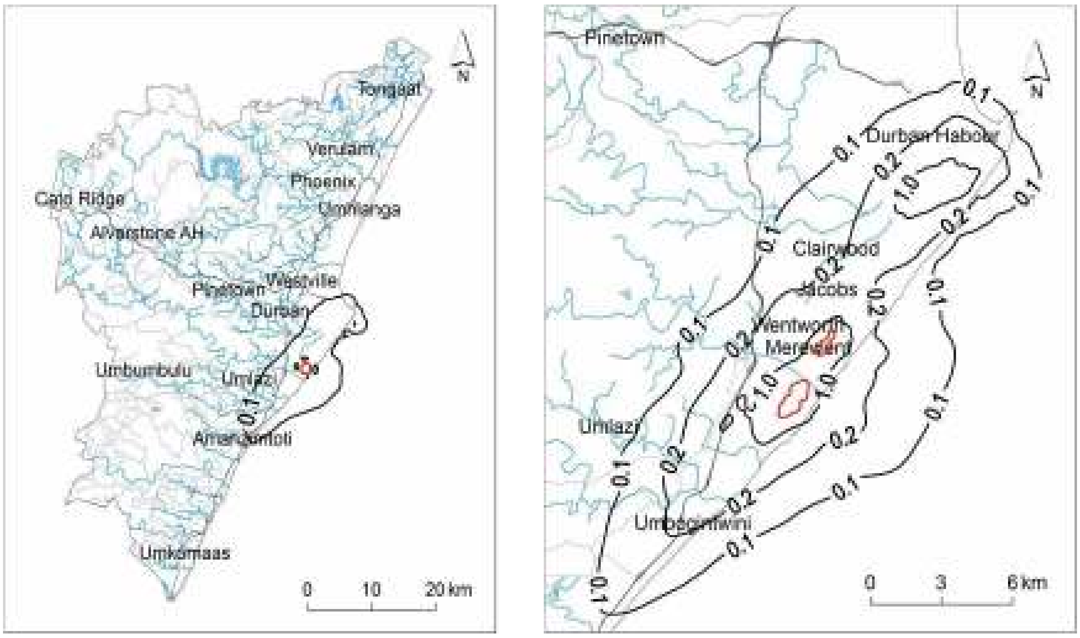


Figure 3-46: Modelled annual ambient benzene concentrations in µg/m^3 in eThekwini Municipality (left) and the CBD and South Durban domain (right) resulting from emissions from industrial sources (Listed Activities and Controlled Emitters)

Points for consideration in the AQMP regarding benzene

a) Annual ambient concentrations of benzene are relatively high at areas with high traffic volumes, such as Warwick Triangle, Turner Street, Isipingo and Amanzimtoti

b) Annual ambient concentrations of benzene are relatively high at Settlers School which is impacted on by emissions from industrial sources and the Southern Treatment Works

c) Dispersion modelling confirms relatively high benzene concentrations in the South Industrial Basin

3.2.5 Ozone (O_3)

There are no sources of ozone (O_3). Rather it forms in the atmosphere as a secondary pollutant through the reaction of hydrocarbons and oxides of nitrogen in sunlight. It is a criteria pollutant and exposure through inhalation can impact negatively on human health. National ambient air quality standards have been set for O_3. Read more in Appendix 6.

Generally O_3 is not found in high concentrations close to the source of the precursor gases. Rather O_3 forms in situ as the precursor gases disperse with the highest concentrations some distance downwind. Due to the numerous sources of precursor gases and the reaction time for O_3 formation, it is considered a regional-scale pollutant. Monitoring for O_3 is typically representative of a region. In eThekwini O_3 background monitoring is conducted at Alverstone (Table 3-17). O_3 is also monitored at Wentworth. Ambient O_3 concentrations at Alverstone are typically higher than at Wentworth because O_3 is consumed closer to the precursor sources, in the photo oxidation of NO and NO_2. Ozone exhibits a clear seasonal signal over southern Africa, and indeed in Durban, with the maximum occurring in spring. This coincides with the peak in regional scale (sub-continental) biomass burning and the preferred movement of gas and particulate matter via the transport corridor to the Indian Ocean. This is evident in the monthly average ozone concentrations at Alverstone in 2013 (Figure 3-47).

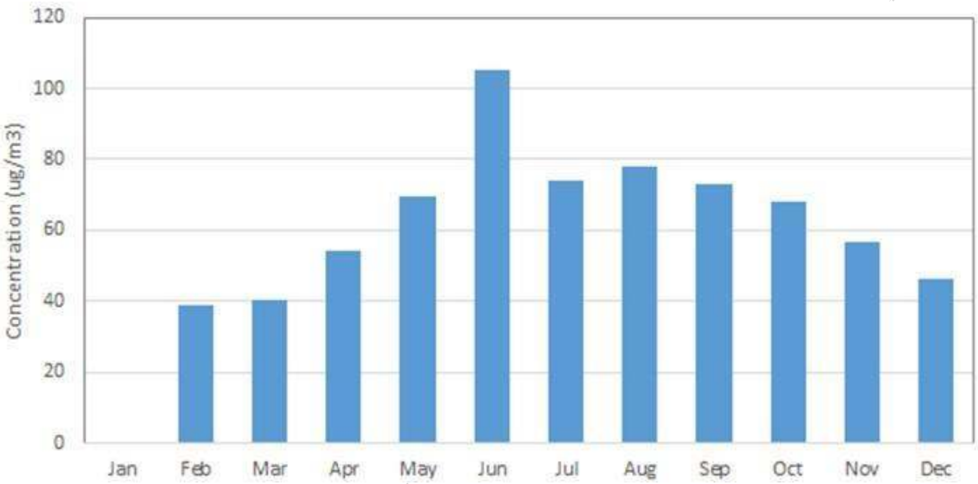


Figure 3-47: Monthly average ambient O_3 concentrations in μg/m^3 at Alverstone in 2013

The limit value of the ambient standard for ozone, unlike other pollutants, is an 8-hour running mean. The US-EPA determined that the original 1-hour ozone standard did not fully protect public health. Therefore, more emphasis was placed on prolonged exposure to ozone in the 1997 review of NAAQS and promulgated in the 8-hour standard, with a strengthened limit value. The South African NAAQS for O_3 followed this trend with the limit value of the 8-hour standard set at 120 μg/m^3, with 11 permitted exceedances per annum.

The ambient O_3 concentrations measured at Wentworth have consistently complied with the NAAQS (Figure 3-48). Ambient ozone concentrations are higher at Alverstone, as mentioned earlier, and 11 exceedances of the 8-hour limit value were recorded in 2005, and 15 in 2013. No measurements were done in 2011 and 2012.

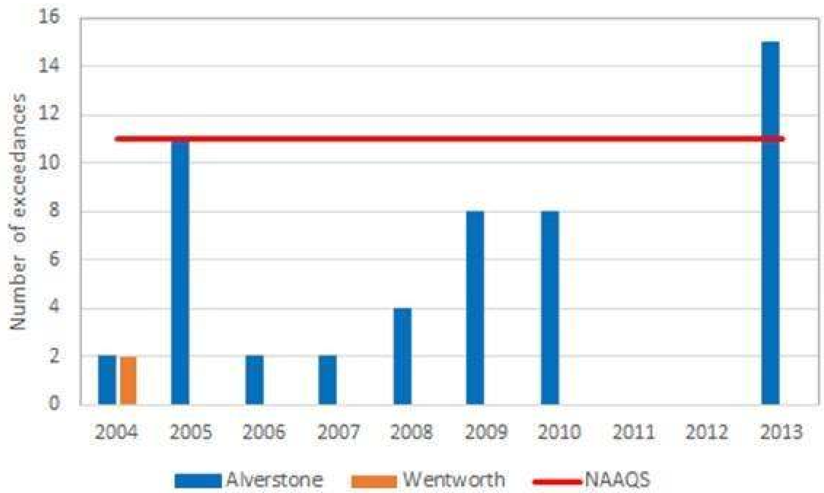


Figure 3-48: Number of exceedances of the limit value of the 8-hour NAAQS for O_3 between 2004 and 2013, showing the permitted number of exceedances

Points for consideration in the AQMP regarding O_3

a) O_3 is measured at Alverstone and Wentworth in eThekwini Municipality
b) The background O_3 concentrations are relatively high and exceedances of the NAAQS have occurred
c) O_3 is a regional pollutant and is impractical to manage on a municipal scale

3.2.6 Carbon monoxide (CO)

CO is a product of incomplete combustion of fossil fuels, predominantly formed in internal combustion engines of motor vehicles. It is a criteria pollutant and exposure through inhalation can impact negatively on human health. National ambient air quality standards have been set for CO. There is a 1-hour standard of 30 mg/m^3 (30 000 μg/m^3) and like ozone, CO has an 8-hour standard. The exposure period refers to exposure during an 8-hour working day with the NAAQS of 10 mg/m^3 (10 000 μg/m^3). Read more about CO in Appendix 5.

In eThekwini, CO is measured at Warwick Triangle, which is predominantly a traffic site. The morning and afternoon peaks in traffic are evident in the recorded CO concentrations (Figure 3-49). The ambient concentrations of CO measured at Warwick Triangle are generally very low relative to the NAAQS. However, exceedances of the limit values of the 1-hour and 8-hour NAAQS have been recorded in 2004, 2005, 2011 and 2012 (Figure 3-50). The frequency of exceedances is well below the permitted number of 88 per annum for the 1-hour and 11 for the 8-hour. Ambient CO concentrations at Warwick Triangle therefore consistently comply with the NAAQS. As this is one of the busiest and most congested traffic areas, it can be assumed that ambient CO concentrations comply with the NAAQS throughout eThekwini.

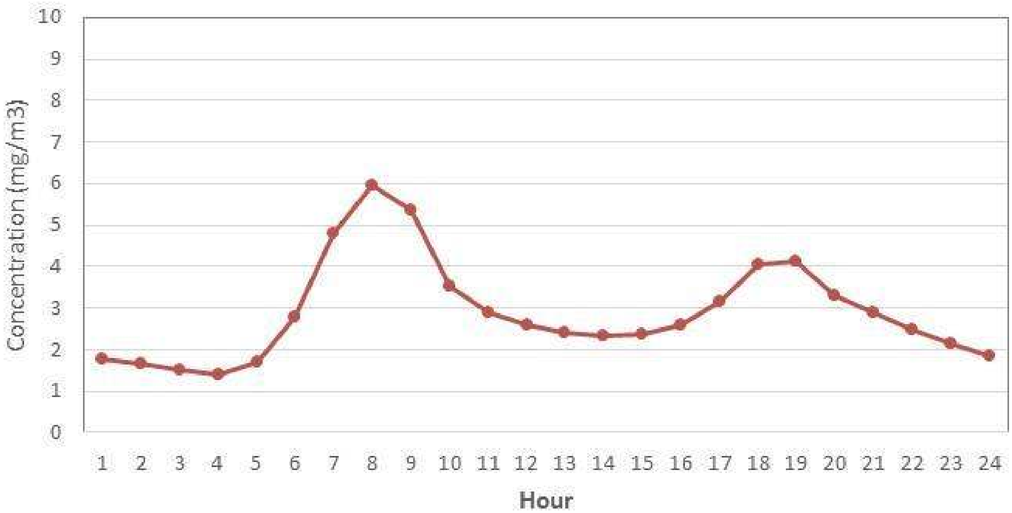


Figure 3-49: Average hourly ambient CO concentrations at Warwick Triangle in 2005

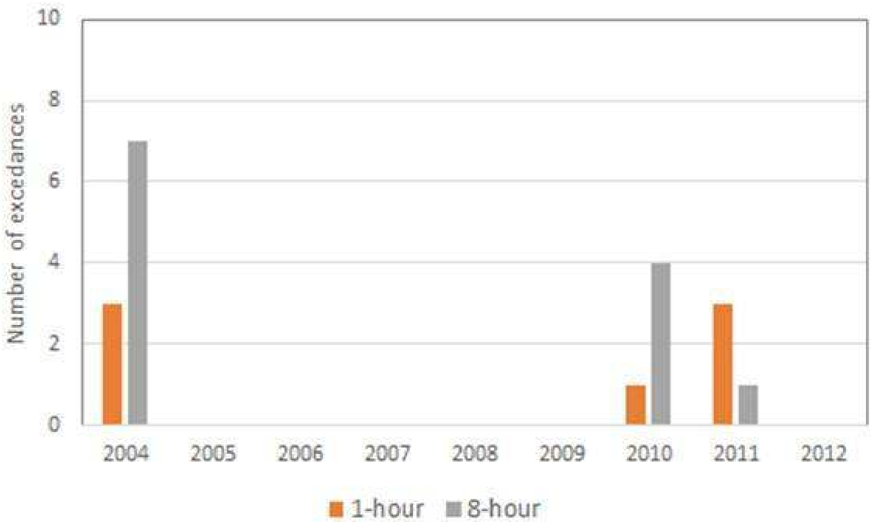


Figure 3-50: Number of exceedances of the limit value of the 1-hour and 8-hour NAAQS for CO at Warwick Triangle between 2004 and 2013

Points for consideration in the AQMP regarding CO

a) Ambient CO concentrations in eThekwini are low relative to the NAAQS
b) CO is not considered a problem pollutant in eThekwini

3.2.7 Lead (Pb)

Lead is a metal that occurs naturally in small amounts in the earth's crust, used in batteries, ammunition, metal products, ceramic glazes and paint. Lead was used as an additive in petrol up to the beginning of 2006. In the atmosphere, it exists primarily in the particulate form and nearly all environmental exposure to inorganic lead compounds occurs through inhalation of contaminated air and ingestion of contaminated food, water and soil. It is a criteria pollutant that can impact negatively on human health. The national annual ambient air quality standard for lead is 0.5 µg/m^3. Read more about Pb in Appendix 5.

eThekwini Municipality monitored ambient lead concentrations at 19 sites from 2004 to 2009. A fire at the Pinetown laboratory resulted in damage to analytical instruments. No data was recovered from 2010 to 2013. The monitoring sites included busy traffic sites with monitors relatively close to the roadside at City Hall, Congella, Gillitts, Brighton Beach, Palmfield and Riverside Road, and background sites such as Alverstone, Gillitts and Tongaat.

The annual average concentration of lead has been consistently below the NAAQS of 0.5 µg/m^3) at all sites in the municipality throughout the monitoring period (Figure 3-51). Noteworthy is the decrease in the annual average, from 0.24 µg/m^3 in 2005 to 0.13 µg/m^3 in 2009 and in 2014. The annual average concentrations are currently less than 50% of the NAAQS at all monitoring sites. The decreasing trend is most evident at the roadside monitoring stations.

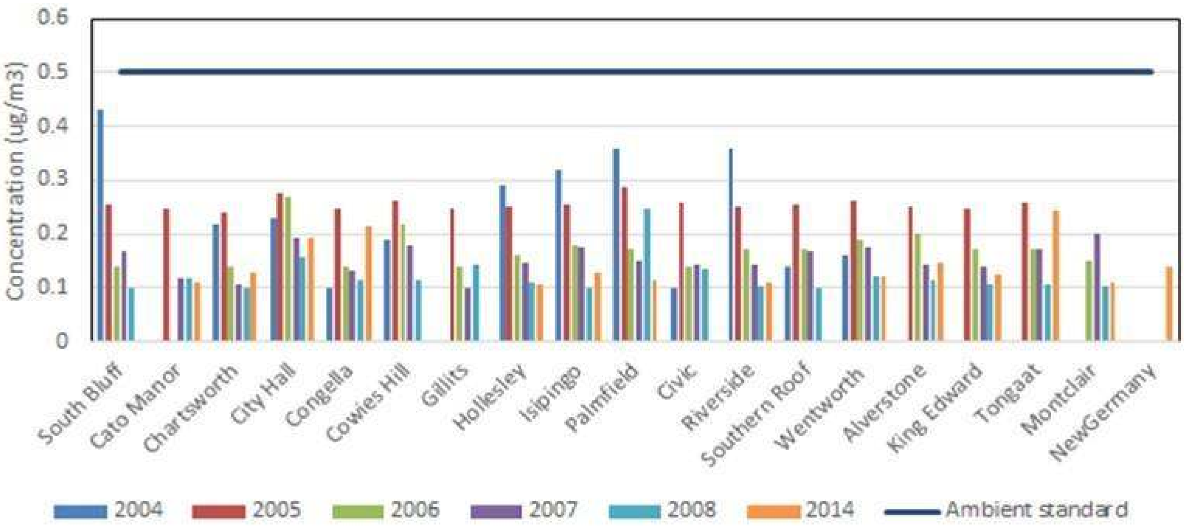


Figure 3-51: Annual lead concentration in eThekwini Municipality in μg/m^3 from 2004 to 2008 and in 2014

Points for consideration in the AQMP regarding Pb
a) Ambient Pb concentrations are very low throughout eThekwini relative to the NAAQS b) Ambient Pb is not an ambient air quality management priority for eThekwini

3.2.8 Air quality complaints

Residents in eThekwini Municipality are proactive in terms of air quality and use the available call centres to lodge complaints. These are directed to the sub-district authorities (Figure 3-52) during normal working hours and to Emergency Services afterhours. Complaints are logged in the respective complaints registers, follow-up action is taken and there is report-back to the complainant.

In October 2013 eThekwini Municipality included reporting on complaints in their Air Quality Management quarterly reports to the Community & Emergency Services Committee. Complaints in the respective sub-districts are reported with comment on the cause and management action taken. A summary of the 523 complaints received in the 12-month period from 1 October 2013 to 30 September 2014 has been extracted from quarterly reports and is shown in Table 3-23.

Most of the complaints concern odour (offensive smells) and chemical smells comprising more than 50% of all complaints, with the majority occurring in the South 3 sub-district. Emissions of air pollutants including fumes from spray painting and other operations received 22% of all complaints with most received in the North 1, North 5 and South 4 sub-districts. Complaints regarding smell from the chicken abattoir in Hammersdale are often lodged directly to the facility rather than to eThekwini Municipality. For a 24-month period from August 2013 to July 2015 a total of 13 complaints were received at the abattoir.

Dust from various operations is a nuisance and resulted in nearly 13% of all complaints. Smoke from refuse burning and industrial operations was also a cause for complaint. Sugarcane burning, while perceived to be a significant nuisance, only received 2 complaints in the North 1 sub-district. Complaints regarding sugarcane burning are usually lodged directly with the growers or the farmer and not eThekwini Municipality.

Table 3-23: Number of complaints received in the respective sub-districts in eThekwini Municipality from October 2013 to September 2014 in 7 categories

	Air pollution emissions	Chemical smell	Dust	Vehicle emissions	Odour	Smoke	Sugarcane burning	Total	Percent
North 1	24	13	13	2	13	1	2	68	13.0
North 2	0	0	0	0	0	0	0	0	0.0
North 3	0	0	0	0	0	0	0	0	0.0
North 4	0	0	0	0	0	0	0	0	0.0
North 5	27	2	10	0	0	6	0	45	8.6
North 6	2	1	3	0	2	13	0	21	4.0
South 1	5	3	1	0	5	0	0	14	2.7
South 2	0	0	0	0	3	0	0	3	0.6
South 3	8	86	15	0	86	6	0	201	38.4
South 4	28	5	9	1	10	5	0	58	11.1
South 5	0	0	0	0	0	1	0	1	0.2
South 6	0	0	0	0	0	0	0	0	0.0
South 7	3	6	0	0	8	0	0	17	3.3
South 8	5	4	9	3	6	4	0	31	5.9
West 1	0	0	0	0	12	0	0	12	2.3
West 2	1	1	0	0	4	0	0	6	1.1
West 3	8	1	1	0	8	2	0	20	3.8
West 4	4	4	5	0	9	4	0	26	5.0
Total	115	126	66	6	166	42	2	523	
Percent	22.0	24.1	12.6	1.1	31.7	8.0	0.4		

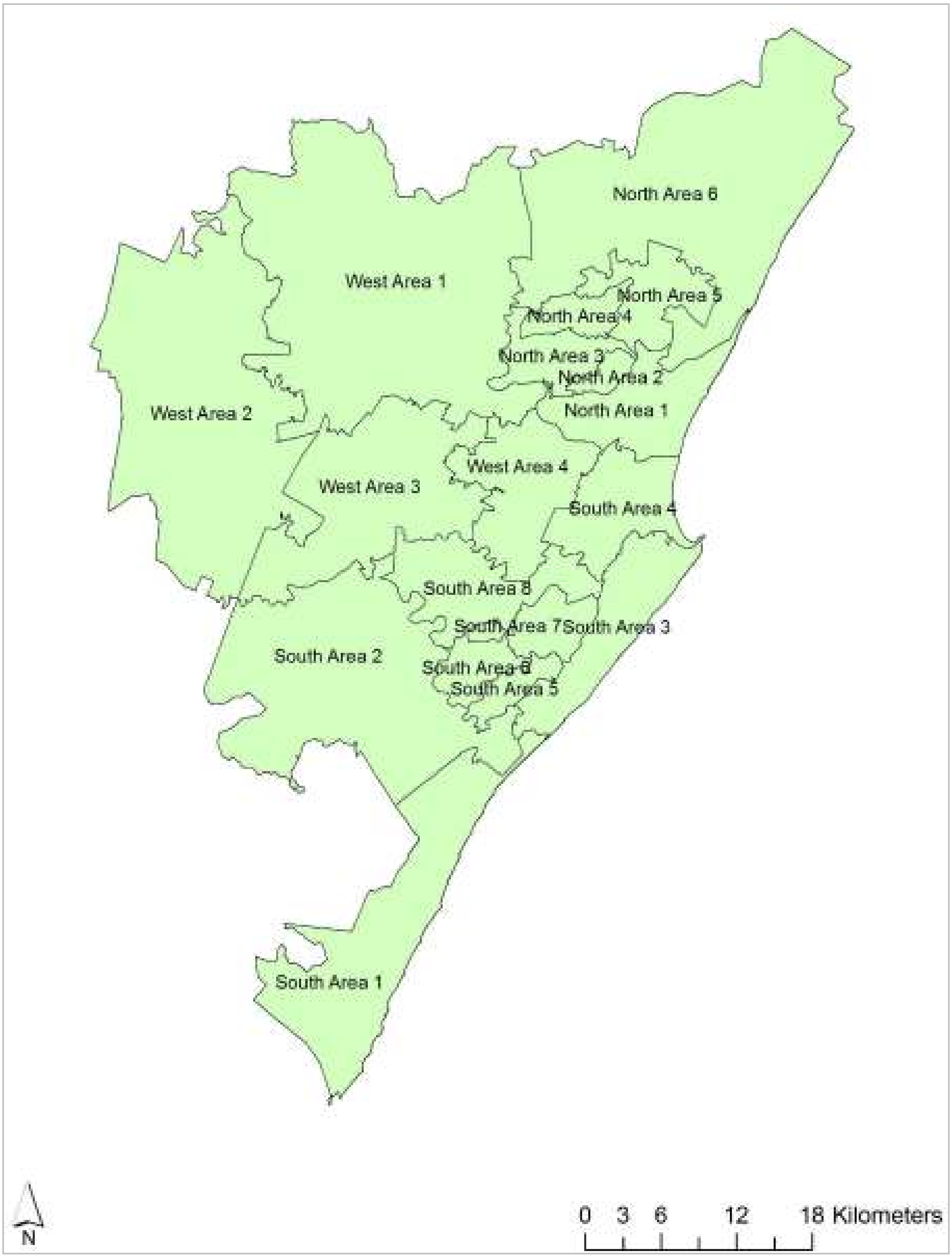


Figure 3-52: eThekwini sub-districts

Points for consideration in the AQMP regarding complaints
a) Most complaints received by eThekwini Municipality relate to air pollution emissions and to chemical smell b) Most complaints received are in the South 3 and South 4 and North 1 sub-districts c) The coordination of complaints data at eThekwini Municipality for quarterly reporting is not efficient d) A complaints data base should be developed to improve the assessment and reporting of complaint information

3.2.9 Air quality incidents

Incidents are regulated in terms of Section 30 of the National Environmental Management Act (Act No. 107 of 2008) (NEMA). An incident is defined as an unexpected or sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution or detriment to the environment, whether immediate or delayed. Section 30 defines, amongst others, the responsible authority, and the obligations of the responsible person in terms of investigating and reporting on the causes, environmental impacts and risks, as well as clean up. National and provincial authorities often carry out the investigation of incidents.

Incidents at facilities involving fire or leaks can result in high emission of a number of pollutants during the course of the event. Such incidents are unplanned and sudden. Ambient monitoring during such events is impractical for a number of reasons. The events are relatively short lived, selecting the monitoring sites and the pollutants to monitor presents challenges, impacting on the selection of the monitoring methodology. In addition, eThekwini Municipality does not have the capability to undertake short term monitoring campaigns.

3.2.10 Ambient data summary

eThekwini Municipality started ambient air quality monitoring in the 1990's using the so-called bubblers to measure smoke and SO_2. This was augmented in 2005 with 10 automated ambient air quality time monitoring stations and in 2013 the network expanded with a further four stations, while the smoke and SO_2 stations continued to operate. The municipality has also done a number of monitoring campaigns. A good record therefore exists for the criteria pollutants, including SO_2, NO_2, CO, O_3, PM_{10} and benzene. Ambient monitoring is also undertaken by a number of facilities in terms of their AELs or mining licenses.

Located on the coast, eThekwini experiences a relatively high frequency of moderate to strong winds. The influence of the warm Indian Ocean impedes the development of strong temperature inversions. Air pollutants generally disperse well and seldom accumulate. Air quality in eThekwini is generally good, complying with NAAQS as a result of the meteorology and emission reduction measures by major industrial facilities through their commitment to the MPP. Industry and motor vehicle emissions however still cause exceedances of the NAAQS for PM_{10}, NO_2 and benzene. Odour or chemical smell is the main cause of complaint to eThekwini Municipality.

Key points to note from the ambient air quality assessment include:

a) A dramatic decrease in ambient SO_2 in the South Industrial Basin occurred in 2006 following the implementation of emission reduction measures by a number of large industrial facilities;
b) Monitoring data shows there is general compliance with the NAAQS for SO_2 throughout eThekwini since 2006, except in the Umkomaas area where exceedances of the NAAQS occur;
c) Ambient SO_2 from industrial facilities is predicted by dispersion modelling to exceed the NAAQS near the Port, in Clairwood, Jacobs, Merewent, Wentworth and at Umbogintwini;
d) There is general compliance with the NAAQS for NO_2 throughout eThekwini except in high traffic zones where exceedances of the NAAQS limit value occur;
e) The background concentration of PM_{10} in eThekwini is about 16 μg/m^3;
f) There is general compliance with the NAAQS for PM_{10} throughout eThekwini except in high traffic zones where exceedances occur. The number of exceedances has however decreased following the phase-in of clean diesel;
g) Annual ambient concentrations of benzene are relatively high at high traffic areas such as Warwick Triangle, Turner Street, Isipingo and Amanzimtoti, and at Settlers School and Southern Treatment Works which are impacted on by emissions from industry industrial sources and the Southern Treatment Works;
h) The background O_3 concentrations in eThekwini are relatively high and exceedances of the NAAQS have occurred;
i) Ambient CO concentrations in eThekwini are low relative to the NAAQS;
j) Ambient lead concentrations are very low throughout eThekwini relative to the NAAQS;
k) The combination of a number of sources of dust in the Coedmore Road area result in nuisance and quality of life issues;
l) Most air pollution related complaints received by eThekwini Municipality relate to emissions and chemical smell; and
m) Most complaints received are in the South 3, South 4 and North 1 sub-districts.

3.3 Capacity

The capacity assessment has been conducted for six essential components of capacity, viz. Structure, System, Skills, incentiveS, Strategies and inter-relationshipS. This is referred to as the '6S' model (T&B Consult, 2002). Each component is evaluated using a set of indicators relevant to the aspect being investigated and responses are presented from the authorities (uMoya-NILU,2014).

3.3.1 Structure

The structural component of capacity refers to the organisation itself and the broader arrangement of air quality staff. It refers to their roles and responsibilities within the department, and also to the lines of communication and command within the department. Each sphere of government is obligated to fulfil an AQM function according to NEM: AQA, including AQO designation and AQMP development.

A well-defined structure forms the basis for establishing and executing the AQM function within an organisation. The National Framework and the NEM: AQA does not strictly define the organisational structure for an AQM function or department. The AQMP often provides recommendations to the organisation on the institutional arrangements to meet legal responsibilities. In eThekwini the air quality management function resides in the Health Unit in the Health Safety and Social Services Cluster, headed by the Senior Manager for Environmental Health Support and Coordination, reporting to the Deputy Head of Pollution Control and Risk Management. The current organogram for the air quality management function provides for 26 posts, reporting to the Senior Manager for Environmental Health Support and Coordination (Figure 3-53). Bruce Dale is the Senior Manager (Pollution Control).

The core function resides at the Health Department in the CBD. It is divided into three sub-regions, the south and central one residing in the municipality and others in the west and the north respectively. The sub-regions are responsible primarily for the regulation of fuel burning appliances in terms of the by-law and complaints management.

eThekwini Municipality have responded to the mandated requirements of the NEM: AQA, including the designation of an Air Quality Officer (AQO) and the function of the Atmospheric Emission Licensing Authority (AELA). Mr Bruce Dale was designated as the Air Quality Officer (AQO) for the eThekwini Municipality in 2011 and an Atmospheric Emission Licensing (AEL) task team was formed in 2012. The AEL task team reports to the AQO in terms of function and resource allocation. In addition to the AELA function, the municipality is responsible for:

- Ambient air quality monitoring;
- Emission inventory management in terms of the requirements of the National Atmospheric Emission Inventory System (NAEIS);
- Management of complaints;
- Comment on Atmospheric Impact Reports (AIR);
- Routine reporting to Council, the Provincial AQO and the National AQO; and
- Compliance and enforcement in terms of the NEM: AQA and the municipal by-laws.

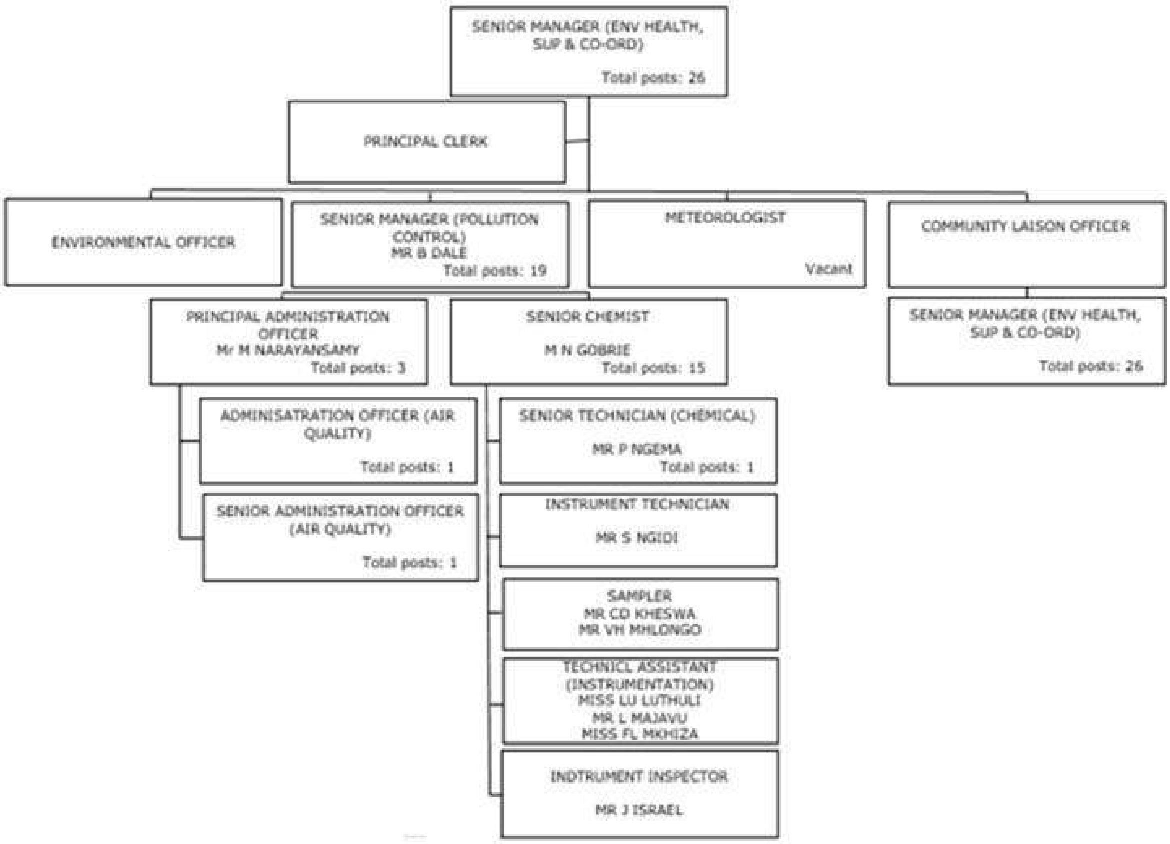


Figure 3-53: Current organogram for air quality management in eThekwini Municipality

The majority of the AEL staff team and the AQO have undergone EMI training, and if there is an air quality incident, council is informed of the matter. eThekwini Municipality liaises with DEA on policy development and reports to the Provincial Department on an ongoing basis. Regular meetings are held between provincial and municipal staff, and national and municipal staff.

Despite the municipality's response to the requirements of the NEM: AQA, some gaps and redundancies exist in the current structure in order for eThekwini to function optimally in terms of their mandated function. The AQO describes the current organogram as dated. The job descriptions are incorrect and do not reflect the needs of the municipality. The following is noted with regard to the modified structure:

i. The AEL task team is appropriate and should be formalised;
ii. There are currently 4 technicians responsible for the on-going servicing and maintenance of the 14 monitoring stations. The supervisor is a Senior Chemist, but additional support to technicians is required;
iii. The meteorologist post is redundant and the job description should rather focus on the emission inventory and dispersion modelling;
iv. The AQM function of the sub-regions is not reflected in the current organogram;

v. Lengthy appointment processes and inappropriate job descriptions inhibit the timeous placement of appropriately qualified staff where they are needed;
vi. The growing organisational requirements of the unit highlight the need for a high level administrative position, this work currently occupies much time of senior staff members;
vii. Linkages to other departments such as waste services, transport and planning should be strengthened to optimise resources within municipal departments; and
viii. There are currently no legal structures with the capacity to assist with compliance and enforcement matters.

3.3.2 Systems

The systems component of capacity refers to the tools at the organisation's disposal to manage air quality. These include equipment and hardware, as well as 'soft' tools such as operational procedures and air quality information. The National Framework provides some guidance and regulations while the development of norms and standards has strengthened AQM systems in the country. Several manuals have been published. The NEM: AQA includes requirements for certain AQM tools, including:

i. National ambient air quality standards, which are applied by eThekwini Municipality;
ii. Ambient air quality monitoring, where eThekwini has a network of 14 continuous monitoring stations as well as an extensive network of passive SO_2 bubblers and conducts campaign measurements of benzene and other pollutants;
iii. Minimum Emission Standards for Listed Activities, which are applied in eThekwini;
iv. Emission monitoring, which is enforced in eThekwini through the AELs;
v. Air quality data management system, where Envidas is the main system used to store data, but it has not been used successfully for all the stations. However, there is no real time access of monitoring data as the number of Envidas licenses needs to be increased. The monitoring data is stored on a dedicated server with a backup. Data is not communicated effectively with stakeholders. A website was hosted in Norway as part of the MPP was effective at the time;
vi. Priority area management applied in eThekwini through the MPP was successful in bringing about marked reductions in emissions relating to the combustion of dirty fuels, and marked improvements in ambient air quality;
vii. National regulations for Controlled Emitters which eThekwini has adopted in the draft municipal by-laws for boilers between 50 MW and 10 MW;
viii. Controlled fuels have not been applied as an air quality management tool in eThekwini Municipality; and
ix. Atmospheric emission licensing as an air quality management tool, is applied by eThekwini Municipality as the licensing authority through the establishment of an AEL task team.

3.3.3 Skills

Skills capacity refers to the ability of the available staff to perform their required functions. Skills in AQM are not defined in any legal document. Skills development is generally incorporated into the authority's AQMP, which is part of the IDP or other departmental planning document.

The eThekwini Municipality personnel have very diverse academic backgrounds, which strengthens their approach to AQM. These range from chemistry and information technology to environmental health and communications. However, there are specific technical skills the staff require to perform mandated functions.

There are two samplers and two vacant positions currently and four technicians tasked with the running of the monitoring network of 14 stations. While the technical staff are fairly confident in their abilities to run the network, they lack specific technical capabilities and there is a need for capacity building, resources and support to effectively run the networks and achieve an 80% data capture.

Capacity development is required to strengthen knowledge of atmospheric sciences, industrial processes and health. Staff are required with a background in these fields. While there are departmental processes in place to foster learning these are largely informal and occur through the attendance of workshops, seminars and meetings. Some staff members have recently attended dust fallout training.

Some of the staff have management skills. There are work skills plans for individual staff members and these are reviewed on an annual basis. All staff have Key Performance Indicators (KPIs) that include personal development plans. In these plans training needs should be linked to the requirements of the NEM: AQA of municipal staff. Particular competencies are required for emission inventory development and dispersion modelling.

3.3.4 Strategy assessment

Strategy as a component of capacity refers to the alignment of the department's structure, systems, skills and incentives to reach the air quality goals that have been set. The most important strategy document for each authority is the AQMP. This summarises all the necessary information relating to the authority and plans a way forward for implementation. This requirement is mandated in the NEM: AQA for each authority. Other supplementary strategy documents include AQMP's that may have been developed by higher authorities, as well as legislation. The NEM: AQA and National Framework are two overarching legal documents that guide all AQM activities in South Africa.

The AQMP developed in 2007 provided some guidance to the municipality, but it was limited to the South Industrial Basin and to the reduction of SO_2. Increasing legislative requirements has meant that the operational strategy has been reactive to ensure compliance with the requirements of the NEM: AQA. The experienced and capable team has achieved considerable success without an overarching strategy. This reactive management of air quality is fraught with shortcomings. The revision of the 2007 AQMP needs to provide a strategy for air quality management in eThekwini Municipality to ensure that objectives are achieved in a structured and coordinated manner, through appropriate resource allocation and management.

3.3.5 Incentives Assessment

Incentives examine the motivational policies at the individual level but also the broader collaborative motivation existing within the department and with other departments and stakeholders. AQMPs require extensive funding, and their mandatory inclusion in IDPs has guaranteed to some extent that air quality interventions will be funded and backed (Naiker *et al*., 2012; Davies, 2008). The 2007 AQMP was included in the IDP and the budget allocation was deemed sufficient for implementation activities (Table 3-24). However, there were limitations experienced as a result of supply chain management processes.

The annual budget for capital expenditure (CAPEX) and operational expenditure (OPEX) is provided for air quality management. The budgets since the 2011/12 financial year are indicated in Table 3-24.

Table 3-24: Air quality management CAPEX and OPEX budgets from 2007 to 2014

Financial year	CAPEX	OPEX
2011/12	R107 160	R2 243 384
2012/13	R605 644	R2 405 553
2013/14	R685 013	R2 549 890
2014/15	R787 370	R2 838 024

Staff members credit the level of implementation success with good management support, staff morale and team work. They also cited sufficient capacity and training as an important factor. There were also specific tasks in the AQMP for which team leaders were assigned and held accountable.

There are opportunities to develop careers but these are limited by resources and the lack of a formal structure. The AQO assists informally by involving staff in meetings, seminars and workshops to gain exposure to air quality issues. Providing other incentives is difficult as finances for air quality management are largely sourced from the municipality. A cut in operational budgets will impact negatively on the ability to perform the air quality function, and in turn, on motivation of staff.

3.3.6 Interrelationships Assessment

Inter-relationships deal with a critical element for implementation capacity, and examine the manner in which the AQM department relates to other departments within the authority and other stakeholders. Relationships between departments within an authority are not defined in legislation. Inter-governmental cooperation is subject to legislation. Departments are compelled to communicate in instances where conflict arises and resolve issues according to legislated steps. An inter-governmental forum is also a necessary tool to foster cooperation and improve relations.

Internal working partners are other departmental Environmental Management Inspectors (EMI), the transport department and the planning department. The eThekwini Municipality also has a productive relationship with DEA, but require further assistance with legal matters. The provincial authority does not provide much support to eThekwini; neither do the other municipalities, largely due to a lack of their capacity.

PCRM actively engages with stakeholders outside of government departments. These include NGOs such as the South Durban Community Environmental Alliance (SDCEA) and Groundwork. Various civil society organisations and academic institutions such as the University of KwaZulu-Natal and Durban University of Technology are also engaged.

3.3.7 Summary

A summary of mandated functions currently fulfilled by the eThekwini Municipality in terms of NEM: AQA (2004) is presented below in Table 3-25. The municipality has excelled in fulfilling these requirements, at times under challenging conditions and without the appropriate institutional structures. However, for eThekwini Municipality to evolve into a multi-faceted, technically strong and diverse group of AQM professionals, the current organogram needs to be revised with a modification of job descriptions.

The management of air quality in the eThekwini Municipality continues to increase in complexity with growth and development in the municipality. The improvement of technical skills and interdisciplinary studies should be driven by an overarching strategy that is robust and holistic.

Table 3-25: Summary of the baseline capacity at eThekwini for air quality management considering the components of the 5 'S' model.

Assessment	Function/responsibility	Status
Structure	AQO designated	Yes
	AQM function in place	Yes
	AQM department in place	Yes
	Reporting line defined	Yes
	Communication line defined	Yes
	Organogram	Outdated
Systems	Defined approach for AQM	Limited
	Performance indicators for AQM	Yes
	Emission inventory	Limited
	Ambient air quality monitoring	Yes
	Air quality data management system	Yes
	Atmospheric emission licensing function	Yes
	Controlled Emitters	Yes
	Air quality by-law	Yes
Skills	Suitability of staff profiles	Limited

	Departmental learning processes available	Yes
	Skill sharing opportunities	Limited
	Technical skills development	Limited
	Management skills development	Limited
Incentives	Salary bonus opportunities	Unsure
	Culture and work environment	Yes
	Career growth/ flexibility	Limited
	Partnerships	Limited
	External funding	No
Strategy	AQMP development	Yes (In progress)
	Level of AQMP implementation	Limited
	Vision, mission internalisation	Limited
	Flexibility of strategy	Limited
	Plan ownership	Limited
	Plan monitoring, evaluation, review	Limited
Interrelationships	Internal working partners	Yes
	External working partners	Yes
	Other organisations	Yes

4 STRATEGIC DEVELOPMENT AND AIR QUALITY

In Chapter 4, strategic development in the eThekwini Municipality is discussed in the context of the potential threats to air quality

The South African Government adopted the National Infrastructure Plan to transform the economic landscape of South Africa, create a significant number of new jobs, strengthen the delivery of basic services to the people of South Africa and support the integration of African economies. There are 18 Strategic Infrastructure Projects (SIPs) covering transportation, telecommunication, energy, health and education and water and sanitation in all nine provinces. Each SIP comprises of a number of specific infrastructure components and programmes. SIP 2 considers, amongst other initiatives, to strengthen the logistics and transport corridor between South Africa's main industrial hubs and improve access to Durban's export and import facilities and the new dig-out port.

The Spatial Development Plan (eThekwini, 2013) emphasises the fundamental importance of the Port of Durban and the premise that eThekwini's economic growth is mostly based on the port and related activities. The Port Expansion and Back of Port redevelopment is the city's number one development priority. Besides the Port, the three other investment priorities are Dube Trade Port and surrounding areas including Cornubia, Cato Ridge industrial area and the Mpumalanga/Hammarsdale area.

The *Port of Durban* is of provincial and national significance. One of the serious constraints to development in eThekwini is the inefficiencies and congestion in the port operations. Improving the Municipality's logistics infrastructure will contribute to ensuring the maximisation of port economic opportunities. Rail linkages, port efficiency, back-of-port operations to enhance capacity and range of business, inter-modal transport hubs in-port and inland and the newly-planned dig-out port are planned projects by eThekwini.

Expansion of the port at its current location seems unfeasible considering that it is surrounded by developed urban properties. The focus has changed from expanding the port to the development of a new port at the old Durban International Airport, referred to as the Dig-Out Port project, because the whole airport has to be dug out to create a harbour basin. The implications of the back-of-port development and the dig-out port for air quality are an increase in emissions associated with harbour activities, and an associated increase in ambient concentrations of air pollutants. In particular, emissions from ships at the proposed site adjacent to the two refineries is likely to increase SO_2 concentrations in the area. Construction of the dig-out port is planned to start in 2021 with completion in 2042.

The *Dube Trade Port* has been established between the ports of Durban and Richards Bay to harness the value of having an air logistics platform. It is developed to promote access to global trade and open up new opportunities for production and export of high–value perishable products and manufactured goods. It is expected to act as a catalyst for economic development and labour intense growth throughout the KZN province. The likely implications for air quality will depend on the nature of activities attracted to the Dube Trade Port, but are likely to be limited to an increase in emissions from motor vehicles as the area expands.

Cato Ridge has been identified as one of the industrial expansion areas in the Municipality that can respond to the increasing demand for industrial land in eThekwini Municipality. However, the area faces challenges especially with regards to accessibility and as a result the area is not used to its full potential. By improving the infrastructure, upgrading the N3 and addressing the sewer issue, these challenges can be addressed and the area can be unlocked for industrial and economic development. The development of Cato Ridge will also stimulate the potential of the surrounding areas of Mpumalanga and Hammersdale. Industrial activities are associated with atmospheric emissions from the combustion of fossil fuels and the processing of raw materials and minerals. Such activity is currently relatively limited in the Cato Ridge area. Expansion of the industrial sector is likely to result in an increase in emissions and ambient concentrations of air pollutants in the area.

The *expansion of transport networks* is integral to eThekwini's development initiatives. Prior to establishment of the eThekwini Transport Authority (ETA), eThekwini was only responsible for fixed transport infrastructure. With the establishment of the ETA this responsibility now extends to the provision, management and control of all transport infrastructure, public transport services, and modes and fleet. The ETA's mission is to provide and manage a world-class transport system, with a public transport focus, providing high levels of mobility and accessibility for the movement of people and goods in a safe, sustainable and affordable manner (eThekwini, 2010).

Four key projects in eThekwini are in various stages of planning and development that will have a major impact on the pattern and extent of travel and land use in the municipal area. All of the projects intend to reduce congestion and improve traffic flow in different ways. In so doing the potential exists for positive implications for air quality in the area. The four projects are:

i) Warwick Junction nodal interchange: Currently, 110 000 vehicles including buses and taxis, approximately 400 000 pedestrians, and the informal trade sector compete for limited space in the precinct on a daily basis. The primary objective of this project is to provide the infrastructure and space in the precinct needed for the smooth and safe operation of public transport, small, medium and micro-enterprise (SMME) Development, and pedestrian movement.

ii) Port and city linkage: The Port of Durban handles five main categories of cargo, namely: containerised cargo, bulk cargo, break-bulk cargo, vehicle exports and imports of petroleum products. Other than the petroleum products, which are transported by pipelines, a high proportion of cargo is transported by road, with a much lower proportion transported by rail. The down side of the road-rail split is that the road infrastructure in and around the harbour is no longer coping with the high heavy-vehicle volumes and congestion with daily congestion at the terminals and access points. With Transnet, eThekwini municipality have planned and, in some cases implemented, improvement schemes.

iii) Integrated Rapid Public Transport Network plan (IRPTN): The objective for this project to develop a programme for the phased implementation of an integrated rapid public transport network with public transport service and support system plans across whole of the eThekwini municipal area. The IRPTN must form an integrated system with Bus Rapid Transit/Integrated Rapid Transit (BRT/IRT): Heavy Rail Transit (HRT) and Light Rail Transit (LRT), where appropriate, to meet current and future demand throughout the metropolitan area on a service/cost effective basis.

iv) Inner City Distribution System: The ultimate goal of the Inner City Distribution System is to provide a high mobility, highly accessible, public transport service in the inner city to reduce the number of motorised vehicles in the area. This strategy reduces noise, congestion, and pollution levels, thereby improving the pedestrian and general public environment. It consists of public bus transport services with state-of-the-art vehicles that connect the Warwick Precinct with the beachfront and major commercial, transport and activity centres of the city. These include the Inkosi Albert Luthuli International Convention Centre, the CBD, Beachfront Hotels, activity centres, Moses Mabhida Stadium and Sports Precinct.

Points for consideration in the AQMP with respect to air quality and future development in eThekwini

a) Development projects have potential impacts on air quality (positive and negative) through either reduced or increased emissions
b) The potential impacts need to be understood in order to proactively manage air quality in the future

5 GAPS AND ISSUES

This baseline assessment has shown that eThekwini Municipality has a long involvement in ambient air quality management, dating back to the 1990's. An increase in activity was brought about by the MPP in 2004 in the South Industrial Basin with an increase in capacity, expansion of the ambient air quality monitoring capability, emission inventory development, modelling and data reporting. This effort brought about a significant reduction in SO_2 emissions with a concomitant improvement in ambient air quality. The air quality baseline assessment shows that ambient air quality complies with the NAAQS and is generally good in eThekwini Municipality.

Regarding air quality management in eThekwini Municipality, the baseline assessment shows that the air quality management requirements of the NEM: AQA are being met. eThekwini Municipality has appointed an AQO and has a dedicated air quality management section. They have established a team to perform the AEL function.

The ambient air quality monitoring network is being upgraded and expanded to other parts of the municipality. There is a dedicated section for air quality management in the eThekwini Municipality. An AQO has been designated and staff are competent and confident in their abilities to fulfil the AQM function. This includes the maintenance of an extensive ambient air quality monitoring network. Ambient air quality data is processed and archived, and is critical to directing AQM activities and ensuring that impacts on human and environmental health and well-being are reduced. The AEL function is performed, and routine reporting occurs, ensuring compliance of Listed Activities.

However, the baseline assessment has highlighted gaps, issues and challenges in air quality management in eThekwini that inhibit fulfilment of the mandate. These are listed in Table 5-1 for the different aspects of air quality:

Table 5-1: Gaps, issues and challenges for air quality management in eThekwini Municipality

Air quality aspect	Gaps, issues and challenges
Capacity	The structure for the air quality function is not ideal: • It is based on a dated organogram that does not account for mandated functional requirements of the NEM: AQA; • Vacancies exist on the organogram, but job descriptions for the posts are dated and do not account for mandated functional requirements of the NEM: AQA; • Mandated functional requirements of the NEM: AQA have increased the work load without staff numbers increasing; • There is a risk of appointing staff without appropriate skills if the current organogram and job descriptions are used as the benchmark.
	Systems for AQM in eThekwini are lacking: • Emission inventory has been updated, but gaps exist and it requires ongoing maintenance and update; • Original ambient monitoring equipment is old and requires replacement and repair; • The is no dispersion modelling capability; • The AEL function is not recognised in the organogram.
	Skills of incumbent staff for air quality management are limited: • Skills exist mostly in ambient monitoring and data management, AELs and reporting; • There are limited opportunities for skills sharing as well as technical and management training.
	Incentives for air quality management are driven by resources to perform the function: • The function has been expanded by the mandated requirements of the NEM: AQA; • Financial resources for the function are currently limited to the available municipal budget; • Available financial resources inhibit function.
Human health	The health study in eThekwini Municipality showed persistent asthma in children was higher in the south than in the north.
	The health status in eThekwini Municipality has not been updated since 2006, prior to the marked SO_2 reductions.
	The links between indoor and ambient air quality in eThekwini are not understood.
Emissions	The emissions for 2012 developed for the baseline assessment includes information for 85 industrial facilities that hold AELs: • AELs have not been issued to all facilities with Listed Activities so not all sources are included; • Emission testing has not been done at all facilities and emissions have not been estimated; • Emissions of SO_2, NO_X, PM_{10} and VOC from Listed Activities are significant; • Most emissions result from the pulp and paper sector, crude oil refining, the metallurgical sector and sugar milling and

	refining.
	The Controlled Emitter database includes 11 facilities: • Not all sources are included; • Information is available for only 5 facilities in the database; • Most emissions result from coal and HFO combustion.
	Motor vehicles: • Motor vehicles are significant sources of CO and NO_X in eThekwini; • They are also a relatively large source of PM_{10} • Emissions from motor vehicles are concentrated in Durban and Pinetown, with lesser emissions elsewhere; • Motor vehicle emissions are estimated using a top-down approach for 9 areas in eThekwini, providing a reasonable coarse estimation.
	The Port of Durban: • Emission is based on 2009 data using the Intergovernmental Panel on Climate Change (IPCC) Tier 1 methodology; • The Port of Durban is a significant source of SO_2, NO_X and VOCs; • Information from a number of sources in the chemical cluster was omitted from the inventory.
	Airports: • KSIA is not a major source of emission in eThekwini; • Emissions were not estimated for Virginia Airport.
	Residential fuel burning: • Emissions of NO_X and PM_{10} from residential fuel burning are relatively small in eThekwini. • The highest emissions occur in the outer west and in the south
	Biomass burning: • Emissions of CO and PM from sugarcane burning are seasonal and relatively small in eThekwini; • Sugarcane burning is a common practice and occurs in close proximity to residential and commercial properties, resulting in nuisance impacts.
	Waste management: • Emissions of air pollutants from WWTW and landfills are relatively small; • The impacts are mostly nuisance related and are localised.
	Mining: • Emissions of particulates from mining are relatively small; • The impacts are mostly nuisance related and are localised.
Ambient monitoring	A number of technical shortcomings were identified during a supporting study, including: • The monitoring network plan is outdated; • It is not necessary to perform meteorological monitoring at so many locations;

	• There is no formal QA/QC system in place that documents operational procedures and the basis for the establishment of the monitoring network; • Shortcomings in QA/QC of data exist; • The municipality does utilise a SANAS accredited laboratory, but the calibrations are only performed annually; • External audits performed as a means of independently verifying eThekwini Municipality monitoring activities.
Ambient modelling	eThekwini Municipality does not have a modelling capability.
	Air quality modelling is not used to inform decisions in eThekwini Municipality.

6 DEVELOPMENT OF THE AQMP

The baseline characterisation has provided valuable insight into the gaps, issues and needs for effective air quality management in eThekwini Municipality. The summary of the emission profile, ambient air quality monitoring assessment, dispersion modelling, and capacity assessment gives an indication of areas of strength and weakness and in turn, areas of focus for the AQMP.

The findings of the baseline assessment together with the identified gaps, issues and challenges will be used to revise the goals and the objectives for the AQMP for eThekwini Municipality. Interventions to achieve the objectives and, in turn, the goals for AQM, will be developed with relevant stakeholders and formulated into an implementation plan.

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APPENDIX 1: eThekwini municipal wards

Ward Number	Ward name	Ward Number	Ward name	Ward Number	Ward name
1	Ximba	36	Durban North	70	Westcliff
2		37	Newlands West	71	Shallcross
3		38	Lindelani	72	Risecliff
4	Hammarsdale	39	Sokwalisa (KwaMashu)	73	Chatsworth
5	Georgedale	40	KwaMashu B	74	Lamontville
6	Mpumalanga North	41	KwaMashu K	75	Clairwood
7	Shongweni	42	Ntuzuma F/H	76	Umlazi V
8	Botha's Hill	43	Ntuzuma E	77	Umlazi H
9	Hillcrest	44	eMachobeni	78	Umlazi K
10	Kloof	45	Ntuzuma B	79	Umlazi G
11	Newlands	46	KwaMashu F	80	Umlazi E
12	KwaNdengezi	47	KwaMashu M	81	Umlazi C
13	Dassenhoek	48	Phoenix Industrial	82	Umlazi R
14	KwaNdengezi	49	Phoenix	83	Umlazi L
15	Mariannhill	50	Forest Haven	84	eMathole
16	Pinetown South	51	Shastri Park	85	
17	Klaarwater	52	Westham	86	Umlazi U
18	Pinetown Central	53	Amaoti	87	Umlazi Q
19	Wyebank	54	Newtown	88	Umlazi S
20	Kwadabeka	55	Inanda	89	Isipingo
21	New Germany	56	eMatikwe	90	Old Airport
22	Clermont	57	Inanda	91	
23	Reservoir Hills	58	La Mercy	92	Pitlochry
24	Westville	59	Verulam	93	Umbogintwini
25	Springfield	60	Verulam	94	
26	South Beach	61	Tongaat	95	
27	Morningside	62	Maidstone	96	
28	DUT/CBD	63	Malvern	97	Amanzimtoti
29	Chesterville	64	Yellowwood Park	98	Illovu
30	Sherwood	65	Hillary	99	Umkomaas
31	Musgrave	66	Bluff	100	
32	Harbour	67	Adam's Mission	101	University of Natal
33	Glenwood	68	Wentworth	102	Mt Edgecombe
34	Effingham	69	Havenside	103	Qadi
35	Umhlanga Rocks				

APPENDIX 2: Emission estimation techniques

1. Industrial sources (Listed Activities and Controlled Emitters)

a. Source testing

Atmospheric Emission Licence (AEL) application forms serve as the principle information source for activity data for estimating emissions from industrial sources. Industries that operate Listed Activities must undertake emission testing to demonstrate compliance with emission limits. The main outputs of emission testing are emission concentrations in units of mg/Nm^3. These emission concentrations were converted to emission rates by utilising the measured gas flowrate (also measured as part of an emission testing campaign) through the stacks and the following equation:

$$Emission\ rate\ \left(\frac{kg}{hr}\right) = Emission\ concentration\ \left(\frac{mg}{m^3}\right) \times Flowrate\ (\frac{m^3}{hr}) \div 10^6 \qquad (1)$$

Emission testing is generally considered to be the most accurate method for estimating emissions, as it entails the direct measurement of pollutant concentrations. However, emission testing companies in South Africa are not accredited. The results of emission testing must therefore be used with caution.

b. Emission factors

Several industries did not submit emission testing data with their AEL applications. It was therefore not possible to estimate emissions using the source testing method. The alternate method was to use fuel consumption data and apply appropriate emission factors to estimate emissions.

Sulphur dioxide

The quantity of SO_2 emitted from combustion processes depends on the mass fraction of sulphur in the fuel burnt. According to CONCAWE, the following equation can be used to estimate SO_2 emissions from combustion processes (Concawe, 2009):

$$Emission\ rate\ (\frac{kg}{year}) = 2000 \times A \times MFS \qquad (2)$$

Where,

A = mass of fuel consumed (ton/year)

MFS = mass fraction of sulphur in fuel

This equation assumes complete combustion of sulphur to SO_2. The composition of sulphur in coal generally varies between 0.5 and 1.3%. A conservative estimate of 1% (or mass fraction of 0.01) was however used in cases where the sulphur content was not provided.

The composition of sulphur in heavy fuel oil (HFO) is generally high at 3.5% or 0.035 (m/m). Sasol gas has the lowest sulphur content of 0.001875%. This value was estimated from information provided by Sasol that the sulphur content of its gas is < 15 mg/m^3. The composition of sulphur in diesel is 500 ppm (m/m), which is commercially available from most suppliers, including the oil companies. In terms of mass fraction, this equates to a value of 0.0005.

Nitrogen oxides

According to Environment Australia (2008), the following equation can be used to estimate emissions from combustion processes using emission factors:

$$Emission\ rate\ (\frac{kg}{year}) = A \times EF \times CE \qquad (3)$$

Where,

A = mass of fuel consumed (ton/year)

EF = uncontrolled emission factor (kg pollutant/ton fuel burnt)

CE = control efficiency of the emission from the use of a control device

The NO_x emission factor for the uncontrolled combustion of coal is 3.8 kg/ton. The NO_x emission factor for the uncontrolled combustion of natural gas (similar to Sasol gas) from boilers of <30 MW is 2.16 kg/ton. The relevant emission factor for the uncontrolled combustion of residual oil (similar to HFO) is 7.32 kg/ton and for diesel it is 2.72 kg/ton. As with SO_2, emissions of NO_x are the highest when residual oil is burnt.

Carbon monoxide

Equation (3) above is also used for the estimation of CO emissions from combustion processes. The CO emission factor for uncontrolled combustion of coal in boilers is 2.5 kg/ton. For residual oil combustion, a CO emission factor 0.67 kg/ton is specified by Environment Australia. This value is almost three times higher for gas combustion at 1.82 kg/ton. The CO emission factor drops to 0.68 kg/ton for diesel, a value similar to that for residual oil.

Particulate matter

The USEPA (2005) provides emission factors of 33 kg/ton for PM and 6.6 kg/ton for PM_{10} for coal combustion from boilers with a spreader stoker feed configuration. For natural gas, Environment Australia provides an emission factor of 0.16 kg/ton for boilers rated < 30 MW. For residual oil, the emission factor for PM_{10} is even less at 0.0542 kg/ton, while it is 0.14 kg/ton for diesel.

Volatile organic compounds (VOCs)

VOC emissions by definition include all emissions of volatile organics with the exception of methane. Emissions of VOCs from combustion processes are estimated by using the emission factor method and equation (3), as presented by Environment Australia. In line with the USEPA, Environment Australia provides an emission factor of 0.03 kg/ton of VOC emissions from the uncontrolled combustion of coal.

With respect to natural gas, the VOC emission factor increases to 0.119 kg/ton. For residual oil and boilers rated < 30 MW, the VOC emission factor is low at 0.04 kg/ton, and decreases further to 0.0272 kg/ton for diesel.

2. *Residential fuel burning*

The estimation of emissions from domestic burning is based on energy use data contained in the 2011 census (StatsSA, 2011), which delineates the number of households utilising fuels for domestic purposes (cooking, lighting, space heating). To determine the average quantity of fuels consumed per household, data on the quantities of fuels consumed in specific geographical areas of South Africa was sourced from the FRIDGE (Fund for Research into Industrial Development, Growth and Equity, 2006) report. The estimation of domestic fuel burning emissions is challenging given that the amount of fuel consumed is not known with certainty. The quantity of fuels consumed varies with geographical areas due to climate (more fuels are consumed in colder areas) and the extent of development (more fuels are consumed in rural areas). However, the FRIDGE report does specify fuel consumption data for residential areas in the eThekwini Municipality. The total fuel consumption was based on household level fuel consumption for wood, paraffin and LPG. Emission factors for the criteria pollutants from domestic burning were also sourced from the FRIDGE report (Table A).

Table A: Emission factors identified for the estimation of household fuel combustion emissions

Fuel	Units	Emission Factors					
		SO_2	NO_x	VOCs	PM_{10}	CO	Benzene
Wood	g/kg	0.18	5	22	15.7	114.6	0.9
Paraffin	g/l	8.5	1.5	0.09	0.2	44.9	0
LPG	g/kg	0.01	1.4	0.5	0.07	13.6	0

3. *Quarries*

Emissions of particulates result from most mining activities, i.e. from the initial removal of topsoil and overburden, to drilling and blasting, loading, hauling, crushing and the storage of ore and waste material. The amount of particulates emitted by any activity depends mostly on the nature and amount of material moved or handled and the nature and extent of the dust control measures, influenced also by rainfall and wind. Emissions may be estimated using emission factors and details of the activities if such data are readily available otherwise this may be a protracted process.

Emissions for mining were rather assumed using an approach that was employed in estimating mining emission for the Waterberg-Bojanala Priority Area (DEA, 2014) apportioning the total annual emissions according to the mine size where size '0' mines half the size of size '1' mines, and so on to size '6' mines with a scaling factor of 1. In so doing, a generic emission is estimated for each mine size from 0 to 6. The four quarries in eThekwini Municipality are size '0' with a particulate emission of less than 34 tons per annum.

4. Motor vehicles

For the top-down approach, fuel sales data for 2012 was sourced from the Department of Energy (DoE). The data is arranged in accordance with the defunct demarcation system of magisterial districts. This necessitated the linking of magisterial districts to local and metropolitan municipalities. Table B presents the Tier 1 emission factors developed by the European Environmental Agency (EEA), which were used in the top-down approach, for combustion.

Table B: Emission factors for motor vehicle combustion

Category	Fuel	Emission Factor (g/kg Fuel)			
		NO_x	SO_2	PM_{10}	CO_2 [1]
Motorcycles	Gasoline	9.50	-	2.7	69 300
Passenger cars	Gasoline	14.5	-	0.037	69 300
	Diesel 50	11	0.1	1.7	74 100
Light-duty vehicles	Gasoline	24	-	0.03	69 300
	Diesel 500	11	1	1.7	74 100
Heavy-duty vehicles and buses	Diesel 500	37	1	1.2	74 100

Notes (1): CO_2 emission factor unit is kg/TJ (IPCC, 2006)

The following equation was used to estimate motor vehicle emissions (with the exception of SO_2 emissions from combustion and PM_{10} emissions from tyre and brake wear and road surface wear) using the Tier 1 (or top-down) approach:

$$Ei = \Sigma j\ (\Sigma m\ (FCj,m \times EFi,j,m)) \qquad (4)$$

Where,

Ei = emission of pollutant i (g),

FCj,m = fuel consumption of vehicle category j using fuel m (kg),

EFi,j,m = fuel consumption-specific emission factor of pollutant i for vehicle category j and fuel m (g/kg).

Since emissions of SO_2 are dependent on the sulphur content of the fuel burnt, the EEA proposes the following equation to estimate SO_2 emissions:

$$E_{SO2,m} = 2 \times k_{S,m} \times FC_m \qquad (5)$$

Where,

$E_{SO2,m}$ = emissions of SO_2 per fuel m (g),

$k_{S,m}$ = weight related sulphur content in fuel of type m (g/g fuel),

FC_m = fuel consumption of fuel m (g).

The $k_{S,m}$ for diesel 50 is 0.00005 and for diesel 500 it is 0.0005. This implies that the SO_2 emission factor for diesel 50 is 0.0001 and for diesel 500 it is 0.001.

The vehicle composition for the priority area was determined using provincial vehicle registration information obtained from eNatis. This shows the breakdown of used and new vehicles according to specific categories. These are:

- Motorcycles
- Passenger cars
- Light-duty vehicles
- Heavy-duty vehicles and buses

This breakdown is consistent with the emission factors developed by the EEA and allows for direct use of the factors without further conversions or assumptions.

Having determined the vehicle composition per province, it was then necessary to correct these figures for fuel type. The relevance of this is related to the use of certain types of fuels by certain types of vehicle categories. For instance, HDVs do not use gasoline and motorcycles do not use diesel. To simplify the task, certain assumptions were also necessary. Included amongst these were:

- Diesel 50 is used exclusively by passenger cars;
- Diesel 500 is not used by passenger cars;
- Gasoline is not used by HDVs and buses;
- The proportion of fuel consumed by a certain class of vehicle is equal to the composition of that class of vehicle in the province. The inherent assumption is that the fuel economy rates are equal for motorcycles, passenger cars and LDVs using gasoline and for LDVs and HDVs using diesel 500. This assumption is not necessary for diesel 50 as only passenger cars use diesel 50.

Using the steps described above, motor vehicles emissions were estimated using the top-down approach to estimate emissions from motor vehicles for municipalities in eThekwini. The emissions were reported in units of ton/year.

5. Biomass burning

Emissions from biomass burning are estimated by using the following equations:

$$M_{ijt} = \sum \left([A]_{ijt} \times [B]_{ijt} \times [CF]_{ijt} \right) \quad (6)$$

Where,

M is the total amount of burned biomass

A is the annually (time) burned area (m^2)

B is the fuel load (kg/m^2) expressed on a dry mass CDM basis

CF is the fraction of available fuel which burns (the combustion factor)

The total emissions of gaseous pollutants and particulate matter are calculated using the following equation:

$$Q(x) = M_{ijt} \times EF(x) \quad (7)$$

Where,

Q(x) Total emissions of gaseous pollutants and particulate matter

χ is the chemical species

EF is the emission factor in gram species per kilogram of dry matter burned

Area Burned:

The determination of annual burned area was based on remote sensing techniques and procedures. Data was sourced from the Meraka Institute, which is an operating unit of the CSIR. The Remote Sensing Research Unit (RSRU) conducts activities related to remote sensing and earth observation application development. Earth surface properties, such as fires, are observed from satellites. One of their main areas of focus is tracking of fires, namely, active fires, burnt area mapping and fire danger modelling.

Notes:

1) A count of 463 m x 463 m pixels in a given year, for a given local municipality (LM), that are flagged as "Burned" by one or other of two algorithms for detecting burned areas from MODIS data.
2) An aggregation of the area of all the "Burned" pixels that are counted in a given year, for a given LM. Unit of measure is m^2. To get hectares, divide by 10 000.
3) The count may include the same areas more than once – this is possible, as a fire can partially burn the area of a pixel observation more than once in a year. Also, each burned area is not necessarily 463 m x 463 m; rather, what the algorithm says is that enough of a pixel has burned to flag the whole pixel as "Burned".

A fuel load of 0.502 kg/m^2 and a combustion factor of 0.63 was applied for sugarcane.

APPENDIX 3: Residential emissions per municipal ward

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
ETH: eThekwini	Gas	13.138	4.66E-05	0.130844	0.017757	0.003738
	Paraffin	2214.753	9.27356	23.51121	6.530892	1.410673
	Wood	2505.283	0.715447	5.008128	412.8128	54.73168
	Coal	90.2658	4.034358	0.59214	17.89433	0.403436
59500001: Ward 1	Gas	0.102	1.89E-07	0.00053	7.20E-05	1.52E-05
	Paraffin	3.3176	0.011945	0.030284	0.008412	0.001817
	Wood	112.392	0.026514	0.1856	15.29874	2.028343
	Coal	0.9284	0.043903	0.006444	0.194732	0.00439
59500002: Ward 2	Gas	0.259	4.70E-07	0.001319	0.000179	3.77E-05
	Paraffin	106.9288	0.143407	0.36358	0.100994	0.021815
	Wood	10.08	0.037083	0.259584	21.39714	2.836882
	Coal	0.2532	0.026105	0.003831	0.115787	0.00261
59500003: Ward 3	Gas	0.138	3.51E-07	0.000985	0.000134	2.81E-05
	Paraffin	77.3894	0.134208	0.340258	0.094516	0.020415
	Wood	2.1168	0.024155	0.169088	13.93768	1.84789
	Coal	0.422	0.034411	0.005051	0.152628	0.003441
59500004: Ward 4	Gas	0.158	5.57E-07	0.001563	0.000212	4.46E-05
	Paraffin	20.6712	0.071601	0.181529	0.050425	0.010892
	Wood	83.4624	0.023936	0.167552	13.81107	1.831104
	Coal	0.9706	0.042717	0.00627	0.189469	0.004272
59500005: Ward 5	Gas	0.051	1.61E-07	0.000451	6.13E-05	1.29E-05
	Paraffin	4.7212	0.020663	0.052388	0.014552	0.003143
	Wood	28.9296	0.006766	0.04736	3.903817	0.517577
	Coal	0.4642	0.017799	0.002612	0.078946	0.00178
59500006: Ward 6	Gas	0.108	3.15E-07	0.000884	0.00012	2.53E-05
	Paraffin	8.0388	0.023135	0.058653	0.016293	0.003519
	Wood	3.4272	0.001006	0.00704	0.580297	0.076937
	Coal	0.211	0.010679	0.001567	0.047367	0.001068
59500007: Ward 7	Gas	0.117	2.96E-07	0.00083	0.000113	2.37E-05
	Paraffin	12.76	0.042356	0.107386	0.029829	0.006443
	Wood	101.0016	0.031781	0.222464	18.33739	2.431214
	Coal	1.0972	0.046276	0.006792	0.205259	0.004628
59500008: Ward 8	Gas	0.673	1.89E-06	0.005313	0.000721	0.000152
	Paraffin	15.5034	0.054438	0.138018	0.038338	0.008281
	Wood	80.8416	0.026807	0.187648	15.46756	2.050725
	Coal	1.1816	0.066448	0.009753	0.29473	0.006645
59500009: Ward 9	Gas	0.519	1.36E-06	0.003804	0.000516	0.000109
	Paraffin	11.484	0.045651	0.11574	0.03215	0.006944
	Wood	50.5008	0.013806	0.09664	7.965897	1.056137
	Coal	0.4642	0.021358	0.003135	0.094735	0.002136

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
59500010: Ward 10	Gas	0.874	2.73E-06	0.007674	0.001041	0.000219
	Paraffin	2.6158	0.012906	0.03272	0.009089	0.001963
	Wood	32.3568	0.006674	0.04672	3.851063	0.510583
	Coal	0.8862	0.034411	0.005051	0.152628	0.003441
59500011: Ward 11	Gas	0.059	2.17E-07	0.000609	8.27E-05	1.74E-05
	Paraffin	6.3162	0.026224	0.066485	0.018468	0.003989
	Wood	5.1408	0.00128	0.00896	0.73856	0.09792
	Coal	0.3798	0.016612	0.002438	0.073683	0.001661
59500012: Ward 12	Gas	0.072	1.47E-07	0.000414	5.61E-05	1.18E-05
	Paraffin	9.8252	0.030961	0.078494	0.021804	0.00471
	Wood	10.08	0.002761	0.019328	1.593179	0.211227
	Coal	0.633	0.030851	0.004528	0.136839	0.003085
59500013: Ward 13	Gas	0.076	2.32E-07	0.00065	8.83E-05	1.86E-05
	Paraffin	13.9722	0.047162	0.119569	0.033214	0.007174
	Wood	12.096	0.002999	0.020992	1.730341	0.229413
	Coal	0.2532	0.014239	0.00209	0.063156	0.001424
59500014: Ward 14	Gas	0.083	1.94E-07	0.000543	7.37E-05	1.55E-05
	Paraffin	13.9084	0.059381	0.150549	0.041819	0.009033
	Wood	20.2608	0.005266	0.036864	3.038647	0.402871
	Coal	0.844	0.04153	0.006096	0.184206	0.004153
59500015: Ward 15	Gas	0.18	4.34E-07	0.001218	0.000165	3.48E-05
	Paraffin	26.4132	0.111966	0.283867	0.078852	0.017032
	Wood	27.4176	0.006437	0.045056	3.713902	0.492398
	Coal	1.5614	0.074754	0.010972	0.331571	0.007475
59500016: Ward 16	Gas	0.146	6.28E-07	0.001761	0.000239	5.03E-05
	Paraffin	18.2468	0.075651	0.191798	0.053277	0.011508
	Wood	13.8096	0.003035	0.021248	1.751442	0.23221
	Coal	0.633	0.023732	0.003483	0.105261	0.002373
59500017: Ward 17	Gas	0.165	4.23E-07	0.001187	0.000161	3.39E-05
	Paraffin	26.2218	0.067894	0.17213	0.047814	0.010328
	Wood	12.096	0.003237	0.022656	1.867502	0.247598
	Coal	0.3376	0.020172	0.002961	0.089472	0.002017
59500018: Ward 18	Gas	0.28	1.23E-06	0.003444	0.000467	9.84E-05
	Paraffin	1.3398	0.004394	0.011139	0.003094	0.000668
	Wood	6.3504	0.001353	0.009472	0.780763	0.103515
	Coal	0.1688	0.011866	0.001742	0.05263	0.001187
59500019: Ward 19	Gas	0.418	8.15E-07	0.002285	0.00031	6.53E-05
	Paraffin	56.782	0.199768	0.506471	0.140686	0.030388
	Wood	14.112	0.006875	0.048128	3.967122	0.52597
	Coal	1.0128	0.047463	0.006966	0.210522	0.004746
59500020: Ward 20	Gas	0.016	5.85E-08	0.000164	2.23E-05	4.69E-06
	Paraffin	4.0832	0.030137	0.076406	0.021224	0.004584

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
	Wood	0.7056	0.000219	0.001536	0.12661	0.016786
	Coal	0.1266	0.009493	0.001393	0.042104	0.000949
59500021: Ward 21	Gas	0.138	4.53E-07	0.001272	0.000173	3.63E-05
	Paraffin	14.8016	0.067139	0.170216	0.047282	0.010213
	Wood	1.9152	0.000585	0.004096	0.337627	0.044763
	Coal	0.2954	0.011866	0.001742	0.05263	0.001187
59500022: Ward 22	Gas	0.582	1.03E-06	0.002895	0.000393	8.27E-05
	Paraffin	74.7736	0.236907	0.600629	0.166841	0.036038
	Wood	5.1408	0.001408	0.009856	0.812416	0.107712
	Coal	0.3376	0.016612	0.002438	0.073683	0.001661
59500023: Ward 23	Gas	0.101	6.69E-07	0.001878	0.000255	5.37E-05
	Paraffin	89.1286	0.361367	0.916173	0.254492	0.05497
	Wood	39.4128	0.008082	0.056576	4.663479	0.618295
	Coal	1.1394	0.072381	0.010624	0.321045	0.007238
59500024: Ward 24	Gas	0.128	7.43E-07	0.002083	0.000283	5.95E-05
	Paraffin	7.656	0.021693	0.054998	0.015277	0.0033
	Wood	3.4272	0.000969	0.006784	0.559195	0.074139
	Coal	0.3376	0.011866	0.001742	0.05263	0.001187
59500025: Ward 25	Gas	0.176	7.53E-07	0.002112	0.000287	6.03E-05
	Paraffin	121.0286	0.533058	1.351459	0.375405	0.081088
	Wood	58.0608	0.010843	0.075904	6.256658	0.829522
	Coal	1.3504	0.067635	0.009927	0.299993	0.006763
59500026: Ward 26	Gas	0.067	2.01E-07	0.000565	7.67E-05	1.61E-05
	Paraffin	0.4466	0.05183	0.131404	0.036501	0.007884
	Wood	0.4032	0.000347	0.002432	0.200466	0.026578
	Coal	0.211	0.013052	0.001916	0.057893	0.001305
59500027: Ward 27	Gas	0.098	7.40E-07	0.002077	0.000282	5.93E-05
	Paraffin	0.2552	0.001373	0.003481	0.000967	0.000209
	Wood	0.1008	0.000146	0.001024	0.084407	0.011191
	Coal	0.2954	0.020172	0.002961	0.089472	0.002017
59500028: Ward 28	Gas	0.029	1.31E-07	0.000366	4.97E-05	1.05E-05
	Paraffin	0.8294	0.003776	0.009572	0.002659	0.000574
	Wood	0.7056	0.000347	0.002432	0.200466	0.026578
	Coal	0.0844	0.007119	0.001045	0.031578	0.000712
59500029: Ward 29	Gas	0.162	5.33E-07	0.001496	0.000203	4.28E-05
	Paraffin	90.277	0.319354	0.809657	0.224905	0.048579
	Wood	10.8864	0.002267	0.015872	1.308306	0.173458
	Coal	0.5486	0.034411	0.005051	0.152628	0.003441
59500030: Ward 30	Gas	0.134	5.64E-07	0.001581	0.000215	4.52E-05
	Paraffin	40.6406	0.276105	0.700009	0.194447	0.042001
	Wood	26.8128	0.005102	0.035712	2.943689	0.390281
	Coal	0.633	0.04865	0.007141	0.215785	0.004865

	Fuel type	Fuel consumption	SO_2	NO_X	CO	PM_{10}
59500031: Ward 31	Gas	0.071	5.79E-07	0.001626	0.000221	4.64E-05
	Paraffin	2.2968	0.014554	0.036898	0.010249	0.002214
	Wood	8.9712	0.001957	0.013696	1.128942	0.149678
	Coal	0.1688	0.010679	0.001567	0.047367	0.001068
59500032: Ward 32	Gas	0.054	2.08E-07	0.000584	7.93E-05	1.67E-05
	Paraffin	22.649	0.064667	0.16395	0.045542	0.009837
	Wood	2.3184	0.000987	0.006912	0.569746	0.075538
	Coal	0.5486	0.020172	0.002961	0.089472	0.002017
59500033: Ward 33	Gas	0.152	7.58E-07	0.002128	0.000289	6.08E-05
	Paraffin	1.4674	0.004394	0.011139	0.003094	0.000668
	Wood	1.512	0.000439	0.003072	0.253221	0.033573
	Coal	0.0844	0.00356	0.000522	0.015789	0.000356
59500034: Ward 34	Gas	0.13	7.86E-07	0.002207	0.000299	6.30E-05
	Paraffin	135.1284	0.51617	1.308644	0.363512	0.078519
	Wood	82.9584	0.016347	0.114432	9.432466	1.250578
	Coal	5.9924	0.204091	0.029955	0.905243	0.020409
59500035: Ward 35	Gas	0.195	1.23E-06	0.003463	0.00047	9.89E-05
	Paraffin	0.638	0.005766	0.01462	0.004061	0.000877
	Wood	7.6608	0.001737	0.01216	1.002331	0.132891
	Coal	0.3376	0.014239	0.00209	0.063156	0.001424
59500036: Ward 36	Gas	0.241	1.58E-06	0.004435	0.000602	0.000127
	Paraffin	1.7226	0.009817	0.024888	0.006913	0.001493
	Wood	1.3104	0.000439	0.003072	0.253221	0.033573
	Coal	0.2532	0.014239	0.00209	0.063156	0.001424
59500037: Ward 37	Gas	0.084	3.26E-07	0.000915	0.000124	2.62E-05
	Paraffin	3.6366	0.015103	0.03829	0.010636	0.002297
	Wood	3.6288	0.000933	0.006528	0.538094	0.071342
	Coal	0.2532	0.011866	0.001742	0.05263	0.001187
59500038: Ward 38	Gas	0.138	3.66E-07	0.001026	0.000139	2.93E-05
	Paraffin	41.0234	0.137435	0.348438	0.096788	0.020906
	Wood	26.9136	0.00587	0.041088	3.386825	0.449033
	Coal	1.2238	0.054582	0.008011	0.2421	0.005458
59500039: Ward 39	Gas	0.042	7.88E-08	0.000221	3.00E-05	6.31E-06
	Paraffin	4.6574	0.024645	0.062482	0.017356	0.003749
	Wood	1.1088	0.000603	0.004224	0.348178	0.046162
	Coal	0.0844	0.002373	0.000348	0.010526	0.000237
59500040: Ward 40	Gas	0.044	8.21E-08	0.00023	3.13E-05	6.58E-06
	Paraffin	7.018	0.025331	0.064223	0.01784	0.003853
	Wood	1.3104	0.000439	0.003072	0.253221	0.033573
	Coal	0.9706	0.029664	0.004354	0.131576	0.002966
59500041: Ward 41	Gas	0.38	1.03E-06	0.002885	0.000392	8.24E-05
	Paraffin	38.7266	0.099609	0.252539	0.07015	0.015152

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
	Wood	1.7136	0.000439	0.003072	0.253221	0.033573
	Coal	0.9706	0.035597	0.005225	0.157891	0.00356
59500042: Ward 42	Gas	0.081	1.52E-07	0.000426	5.78E-05	1.22E-05
	Paraffin	9.3148	0.043249	0.109648	0.030458	0.006579
	Wood	5.2416	0.001445	0.010112	0.833518	0.11051
	Coal	0.8862	0.029664	0.004354	0.131576	0.002966
59500043: Ward 43	Gas	0.074	1.88E-07	0.000527	7.15E-05	1.51E-05
	Paraffin	16.6518	0.069198	0.175437	0.048733	0.010526
	Wood	16.4304	0.003511	0.024576	2.025765	0.268581
	Coal	0.7596	0.036784	0.005399	0.163154	0.003678
59500044: Ward 44	Gas	0.084	2.61E-07	0.000732	9.94E-05	2.09E-05
	Paraffin	11.803	0.050869	0.128967	0.035824	0.007738
	Wood	7.6608	0.002999	0.020992	1.730341	0.229413
	Coal	1.1394	0.047463	0.006966	0.210522	0.004746
59500045: Ward 45	Gas	0.096	2.18E-07	0.000612	8.31E-05	1.75E-05
	Paraffin	10.3994	0.067139	0.170216	0.047282	0.010213
	Wood	24.2928	0.004919	0.034432	2.838181	0.376293
	Coal	0.7596	0.055769	0.008185	0.247363	0.005577
59500046: Ward 46	Gas	0.037	8.55E-08	0.00024	3.26E-05	6.85E-06
	Paraffin	5.423	0.023615	0.059871	0.016631	0.003592
	Wood	0.504	0.000366	0.00256	0.211017	0.027977
	Coal	0.1266	0.009493	0.001393	0.042104	0.000949
59500047: Ward 47	Gas	0.047	8.89E-08	0.000249	3.38E-05	7.13E-06
	Paraffin	3.0624	0.018467	0.046818	0.013005	0.002809
	Wood	1.4112	0.000512	0.003584	0.295424	0.039168
	Coal	0.2954	0.011866	0.001742	0.05263	0.001187
59500048: Ward 48	Gas	0.027	1.25E-07	0.00035	4.76E-05	1.00E-05
	Paraffin	1.276	0.003844	0.009747	0.002707	0.000585
	Wood	4.6368	0.001627	0.011392	0.939026	0.124498
	Coal	0.211	0.008306	0.001219	0.036841	0.000831
59500049: Ward 49	Gas	0.054	1.69E-07	0.000474	6.43E-05	1.35E-05
	Paraffin	0.8294	0.003158	0.008006	0.002224	0.00048
	Wood	2.016	0.000658	0.004608	0.379831	0.050359
	Coal	0.2954	0.009493	0.001393	0.042104	0.000949
59500050: Ward 50	Gas	0.021	1.23E-07	0.000344	4.67E-05	9.83E-06
	Paraffin	0.5104	0.001785	0.004525	0.001257	0.000272
	Wood	0.9072	0.000347	0.002432	0.200466	0.026578
	Coal	0.2532	0.008306	0.001219	0.036841	0.000831
59500051: Ward 51	Gas	0.04	2.03E-07	0.000568	7.71E-05	1.62E-05
	Paraffin	1.6588	0.00611	0.01549	0.004303	0.000929
	Wood	3.3264	0.001061	0.007424	0.61195	0.081134
	Coal	0.2954	0.013052	0.001916	0.057893	0.001305

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
59500052: Ward 52	Gas	0.092	2.03E-07	0.000568	7.71E-05	1.62E-05
	Paraffin	0.4466	0.002059	0.005221	0.00145	0.000313
	Wood	1.1088	0.000384	0.002688	0.221568	0.029376
	Coal	0.1266	0.005933	0.000871	0.026315	0.000593
59500053: Ward 53	Gas	0.158	3.98E-07	0.001117	0.000152	3.19E-05
	Paraffin	48.9346	0.206427	0.523353	0.145376	0.031401
	Wood	58.6656	0.012178	0.085248	7.026871	0.931639
	Coal	2.2788	0.098486	0.014455	0.436832	0.009849
59500054: Ward 54	Gas	0.047	1.17E-07	0.000328	4.46E-05	9.38E-06
	Paraffin	19.14	0.046544	0.118002	0.032778	0.00708
	Wood	5.544	0.001445	0.010112	0.833518	0.11051
	Coal	0.3798	0.017799	0.002612	0.078946	0.00178
59500055: Ward 55	Gas	0.123	2.72E-07	0.000764	0.000104	2.18E-05
	Paraffin	23.7974	0.09906	0.251147	0.069763	0.015069
	Wood	9.8784	0.002633	0.018432	1.519323	0.201435
	Coal	0.5064	0.040344	0.005921	0.178943	0.004034
59500056: Ward 56	Gas	0.171	4.04E-07	0.001133	0.000154	3.24E-05
	Paraffin	17.0346	0.112653	0.285608	0.079335	0.017136
	Wood	26.9136	0.008137	0.05696	4.695131	0.622491
	Coal	1.3504	0.061702	0.009056	0.273678	0.00617
59500057: Ward 57	Gas	0.13	2.86E-07	0.000802	0.000109	2.29E-05
	Paraffin	47.212	0.192354	0.487674	0.135465	0.02926
	Wood	17.9424	0.004425	0.030976	2.553307	0.338523
	Coal	1.055	0.04865	0.007141	0.215785	0.004865
59500058: Ward 58	Gas	0.17	7.70E-07	0.002159	0.000293	6.17E-05
	Paraffin	55.6336	0.192285	0.4875	0.135417	0.02925
	Wood	13.8096	0.004096	0.028672	2.363392	0.313344
	Coal	0.7596	0.040344	0.005921	0.178943	0.004034
59500059: Ward 59	Gas	0.129	3.09E-07	0.000868	0.000118	2.48E-05
	Paraffin	35.6004	0.147114	0.372978	0.103605	0.022379
	Wood	32.76	0.016731	0.11712	9.654034	1.279954
	Coal	1.6458	0.071195	0.01045	0.315782	0.007119
59500060: Ward 60	Gas	0.126	4.14E-07	0.001162	0.000158	3.32E-05
	Paraffin	49.5726	0.188647	0.478276	0.132854	0.028697
	Wood	24.0912	0.007899	0.055296	4.55797	0.604306
	Coal	1.6036	0.071195	0.01045	0.315782	0.007119
59500061: Ward 61	Gas	0.096	4.58E-07	0.001285	0.000174	3.67E-05
	Paraffin	41.2786	0.271094	0.687304	0.190918	0.041238
	Wood	82.5552	0.01675	0.117248	9.664585	1.281353
	Coal	0.7174	0.049836	0.007315	0.221048	0.004984
59500062: Ward 62	Gas	0.124	5.05E-07	0.001417	0.000192	4.05E-05
	Paraffin	29.9222	0.196061	0.497072	0.138076	0.029824

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
	Wood	34.3728	0.008283	0.057984	4.779538	0.633682
	Coal	0.9706	0.061702	0.009056	0.273678	0.00617
59500063: Ward 63	Gas	0.121	8.38E-07	0.002352	0.000319	6.72E-05
	Paraffin	9.6338	0.043798	0.111041	0.030845	0.006662
	Wood	14.616	0.00331	0.023168	1.909705	0.253193
	Coal	0.5486	0.017799	0.002612	0.078946	0.00178
59500064: Ward 64	Gas	0.087	4.55E-07	0.001275	0.000173	3.64E-05
	Paraffin	1.8502	0.005355	0.013576	0.003771	0.000815
	Wood	2.9232	0.001042	0.007296	0.601399	0.079735
	Coal	0.2532	0.009493	0.001393	0.042104	0.000949
59500065: Ward 65	Gas	0.106	6.23E-07	0.001749	0.000237	5.00E-05
	Paraffin	16.269	0.063157	0.160121	0.044478	0.009607
	Wood	31.248	0.006766	0.04736	3.903817	0.517577
	Coal	0.9284	0.034411	0.005051	0.152628	0.003441
59500066: Ward 66	Gas	0.109	7.43E-07	0.002083	0.000283	5.95E-05
	Paraffin	1.7226	0.00508	0.012879	0.003578	0.000773
	Wood	2.2176	0.00064	0.00448	0.36928	0.04896
	Coal	0.5064	0.014239	0.00209	0.063156	0.001424
59500067: Ward 67	Gas	0.087	3.89E-07	0.001092	0.000148	3.12E-05
	Paraffin	17.545	0.077504	0.196497	0.054582	0.01179
	Wood	55.44	0.018633	0.130432	10.75132	1.425435
	Coal	0.6752	0.04153	0.006096	0.184206	0.004153
59500068: Ward 68	Gas	0.072	2.19E-07	0.000616	8.35E-05	1.76E-05
	Paraffin	2.1054	0.007139	0.018101	0.005028	0.001086
	Wood	8.3664	0.002706	0.018944	1.561527	0.207031
	Coal	0.211	0.008306	0.001219	0.036841	0.000831
59500069: Ward 69	Gas	0.041	1.61E-07	0.000451	6.13E-05	1.29E-05
	Paraffin	20.6712	0.05588	0.141673	0.039353	0.0085
	Wood	1.6128	0.00053	0.003712	0.305975	0.040567
	Coal	0.2532	0.014239	0.00209	0.063156	0.001424
59500070: Ward 70	Gas	0.027	1.70E-07	0.000477	6.47E-05	1.36E-05
	Paraffin	1.3398	0.004599	0.011661	0.003239	0.0007
	Wood	0.9072	0.000439	0.003072	0.253221	0.033573
	Coal	0.1688	0.005933	0.000871	0.026315	0.000593
59500071: Ward 71	Gas	0.069	3.15E-07	0.000884	0.00012	2.53E-05
	Paraffin	43.3202	0.231072	0.585835	0.162732	0.03515
	Wood	72.2736	0.013659	0.095616	7.88149	1.044946
	Coal	0.7596	0.051023	0.007489	0.226311	0.005102
59500072: Ward 72	Gas	0.102	2.80E-07	0.000786	0.000107	2.25E-05
	Paraffin	33.6226	0.186931	0.473924	0.131646	0.028435
	Wood	28.9296	0.006802	0.047616	3.924919	0.520375
	Coal	0.9706	0.066448	0.009753	0.29473	0.006645

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
59500073: Ward 73	Gas	0.028	1.22E-07	0.000341	4.63E-05	9.74E-06
	Paraffin	0.4466	0.001854	0.004699	0.001305	0.000282
	Wood	1.9152	0.000713	0.004992	0.411483	0.054555
	Coal	0.0422	0.002373	0.000348	0.010526	0.000237
59500074: Ward 74	Gas	0.015	1.17E-07	0.000328	4.46E-05	9.38E-06
	Paraffin	5.104	0.035835	0.090851	0.025237	0.005451
	Wood	2.3184	0.000768	0.005376	0.443136	0.058752
	Coal	0.3376	0.011866	0.001742	0.05263	0.001187
59500075: Ward 75	Gas	0.025	1.58E-07	0.000442	6.00E-05	1.26E-05
	Paraffin	4.466	0.039816	0.100946	0.028041	0.006057
	Wood	0.9072	0.000329	0.002304	0.189915	0.025179
	Coal	0.0844	0.009493	0.001393	0.042104	0.000949
59500076: Ward 76	Gas	0.055	1.72E-07	0.000483	6.55E-05	1.38E-05
	Paraffin	67.5004	0.181301	0.459653	0.127681	0.027579
	Wood	23.688	0.004754	0.03328	2.743223	0.363703
	Coal	0.844	0.035597	0.005225	0.157891	0.00356
59500077: Ward 77	Gas	0.136	3.78E-07	0.001061	0.000144	3.03E-05
	Paraffin	47.5948	0.182949	0.46383	0.128842	0.02783
	Wood	52.1136	0.011886	0.0832	6.858057	0.909257
	Coal	5.7392	0.194598	0.028562	0.863138	0.01946
59500078: Ward 78	Gas	0.046	1.37E-07	0.000385	5.23E-05	1.10E-05
	Paraffin	5.9972	0.033707	0.085456	0.023738	0.005127
	Wood	6.048	0.001426	0.009984	0.822967	0.109111
	Coal	0.2532	0.020172	0.002961	0.089472	0.002017
59500079: Ward 79	Gas	0.073	2.25E-07	0.000631	8.57E-05	1.80E-05
	Paraffin	18.4382	0.085399	0.216512	0.060142	0.012991
	Wood	5.544	0.001829	0.0128	1.055086	0.139886
	Coal	0.5064	0.023732	0.003483	0.105261	0.002373
59500080: Ward 80	Gas	0.056	1.55E-07	0.000436	5.91E-05	1.24E-05
	Paraffin	11.6754	0.04524	0.114696	0.03186	0.006882
	Wood	9.2736	0.00203	0.014208	1.171145	0.155273
	Coal	0.5908	0.027291	0.004006	0.12105	0.002729
59500081: Ward 81	Gas	0.031	1.07E-07	0.0003	4.07E-05	8.57E-06
	Paraffin	7.975	0.030549	0.07745	0.021514	0.004647
	Wood	3.7296	0.001024	0.007168	0.590848	0.078336
	Coal	0.3798	0.015425	0.002264	0.06842	0.001543
59500082: Ward 82	Gas	0.04	1.13E-07	0.000316	4.28E-05	9.02E-06
	Paraffin	10.6546	0.03913	0.099206	0.027557	0.005952
	Wood	3.528	0.000933	0.006528	0.538094	0.071342
	Coal	0.5064	0.020172	0.002961	0.089472	0.002017
59500083: Ward 83	Gas	0.049	1.40E-07	0.000391	5.31E-05	1.12E-05
	Paraffin	9.3786	0.038512	0.097639	0.027122	0.005858

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
	Wood	3.4272	0.001042	0.007296	0.601399	0.079735
	Coal	1.055	0.040344	0.005921	0.178943	0.004034
59500084: Ward 84	Gas	0.061	2.22E-07	0.000622	8.44E-05	1.78E-05
	Paraffin	13.9084	0.069335	0.175785	0.048829	0.010547
	Wood	52.6176	0.014793	0.103552	8.535643	1.131675
	Coal	0.6752	0.023732	0.003483	0.105261	0.002373
59500085: Ward 85	Gas	0.055	1.51E-07	0.000423	5.74E-05	1.21E-05
	Paraffin	6.2524	0.02794	0.070836	0.019677	0.00425
	Wood	6.1488	0.001317	0.009216	0.759662	0.100718
	Coal	0.3798	0.016612	0.002438	0.073683	0.001661
59500086: Ward 86	Gas	0.091	2.68E-07	0.000751	0.000102	2.15E-05
	Paraffin	5.6144	0.033432	0.08476	0.023544	0.005086
	Wood	10.4832	0.002505	0.017536	1.445467	0.191643
	Coal	0.6752	0.024918	0.003657	0.110524	0.002492
59500087: Ward 87	Gas	0.054	1.08E-07	0.000303	4.11E-05	8.66E-06
	Paraffin	7.975	0.04469	0.113303	0.031473	0.006798
	Wood	5.8464	0.001371	0.0096	0.791314	0.104914
	Coal	0.9706	0.040344	0.005921	0.178943	0.004034
59500088: Ward 88	Gas	0.048	1.55E-07	0.000436	5.91E-05	1.24E-05
	Paraffin	17.3536	0.081692	0.207113	0.057532	0.012427
	Wood	2.7216	0.000859	0.006016	0.49589	0.065746
	Coal	0.5486	0.051023	0.007489	0.226311	0.005102
59500089: Ward 89	Gas	0.116	5.65E-07	0.001585	0.000215	4.53E-05
	Paraffin	101.3782	0.395898	1.003717	0.27881	0.060223
	Wood	34.4736	0.007168	0.050176	4.135936	0.548352
	Coal	2.5742	0.125777	0.018461	0.557882	0.012578
59500090: Ward 90	Gas	0.084	3.98E-07	0.001117	0.000152	3.19E-05
	Paraffin	19.2676	0.156657	0.397171	0.110325	0.02383
	Wood	8.3664	0.001774	0.012416	1.023433	0.135689
	Coal	0.422	0.039157	0.005747	0.17368	0.003916
59500091: Ward 91	Gas	0.124	4.64E-07	0.001301	0.000177	3.72E-05
	Paraffin	41.47	0.107779	0.273251	0.075903	0.016395
	Wood	9.072	0.002542	0.017792	1.466569	0.194441
	Coal	0.3798	0.020172	0.002961	0.089472	0.002017
59500092: Ward 92	Gas	0.154	6.00E-07	0.001683	0.000228	4.81E-05
	Paraffin	33.176	0.133247	0.337821	0.093839	0.020269
	Wood	6.3504	0.001609	0.011264	0.928475	0.123099
	Coal	1.0128	0.04509	0.006618	0.199995	0.004509
59500093: Ward 93	Gas	0.134	5.72E-07	0.001604	0.000218	4.58E-05
	Paraffin	8.0388	0.058626	0.148634	0.041287	0.008918
	Wood	15.3216	0.005138	0.035968	2.964791	0.393079
	Coal	0.633	0.029664	0.004354	0.131576	0.002966

	Fuel type	Fuel consumption	SO_2	NO_x	CO	PM_{10}
59500094: Ward 94	Gas	0.059	1.51E-07	0.000423	5.74E-05	1.21E-05
	Paraffin	10.9098	0.04524	0.114696	0.03186	0.006882
	Wood	14.3136	0.004754	0.03328	2.743223	0.363703
	Coal	0.211	0.011866	0.001742	0.05263	0.001187
59500095: Ward 95	Gas	0.167	4.17E-07	0.001171	0.000159	3.35E-05
	Paraffin	16.1414	0.068374	0.173349	0.048152	0.010401
	Wood	13.2048	0.004974	0.034816	2.869833	0.380489
	Coal	1.3504	0.056956	0.00836	0.252626	0.005696
59500096: Ward 96	Gas	0.066	3.13E-07	0.000878	0.000119	2.51E-05
	Paraffin	4.7212	0.043249	0.109648	0.030458	0.006579
	Wood	49.7952	0.019328	0.135296	11.15226	1.478592
	Coal	0.633	0.030851	0.004528	0.136839	0.003085
59500097: Ward 97	Gas	0.216	1.06E-06	0.002983	0.000405	8.52E-05
	Paraffin	0.638	0.002128	0.005395	0.001499	0.000324
	Wood	2.016	0.000695	0.004864	0.400933	0.053157
	Coal	0.2954	0.020172	0.002961	0.089472	0.002017
59500098: Ward 98	Gas	0.218	7.98E-07	0.002238	0.000304	6.39E-05
	Paraffin	34.452	0.1189	0.301446	0.083735	0.018087
	Wood	22.7808	0.009399	0.065792	5.423141	0.719013
	Coal	0.7596	0.046276	0.006792	0.205259	0.004628
59500099: Ward 99	Gas	0.155	7.34E-07	0.002058	0.000279	5.88E-05
	Paraffin	12.6962	0.099129	0.251321	0.069811	0.015079
	Wood	94.0464	0.028306	0.198144	16.33273	2.165431
	Coal	1.7724	0.084247	0.012365	0.373676	0.008425
59500100: Ward 100	Gas	0.062	2.08E-07	0.000584	7.93E-05	1.67E-05
	Paraffin	9.3148	0.043317	0.109822	0.030506	0.006589
	Wood	167.6304	0.060142	0.420992	34.70177	4.600841
	Coal	0.5064	0.034411	0.005051	0.152628	0.003441
59500101: Ward 101	Gas	0.264	1.02E-06	0.002873	0.00039	8.21E-05
	Paraffin	79.6224	0.439764	1.114932	0.309703	0.066896
	Wood	13.8096	0.002725	0.019072	1.572078	0.20843
	Coal	9.3684	0.325122	0.047719	1.442073	0.032512
59500102: Ward 102	Gas	0.094	6.45E-07	0.001809	0.000245	5.17E-05
	Paraffin	32.7932	0.132835	0.336777	0.093549	0.020207
	Wood	15.3216	0.003328	0.023296	1.920256	0.254592
	Coal	0.9706	0.043903	0.006444	0.194732	0.00439
59500103: Ward 103	Gas	0.18	7.50E-07	0.002105	0.000286	6.02E-05
	Paraffin	11.6754	0.052173	0.132274	0.036743	0.007936
	Wood	63.1008	0.018048	0.126336	10.4137	1.380672
	Coal	0.844	0.036784	0.005399	0.163154	0.003678

APPENDIX 4: Dispersion modelling plan

1 *INTRODUCTION*

1.1 Background

The eThekwini Municipality appointed uMoya-NILU Consulting (Pty) Ltd to develop an Air Quality Management Plan (AQMP). A baseline assessment is the first step in the development of an AQMP and includes the assessment of the status of the air quality management tools and systems, including dispersion modelling. The focus of this report is on a dispersion modelling plan for the eThekwini Municipality, according to the requirements of the Department of Environmental Affairs (DEA) regulation for dispersion modelling, documented in the Guideline for Air Dispersion Modelling for Air Quality Management in South Africa (DEA, 2012).

1.2 Project Location

The eThekwini Municipality is located on the east coast of South Africa in the Province of KwaZulu-Natal (KZN) (Figure 1-1).

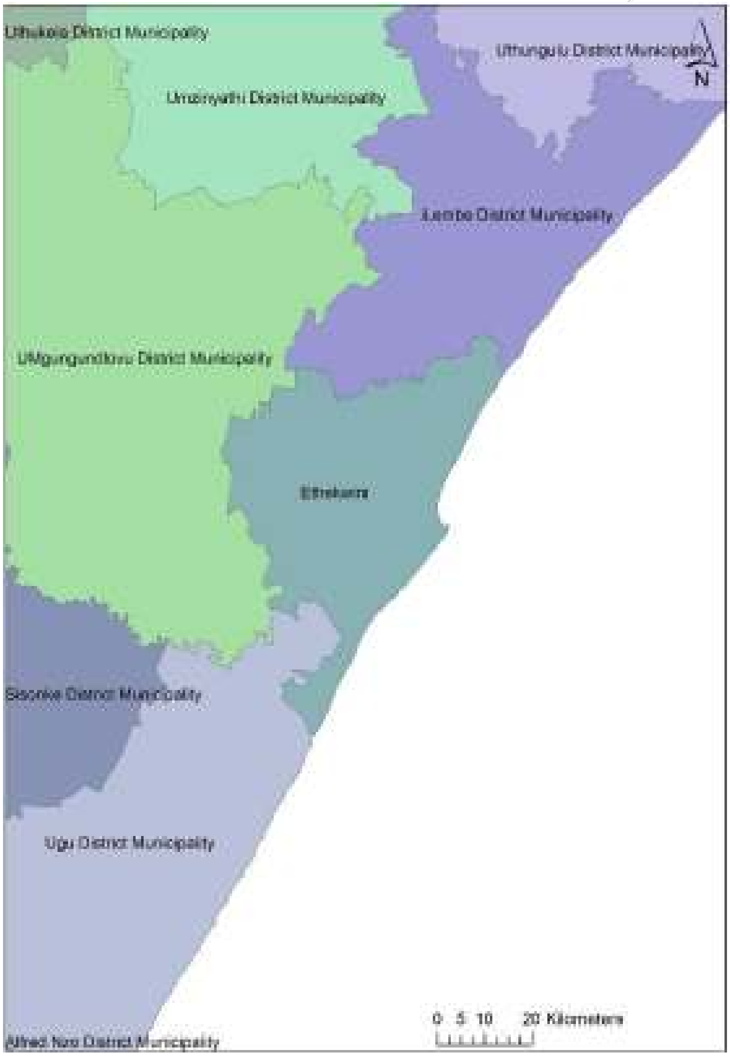

Figure 1-1: eThekwini Municipality

1.3 Land use determination in the modelling domain

The Guideline for Air Dispersion Modelling for Air Quality Management in South Africa (DEA, 2012) recommends the Land Use Procedure as sufficient for determining the urban/rural status of a modelling domain. The classification of the study area as urban or rural is based on the Auer method specified in the US EPA guideline on air dispersion models (US EPA, 2005). From the Auer's method, 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 1-1. The land use classification within the eThekwini Municipality is shown in Figure 1-2.

Table 1-1: Land types, use and structures and vegetation cover

Urban Land Use		
Type	**Use and Structures**	**Vegetation**
I1	Heavy industrial	Less than 5%
I2	Light/moderate industrial	Less than 5%
C1	Commercial	Less than 15%
R2	Dense single/multi-family	Less than 30%
R3	Multi-family, two-story	Less than 35%

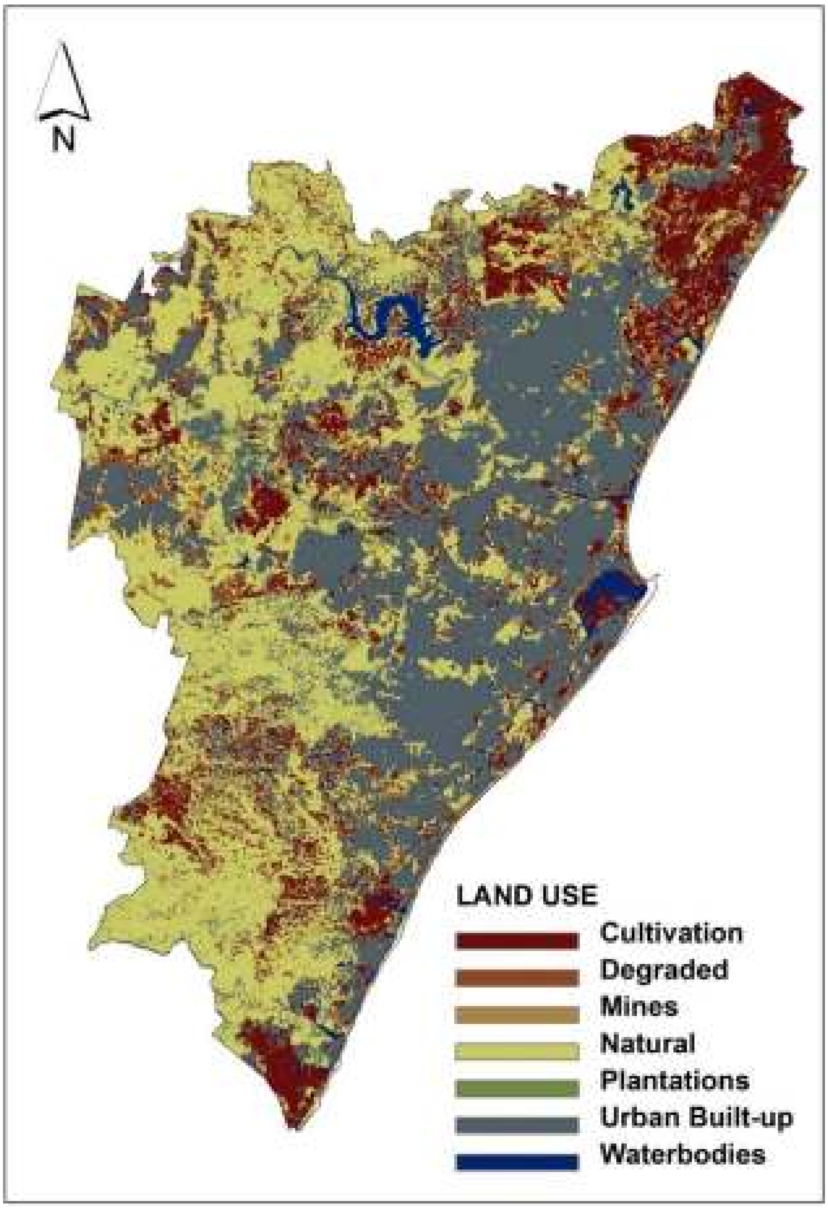

Figure 1-2: Land use classification within the eThekwini Municipality

1.4 Elevation data (DEM) and resolution

The topographical and land use for the respective modelling domains is obtained from the dataset accompanying the CSIRO's The Air Pollution Model (TAPM) modelling package. This dataset includes global terrain elevation and land use classification data on a longitude/latitude grid at 30-second grid spacing from the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center.

2 EMISSIONS CHARACTERISATION

Emissions of air pollutants result from a number of source sectors in eThekwini, including:

- Industrial facilities (Listed Activities and controlled emitters);
- Transport (motor vehicles; the Port of Durban; King Shaka International Airport);
- Waste management (landfill sites and wastewater treatment works);
- Biomass burning (sugarcane);

- Residential fuel burning;
- Quarries; and
- Biogenic emissions.

A comprehensive emission inventory is being developed as part of the baseline assessment.

2.1 Baseline Assessment Scenario

The comprehensive emission inventory which is being developed as part of the baseline assessment shows that Listed Activities, Controlled Emitters, the Port of Durban and King Shaka International Airport are sources of concern that need to be understood better. These four source categories are modelled in the baseline assessment to augment ambient monitoring data. Emissions from motor vehicles are relatively small and are not modelled. Similarly, emissions from waste management, biomass burning, residential fuel burning, biogenic emissions and quarries are also relatively small and are not modelled.

2.2 Background concentrations

A background concentration is the portion of the ambient concentration of a pollutant at a site due to sources, both natural and anthropogenic, other than the source being assessed. In this study, measured ambient concentrations of PM_{10} at one of eThekwini Municipality's background monitoring stations will be used to determine a PM_{10} background. A representative background concentration derived from the ambient monitoring data will be used in the model predictions.

3 METEOROLOGICAL DATA

The South African Weather Service (SAWS) and the eThekwini Municipality operate a number of meteorological monitoring stations within the municipality. These do not provide adequate coverage across the municipality. To address the challenges relating to data scarcity in eThekwini, TAPM meteorological data will be used to supplement the meteorology in the modelling domain.

Three years of hourly observed meteorological data for the period 2010-2012, from SAWS meteorological stations at the Old Durban Airport in the south and the King Shaka International Airport in the north will be input to TAPM to 'nudge' the modelled meteorology towards the observations and to create a continuous meteorological input file for the domain. These datasets are chosen as they are the more complete in terms of data, and it is more representative of the surrounding areas. TAPM is set-up in a nested configuration of two domains. The outer domain is 420 km by 420 km at a 12 km grid resolution and the inner domain is 105 km by 105 km at a 3 km grid resolution. The subset of the entire TAPM model output in the form of pre-processed gridded surface meteorological data fields will be input into CALMET. This approach eliminates potential issues associated with missing observational data. Upper air data is included in the pre-processed TAPM meteorological fields.

4 MODELLING PROCEDURES

4.1 Proposed Model

A Level 3 air quality assessment is conducted in situations where the purpose of the assessment requires a detailed understanding of the air quality impacts (time and space variation of the concentrations) and when it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types and chemical transformations (DEA, 2012). A Level 3 assessment may be used in situations where there is a need to evaluate air quality consequences under a permitting or environmental assessment process for large industrial developments that have considerable social, economic and potential environmental consequences. Under these circumstances, this study clearly demonstrates the need for a Level 3 assessment. CALPUFF is a US-EPA approved air dispersion model (http://www.src.com/calpuff/calpuff1.htm) and is recommended by the DEA for Level 3 assessments (DEA, 2012). CALPUFF is considered to be an appropriate air dispersion model for the purpose of this assessment as it is well suited to simulate dispersion from the large array of sources and source types.

4.2 Grid receptors

Six modelling domains (Figure 4-1) will be used for the CALMET and CALPUFF model runs. These focus on the concentration of emission sources and current or future air pollution hotspots. Modelling grid specifications are given in Table 4-1.

eThekwini Municipality (Modelling domain 1)
A CALPUFF modelling domain of 7220 km^2 which covers the entire eThekwini Municipality, where the domain extends 76 km (west-east) by 95 km (north-south). It will consist of a uniformly spaced receptor grid with 1 km spacing, giving 7220 grid cells (76x95 grid cells). The modelling domain caters for a buffer zone around the boundaries of the municipality, of 5 km to the north, south and west and 10 km to the east.

CBD and South Durban (Modelling domain 2)
A CALPUFF modelling domain of 525 km^2, where the domain extends 21 km (west-east) by 25 km (north-south). It will consist of a uniformly spaced receptor grid with 250 m spacing, giving 8400 grid cells (84x100 grid cells).

Outer West (Modelling domain 3)
A CALPUFF modelling domain of 72 km^2, where the domain extends 9 km (west-east) by 8 km (north-south). It will consist of a uniformly spaced receptor grid with 250 m spacing, giving 1152 grid cells (36x32 grid cells).

Inner West (Modelling domain 4)
A CALPUFF modelling domain of 117 km^2, where the domain extends 13 km (west-east) by 9 km (north-south). It will consist of a uniformly spaced receptor grid with 250 m spacing, giving 1872 grid cells (52x36 grid cells).

Northern Region (Modelling domain 5)

A CALPUFF modelling domain of 252 km^2, where the domain extends 18 km (west-east) by 14 km (north-south). It will consist of a uniformly spaced receptor grid with 250 m spacing, giving 4032 grid cells (72x56 grid cells).

Southern Region (Modelling domain 6)

A CALPUFF modelling domain of 256 km^2, where the domain extends 16 km (west-east) by 16 km (north-south). It will consist of a uniformly spaced receptor grid with 250 m spacing, giving 4096 grid cells (64x64 grid cells).

Table 4-1: Modelling domain specifications

		Modelling Domains					
		eThekwini Municipality	CBD and South Durban	Outer West	Inner West	Northern Region	Southern Region
Modelling grid specifications	Area (km^2)	7220	525	72	117	252	256
	Distance (km) in west-east and north-south direction	76x95	21x25	9x8	13x9	18x14	16x16
	Grid resolution (m)	1000	250	250	250	250	250
	Number of grid cells in west-east and north-south direction	76x95	84x100	36x32	52x36	72x56	64x6
	Total number of grid cells in modelling domain	7220	8400	1152	1872	4032	4096

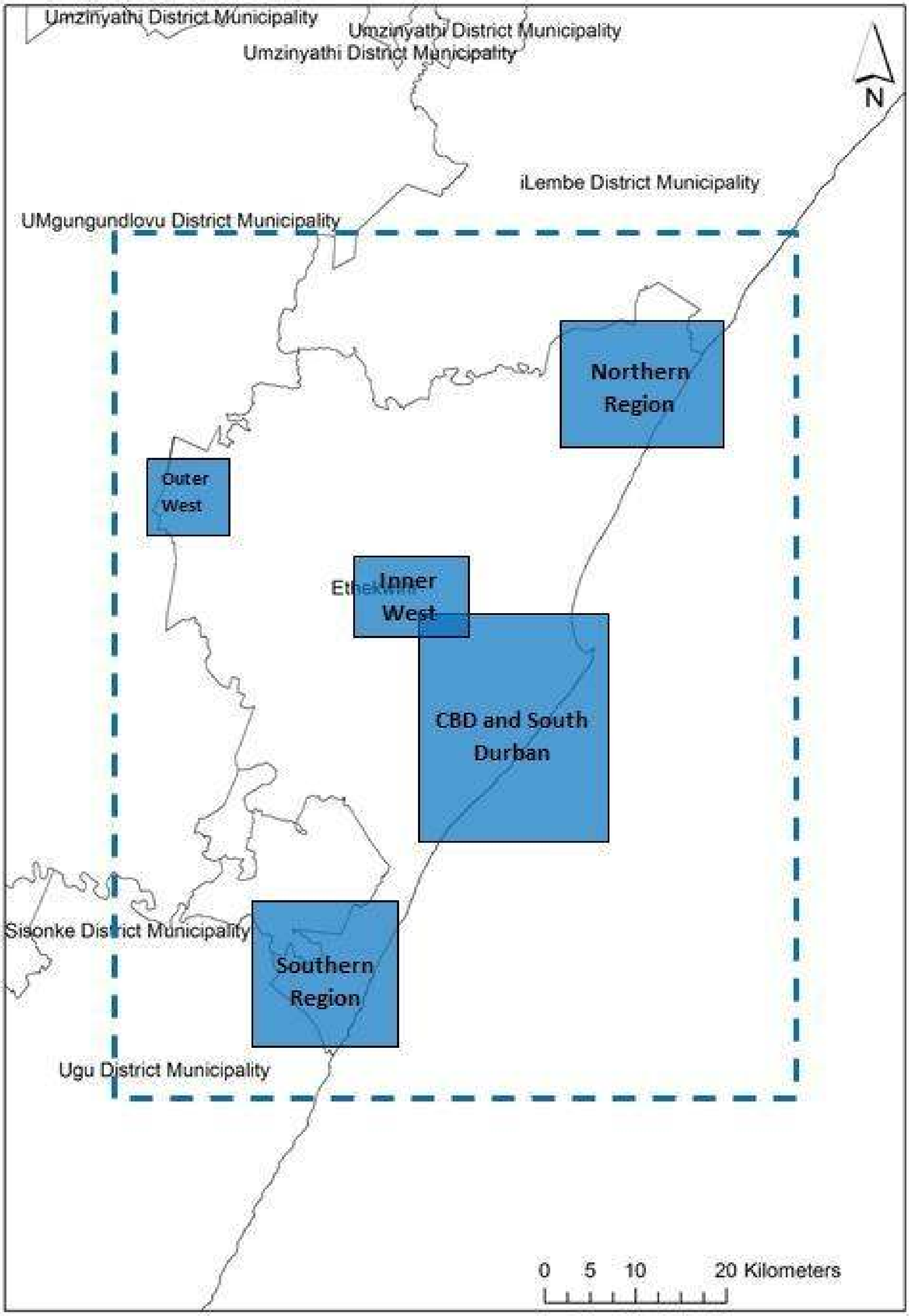

Figure 4-1: Relative location of the six modelling domains that will be used for the CALMET and CALPUFF model runs. The eThekwini modelling domain is represented by the dashed lines

4.3 Emission included in modelling for each domain

eThekwini Municipality (Modelling domain 1)

Includes industrial facilities (Listed Activities and Controlled Emitters) in the entire eThekwini Municipality, the Port of Durban and the King Shaka International Airport (Table 4-2).

CBD and South Durban (Modelling domain 2)

Includes industrial facilities (Listed Activities and Controlled Emitters) in South Durban Basin and the Port of Durban (Table 4-2).

Outer West (Modelling domain 3)

Includes industrial facilities (Listed Activities and Controlled Emitters) in Cato Ridge (Table 4-2).

Inner West (Modelling domain 4)

Includes industrial facilities (Listed Activities and Controlled Emitters) in Westmead, Pinetown and New Germany (Table 4-2).

Northern Region (Modelling domain 5)

Includes industrial facilities (Listed Activities and Controlled Emitters) in Verulam, Tongaat and the King Shaka International Airport (Table 4-2).

Southern Region (Modelling domain 6)

Includes industrial facilities (Listed Activities and Controlled Emitters) in Umkomaas (Table 4-2).

Table 4-2: Emission scenarios

		Modelling Domains					
		eThekwini Municipality	CBD and South Durban	Outer West	Inner West	Northern Region	Southern Region
Source categories	Listed Activities	X	X	X	X	X	X
	Controlled Emitters	X	X	X	X	X	X
	Port of Durban	X	X				
	King Shaka International Airport	X				X	

4.2 Model settings

The parameterisation of key variables that will apply in CALMET and CALPUFF are indicated in Table 4-3 and Table 4-4 respectively.

Table 4-3: Parameterisation of key variables for CALMET

Parameter	Model value
12 vertical cell face heights (m)	0, 20, 40, 80, 160, 320, 640, 1000, 1500, 2000, 2500, 3000, 4000
Coriolis parameter (per second)	0.0001
Empirical constants for mixing height equation	Neutral, mechanical: 1.41 Convective: 0.15 Stable: 2400 Overwater, mechanical: 0.12
Minimum potential temperature lapse rate (K/m)	0.001
Depth of layer above convective mixing height through which lapse rate is computed (m)	200
Wind field model	Diagnostic wind module
Surface wind extrapolation	Similarity theory
Restrictions on extrapolation of surface data	No extrapolation as modelled upper air data field is applied
Radius of influence of terrain features (km)	5
Radius of influence of surface stations (km)	Not used as continuous surface data field is applied

Table 4-4: Parameterisation of key variables for CALPUFF

Parameter	Model value
Chemical transformation	Default NO_2 conversion factor is applied
Wind speed profile	Rural
Calm conditions	Wind speed < 0.5 m/s
Plume rise	Transitional plume rise, stack tip downwash, and partial plume penetration is modelled
Dispersion	CALPUFF used in PUFF mode
Dispersion option	Pasquill-Gifford coefficients are used for rural and McElroy-Pooler coefficients are used for urban
Terrain adjustment method	Partial plume path adjustment

4.3 Model accuracy

Air quality models attempt to predict ambient concentrations based on "known" or measured parameters, such as wind speed, temperature profiles, solar radiation and emissions. There are however, variations in the parameters that are not measured, the so-called "unknown" parameters as well as unresolved details of atmospheric turbulent flow. Variations in these "unknown" parameters can result in deviations of the predicted concentrations of the same event, even though the "known" parameters are fixed.

There are also "reducible" uncertainties that result from inaccuracies in the model, errors in input values and errors in the measured concentrations. These might include poor quality or unrepresentative meteorological, geophysical and source emission data, errors in the measured concentrations that are used to compare with model predictions and inadequate model physics and formulation used to predict the concentrations. "Reducible" uncertainties can be controlled or minimised. This is done by using accurate input data, preparing the input files correctly, checking and re-checking for errors, correcting for odd model behaviour, ensuring that the errors in the measured data are minimised and applying appropriate model physics.

Models recommended in the DEA dispersion modelling guideline (DEA, 2012) have been evaluated using a range of modelling test kits (http://www.epa.gov./scram001). CALPUFF is one of the models that have been evaluated and it is therefore not mandatory to perform any modelling evaluations. Rather the accuracy of the modelling in this assessment is enhanced by every effort to minimise the "reducible" uncertainties in input data and model parameterisation.

REFERENCES

DEA, 2012. Manual for Air Quality Management Planning, April 2012.

eThekwini, 2013. Spatial Development Framework (SDF) Report, 2013/14, http://www.durban.gov.za/Resource_Centre/public_notices/March%202013/Final%20SPATIAL%20DEVELOPMENT%20FRAMEWORK%20for%20public%20comment.pdf

US EPA, 2005. Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule. US EPA.

APPENDIX 5: Legislative background

Introduction

The Bill of Rights contained in the Constitution of the Republic of South Africa enshrines the rights of all people in the country and affirms the democratic values of human dignity, equality and freedom. The state must respect, protect, promote and fulfil the requirements in the Bill of Rights. Section 24 of the Constitution states that everyone has the right:

a) *To an environment that is not harmful to their health or well-being; and*
b) *To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that -*
    i. *Prevent pollution and ecological degradation;*
    ii. *Promote conservation; and*
    iii. *Secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development.*

In order to give effect to this right in the context of air quality, it is necessary to ensure that levels of air pollution are not harmful to human health or well-being. It follows that the setting of ambient air quality standards is necessary, as well as mechanisms to ensure that ambient air quality standards are achieved and maintained. Hence, the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (the AQA) provides an objectives-based approach to the management of air quality at different governance and operational levels and is the legislative means to ensuring that the rights described above are upheld. An overview of some legislative tools that enable authorities to manage air quality is provided here:

Priority Areas

Sections 18 of the AQA provides for the Minister of Water and Environmental Affairs to declare an area a priority area if ambient air quality are or may be exceeded, or a situation exists where negative impacts on air quality may occur and the area requires specific air quality management to rectify the situation. The declaration provides for situations of national interest, where impacts may affect neighbouring counties, or if the situation extends beyond provincial borders.

The declaration of a Priority Area triggers the requirement for the development of a Priority Area AQMP (Section 19(1)(a)). The AQMP, in turn, provides authorities with a means to address the ambient air quality situation. Section 19(6) specifies that the AQMP must (a) be aimed at co-ordinating air quality management in the area, (b) must address the issues relating to air quality, and (c) must provide for the implementation of the plan by a committee representing relevant role-players. Further to this, Section 20 of the AQA provides for the development of regulations for the implementation and enforcement of the AQMP.

National ambient air quality standards

Health based ambient air quality standards have been established for criteria pollutants and one toxic air pollutant in South Africa (DEA, 2009 and 2012) (Table 1). The national ambient air quality standard consists of a *limit value* and a *tolerance* or permitted frequency of exceedance. The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant. The permitted frequency of exceedance is the 99^{th} percentile and represents the tolerated exceedance of the limit value. It accounts for high concentrations due to process upsets and meteorological variations. Compliance with the ambient standard therefore implies the frequency of exceedance does not exceed the permitted tolerance.

Table 1: Ambient air quality standards for SO_2, NO_2, PM_{10}, O_3, benzene, ozone and lead (DEA, 2009) and $PM_{2.5}$ (2012)

Pollutant	Averaging Period	Limit value ($\mu g/m^3$)	Number of exceedances per annum
SO_2	1 hour	350	88
	24 hour	125	4
	1 year	50	0
NO_2	1 hour	200	88
	1 year	40	0
PM_{10}	24 hour	75	4
	1 year	40	0
$PM_{2.5}$	24 hour	65 40[1] 25[2]	0 0 0
	1 year	25 20[1] 15[2]	0 0 0
O_3	8 hours	120	11
Benzene	1year	5	0
Pb	1 year	5	0
CO	1 hour 8 hours	30 10	88 11

1: Effective date is 1 January 2016
2: Effective date is 1 January 2030

Minimum Emission Standards

On 31 March 2010 the Minister of Water and Environmental Affairs published Notice No. 537 in the Government Gazette, terms of Section 21 of the AQA, declaring Listed Activities and related Minimum Emission Standards. These were subsequently revised and published in Notice No. 893 in Government Gazette 37054 on 22 November 2011 for 10 Listed Activity categories and a total of 64 sub-categories. For each sub-category emission standards are specified as concentrations for relevant pollutants, as well as the requirements for emissions measurements, compliance timeframes, reporting and the methods for emission sampling and analysis.

Facilities that operate Listed Activities must be in the possession of an Atmospheric Emission License (AEL) in terms of Section 22 of the AQA. Compliance with Minimum Emission Standards is enforced by the AEL Authority through the conditions of the AEL.

Controlled Emitters

Controlled Emitters are a category of source that is defined in Section 23 of the AQA, and caters for appliance or activities that are not Listed Activities, but result in atmospheric emissions that present a threat to health or the environment. On 1 November 2014 the

Minister of Water and Environmental Affairs declared boilers of less than 50 MW heat input the first Controlled Emitter through the publication of Notice No. 831 in Government Gazette 36973.

This declaration provides municipal regulators with a means of managing emissions from smaller facilities by enforcing the requirements of the regulations. This applies to limiting black visible smoke, enforcing emission standards specified in the regulation, enforcing emission measurements and reporting.

On 28 March 2014 the Minister published her intention to declare temporary asphalt plants as Controlled Emitters through the publication of Notice No. 201 in Government Gazette 37461.

National dust control regulation

On 1 November 2013 the Minister of Water and Environmental Affairs published the National Dust Control Regulations in terms of Section 53(o) of the AQA, prescribing general measures for the control of dust in all areas (DEA, 2013_c). The regulation provides standards for acceptable dust fall for residential and non-residential areas, as well as the requirements and methods of monitoring and reporting. The regulations are enforced by the Air Quality Officer.

Policy for the thermal treatment of general and hazardous waste

The Minister of Water and Environmental Affairs published the National Policy on Thermal Treatment of General and Hazardous Waste on 24 July 2009 in Notice No. 777 in Government Gazette 32439.

Schedule 1 of the policy provided interim emission standards for waste incineration as the Minimum Emissions were being developed. The interim emission standards in Schedule 1 were superseded by the Minimum Emission Standards in Category 8 of Notice No. 537 of 31 March 2010, and then later in Notice No. 893 of 22 November 2013. Waste incineration is a Listed Activity and the Minimum Emission Standards are enforced by the Air Quality Officer through the AEL.

Similarly, Schedule 2 of the policy provided interim emission standards for the use of Alternative Fuels and Resources (AFR) co-processing. The interim emission standards in Schedule 2 were superseded by the Minimum Emission Standards in Sub-Category 5.4 of Notice No. 537 of 31 March 2010, and then later in Notice No. 893 of 22 November 2013. Schedule 4 of the policy specifies the conditions for environmental authorisation for AFR co-processing, specifying conditions for operational management and air quality management. The Minimum Emission Standards and conditions for AFR co-processing are enforced by the Air Quality Officer through the AEL.

Regulations for the burning of sugarcane

The Department of Agriculture, Environmental Affairs and Rural Development prepared a guideline document for sugarcane burning in KZN. The guideline is designed to assist Air Quality Officers (AQOs) and Environmental Health Practitioners (EHPs) responsible for air quality management within the province. The document responds to the requirements of the National Environmental Management: Air Quality Act 39 of 2004 (eThekwini Municipality: AQA).

The guideline describes the local and provincial governance role through the following main activities:

1. Facilitation of and resolution of complaints and the development of a complaints summary report.
2. Collation of data in terms of sugarcane burning practices, including the data required for the development of an emission inventory for sugarcane burning.
3. Ensuring compliance with the Draft National Dust Control Regulations, the Veld and Forest Act (Act No. 101 of 1998), and local by-laws.
4. Development of an emission inventory that is updated to understand the changes in the emissions through the efforts of the sugarcane growers to reduce these emissions.

The South African Sugar Association (SASA) has recognised a number of energy and economic benefits to be gained from green cane harvesting, i.e. not burning. It is endeavouring to promote the practice and to phase out pre-harvest burning in its longer term strategy (SASA, 2015).

eThekwini's Air Quality Management by-law

eThekwini Municipality are in the process of drafting the Air Quality Management By-Law. The by-law extends the mandate provided to the Municipality under the eThekwini Municipality: AQA and the are to:

(a) give effect to the right contained in section 24 of the Constitution by regulating air pollution within the area of the Municipality's jurisdiction;
(b) provide, in conjunction with any other applicable law, an effective legal and administrative framework within which the Municipality can manage and regulate activities that have the potential to adversely impact the environment, public health and well being; and
(c) ensure that air pollution is avoided, or where it cannot be altogether avoided, mitigated or minimised.

The section on Duty of Care prescribes the requirements in terms of air pollution prevention and mitigation, as well as the responsibilities of the municipality and those wholly or partially responsible for causing air pollution or creating a risk of air pollution occurring. The designation of the Air Quality Officer and the Environmental Management Inspectors is in accordance with the requirements of the eThekwini Municipality: AQA. The legal mandate of the Municipality is affirmed in the by-law regarding local emission standards, the prioritisation of substances in ambient air that present a threat to public health, well-being or the environment, and the declaration of air pollution control zones.

Smoke emissions from premises other than dwellings is addressed. Included are the prohibition of dark smoke, the installation and operation of fuel burning equipment, and monitoring and sampling as well as the installation and operation of obscuration measuring equipment. The prohibition of smoke from dwellings is also addressed. Open burning and the burning of material is subject to municipal authorisation. Similarly, written authorisation is required to carry out or permit the burning of any tyres, rubber or other synthetically coated, covered or insulated products and electronic or other equipment on any land or premises for the recovery of metal, as well as the possession, storage, transport or trade in any burnt metal or fibre reinforcements. The by-law addresses activities that result in dust emissions and the requirements for the control or prevention of dust emissions. It also addresses emissions from motor vehicles through emission testing and the issuing of a repair notice for vehicles found to be emitting dark smoke. The by-law requires control measures for spray painting facilities, sand blasting, shot blasting, grinding, finishing or similar activities which customarily produce emissions of dust and other pollutants that may be harmful to public health or cause a nuisance.

APPENDIX 6: Air pollutants and risks to human health

The route of exposure to air pollutants is mostly inhalation. Different groups of people are affected differently from exposure to air pollutants, depending on their level of sensitivity with the elderly, young children and the health impaired being more susceptible. The factor that links an air pollutant to an observed health effect is the level of the concentration and the duration of the exposure to that particular air pollutant, known as the dose. The effects may be with short-term (acute) effects or long-term (chronic).

Short-term effects include irritation to the eyes, nose and throat and the upper respiratory system, headaches, nausea and allergic reactions. Short-term exposure can aggravate existing health problems such as asthma and emphysema. Long-term effects include chronic respiratory disease, lung cancer, heart disease and damage to the nervous and renal systems. An overview of the pollutants for which there are national ambient air quality standards is provided in the following text.

Sulphur dioxide (SO_2)

Dominant sources of SO_2 include fossil fuel combustion from industry and power plants. SO_2 is emitted when coal is burnt for energy. The combustion of oil also results in high SO_2 emissions. Domestic coal or kerosene burning can thus also result in the release of SO_2. Motor vehicles also emit SO_2, in particular diesel vehicles due to the higher sulphur content of diesel fuel. Mining processes where smelting of mineral ores occurs can also result in the production of SO_2 as metals usually exist as sulphides within the ore.

On inhalation, most SO_2 only penetrates as far as the nose and throat, with minimal amounts reaching the lungs, unless the person is breathing heavily, breathing only through the mouth, or if the concentration of SO_2 is high (CCINFO, 1998). The acute response to SO_2 is rapid, within 10 minutes in asthmatics (WHO, 2005). Effects such as a reduction in lung function, an increase in airway resistance, wheezing and shortness of breath, are enhanced by exercise that increases the volume of air inspired, as it allows SO_2 to penetrate further into the respiratory tract (WHO, 1999).

SO_2 reacts with cell moisture in the respiratory system to form sulphuric acid. This can lead to impaired cell function and effects such as coughing, broncho-constriction, exacerbation of asthma and reduced lung function.

SO_2 has the potential to form sulphurous acid or slowly form sulphuric acid in the atmosphere via oxidation by the hydroxyl radical. The sulphuric acid may then dissolve in water droplets and fall as precipitation. This may decrease the pH of rain water, altering any balance within ecosystems and can be damaging to man-made structures.

Nitrogen dioxide (NO_2)

Nitrogen dioxide (NO_2) and nitric oxide (NO) are formed simultaneously in combustion processes and other high temperature operations such as metallurgical furnaces, blast furnaces, plasma furnaces, and kilns. NO_X is a term commonly used to refer to the combination of NO and NO_2. NO_X can also be released from nitric acid plants and other types of industrial processes involving the generation and/or use of nitric acid. NO_X also forms naturally by denitrification by anaerobic bacteria in soils and plants. Lightning is a source of NO_X during the discharge and the rapid cooling of air after the electric discharge.

The route of exposure to NO_2 is inhalation and the seriousness of the effects depend more on the concentration than the length of exposure. The site of deposition for NO_2 is the distal lung where NO_2 reacts with moisture in the fluids of the respiratory tract to form nitrous and nitric acids (WHO, 1997). About 80 to 90% of inhaled NO_2 is absorbed through the lungs (CCINFO, 1998). Nitrogen dioxide (present in the blood as the nitrite ion) oxidises unsaturated membrane lipids and proteins, which then results in the loss of control of cell permeability. Nitrogen dioxide caused decrements in lung function, particularly increased airway resistance. People with chronic respiratory problems and people who work or exercise outside will be more at risk to NO_2 exposure (EAE, 2006). People with a vitamin C deficiency may be more at risk, as vitamin C inhibits the oxidation reactions of NO_2 in the body (WHO, 1997).

NO_x also reacts with water in the atmosphere and can contribute to the formation of acid rain. It is an important pre-cursor in the formation of ozone. NO_X is a key ingredient in atmospheric photochemistry and the formation of secondary pollutants such as ozone and smog.

Particulates

Particulate matter is a broad term used to describe the fine particles found in the atmosphere, including soil dust, dirt, soot, smoke, pollen, ash, aerosols and liquid droplets. The most distinguishing characteristic of PM is the particle size and the chemical composition. Particle size has the greatest influence on the behaviour of PM in the atmosphere with smaller particles tending to have longer residence times than larger ones. PM is categorised, according to particle size, into TSP, PM_{10} and $PM_{2.5}$.

Total suspended particulates (TSP) consist of all sizes of particles suspended within the air smaller than 100 micrometres (µm). TSP is useful for understanding nuisance effects of PM, e.g. settling on houses, deposition on and discolouration of buildings, and reduction in visibility.

Sometimes referred to simply as coarse particles, they are generally emitted from motor vehicles (primarily those using diesel engines), factory and utility smokestacks, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood. Natural sources include sea spray, windblown dust and volcanoes. Coarse particles tend to have relatively short residence times as they settle out rapidly and PM_{10} is generally found relatively close to the source except in strong winds.

$PM_{2.5}$ describes all particulate matter in the atmosphere with a diameter equal or less than 2.5 µm. They are often called fine particles, and are mostly related to combustion (motor vehicles, smelting, incinerators), rather than mechanical processes as is the case with PM_{10}. $PM_{2.5}$ may be suspended in the atmosphere for long periods and can be transported over large distances.

Fine particles can form in the atmosphere in three ways: when particles form from the gas phase, when gas molecules aggregate or cluster together without the aid of an existing surface to form a new particle, or from reactions of gases to form vapours that nucleate to form particles.

Particulate matter may contain both organic and inorganic pollutants. The extent to which particulates are considered harmful depends on their chemical composition and size, e.g. particulates emitted from diesel vehicle exhausts mainly contain unburned fuel oil and hydrocarbons that are known to be carcinogenic. Very fine particulates pose the greatest health risk as they can penetrate deep into the lung, as opposed to larger particles that may be filtered out through the airways' natural mechanisms.

In normal nasal breathing, particles larger than 10 µm are typically removed from the air stream as it passes through the nose and upper respiratory airways, and particles between 3 µm and 10 µm are deposited on the mucociliary escalator in the upper airways. Only particles in the range of 1 µm to 2 µm penetrate deeper where deposition in the alveoli of the lung can occur (WHO, 2003).

Coarse particles (PM_{10} to $PM_{2.5}$) can accumulate in the respiratory system and aggravate health problems such as asthma. $PM_{2.5}$ which can penetrate deeply into the lungs, are more likely to contribute to the health effects (e.g. premature mortality and hospital admissions) than coarse particles (WHO, 2003). People with existing health conditions such as cardiovascular disease and asthmatics, as well as the elderly and children, are more at risk to the inhalation of particulates than normal healthy people (Pope, 2000; Zanobetti *et al*., 2000).

Carbon monoxide (CO)

Carbon monoxide (CO) is a product of incomplete combustion of fossil fuels. It is predominantly formed in internal combustion engines of motor vehicles, but the combustion of any carbon-based material can release CO. Chemical reactions in the atmosphere may also lead to the formation of CO by the oxidation of other carbon-based gases such as methane. Decomposition of organic material within soils can also result in the release of CO. When inhaled, CO enters the blood stream by crossing the alveolar, capillary and placental membranes. In the bloodstream approximately 80-90% of absorbed CO binds with haemoglobin to form carboxyhaemoglobin. The haemoglobin affinity for CO is approximately 200-250 times higher than that of oxygen. Carboxyhaemoglobin reduces the oxygen carrying capacity of the blood and reduces the release of oxygen from haemoglobin, which leads to tissue hypoxia. This may lead to neurological effects and sometimes delayed severe neurological effects that may include impaired coordination, vision problems, reduced vigilance and cognitive ability, reduced manual dexterity, and difficulty in performing complex tasks (WHO, 1999).

Ozone (O_3)

Oxone (O_3) is a colourless gas which carries a harsh odour. It occurs naturally in the lower stratosphere as the ozone layer. This layer protects the earth from shortwave ultraviolet radiation. Near the earth's surface, ozone is a secondary pollutant and a major constituent of photochemical smog. The formation of ozone is dependent on the availability of NO_X, VOCs and sunlight. Thus, ozone may not be related directly to any source. Rather it may be associated with the sources of its precursor gases (NOx and VOCs). Ozone may also reach the lower troposphere from the stratosphere, mostly associated with deep frontal systems or with deep convective storms. Ozone is a very reactive gas and a strong oxidant, associated with a number of health effects. These include respiratory system effects such as coughing, aggravation of asthma and reduced lung function

Lead (Pb)

Lead (Pb) is a metal that occurs naturally in small amounts in the earth's crust. It is used in the production of some types of batteries, ammunition, metal products (such as solder and pipes) ceramic glazes and paint. Chemicals containing lead, such as tetraethyl lead and tetramethyl lead are used as gasoline additives. In the atmosphere, lead exists primarily in the particulate form and is removed from air by wet and dry deposition. Nearly all environmental exposure to lead is to inorganic compounds. Exposure to Pb may be through inhalation of contaminated air and ingestion of contaminated food, water and soil. Hand-mouth contact is the main route of exposure for children. Lead can accumulate in plants and animals. The half-life of lead in human blood (it affects haemoglobin synthesis in the blood) is 28 to 36 days, but lead accumulates in the bones and teeth where it can stay for decades and be released again. Children absorb more and excrete less of the absorbed lead than adults.

Benzene (C_6H_6)

Benzene (C_6H_6) is a natural component of crude oil, petrol, diesel and other liquid fuels and is emitted when these fuels are combusted. Diesel exhaust emissions therefore contain benzene. After exposure to benzene, several factors determine whether harmful health effects will occur, as well as the type and severity of such health effects. These factors include the amount of benzene to which an individual is exposed and the length of time of the exposure. For example, brief exposure (5–10 minutes) to very high levels of benzene (14000 – 28000 $\mu g/m^3$) can result in death (ATSDR, 2007). Lower levels (980 – 4200 $\mu g/m^3$) can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion and unconsciousness. In most cases, people will stop feeling these effects when they are no longer exposed and begin to breathe fresh air. Inhalation of benzene for long periods may result in harmful effects in the tissues that form blood cells, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components. Excessive exposure to benzene can be harmful to the immune system, increasing the chance for infection. Both the International Agency for Cancer Research and the US-EPA have determined that benzene is carcinogenic to humans as long-term exposure to benzene can cause leukaemia, a cancer of the blood-forming organs.