KWAZULU-NATAL PROVINCE
ECONOMIC DEVELOPMENT, TOURISM AND ENVIRONMENTAL AFFAIRS
REPUBLIC OF SOUTH AFRICA

KwaZulu-Natal Air Quality Management Plan

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EXECUTIVE SUMMARY

Air quality in South Africa is governed under the National Environmental Management Air Quality Act (NEM: AQA) and related legislation such as the National Ambient Air Quality Standards (NAAQS). The NEM: AQA (Section 15(2)) requires Provinces to develop Air Quality Management Plans (AQMPs) that seek to improve air quality by identifying and addressing emissions that are harmful to human health. Provinces are further required to include their AQMP as part of their environmental implementation plan.

The KwaZulu-Natal province is one of the nine provinces in South Africa. The KZN province is formed by one metropolitan municipality, ten district municipalities, and 43 local municipalities covering an area of approximately 12 141km^2. Manufacturing, agriculture, construction, and mining are the main economic sectors in the KZN province (StatsSA, 2016).

Based on the 2016 Community Statistics, the KZN province had a total population of 11 065 240. The population increased by approximately 1.7% from 2011 to 2016 According to the most recent update, the total population of KZN in 2020 was 11 531 628 (StatsSA, 2020).

The Approach Followed in Developing The AQMP For KZN

The main objective of this project is to develop the KZN AQMP. The development of the AQMP is based on guidelines outlined in the 2017 National Framework for Air Quality Management in the Republic of South Africa (NFAQM) (Government Notice No. 1144, 2018) and the Air Quality Management Plan Guideline Documents (DEA, 2012) provided by the Department of Forestry Fisheries and Environment The process of developing the AQMP followed a series of steps which included:

Status Quo Assessment

This phase included a detailed baseline assessment of the meteorological conditions and the ambient air quality situation in KZN. An emissions inventory was compiled for air pollution sources, with specific focus on large quantifiable sources such as industries, vehicles, agriculture, waste, mines/quarries, biomass burning and residential fuel burning.

Gap and Capacity Analysis

An evaluation was undertaken of the current capacity of Government (Local, District and Province) for air quality management and control in terms of personnel, skills, resources and tools.

Air Quality Management Plan

Findings from the Status Quo Assessment and the Gap and Capacity Analysis were consolidated to develop the Air Quality Management Plan which articulates emission control and management strategies for KZN.

Geospatial Air Quality Risk Assessment

The geospatial air quality risk assessment showed that Emnambithi, eThekwini, Greater Kokstad, Hibiscus Coast, KwaDukuza, Mandeni, Newcastle, Msunduzi, and uMhlathuze has the largest area where a high probability of exposure is indicated. This means that people living in this area are being exposed to multiple air pollution sources.

Emissions Inventory by Sector

Vehicle Emissions

Two different methods and sets of emission factors were used to estimate emissions from vehicles in KZN. A top-down and bottom-up emissions approach was used to calculate Emissions from the 2022 magisterial fuel sales volume (diesel and petrol) (DoE, 2022). CO emissions are the highest of the criteria pollutant emissions from vehicles in KZN by mass. CO, PM and NO_X are the main criteria pollutants resulting from the combustion of petrol and diesel in KZN.

Residential Fuel Burning

Emissions from residential burning of paraffin, wood and coal (for cooking, heating and lighting) were calculated at municipal level. Wood burning is the biggest polluter by mass of the fuel burnt, in terms of SO_2, NO and PM_{10}. There is a relatively large number of households using wood for fuel compared to coal and paraffin. In total, by mass emitted, PM_{10} is the largest criteria pollutant emitted from residential fuel burning in KZN.

Biomass Burning

On average, the vegetation across an area of 2 176 845 ha burns in veld fires (excluding sugarcane fields) annually in the KZN. The total area of sugarcane cropland burned in KZN annually is approximately 94 311 ha. Emissions due to this biomass burning were highest in CO and $PM_{2.5}$. Most of these fires occur during the mid to late dry season.

Crop farming

Emissions from agricultural activities in KZN were calculated using the Agricultural Census data for commercial areas within KZN (StatsSA, 2017). Emissions were calculated for crop production and agricultural soils. PM_{10} is the largest criteria pollutant emitted from agricultural activities.

Livestock Farming

PM emissions from livestock farming were calculated at the district level (StatsSA, 2016). The number of cattle exceeds the number of other livestock accounting for the highest emissions.

Denuded land

Denuded land in KZN is approximately 17% of the total district area. Approximately 765 tonnes of PM_{10} and 115 tonnes of $PM_{2.5}$ are emitted into the air from an area of 2 124.31 km^2.

Mines and Quarries

KZN has quarries, sand, and coal mines covering a total area of approximately 92 km^2. Sand mining activities account for approximately 35 976 tonnes of PM10 emissions and 14 808 tonnes of PM2.5 emissions per annum. Emissions from coal mining activities are estimated as 5 7945 tonnes of PM10 and 869 tonnes of PM2.5

Landfills

Landfills are known to emit substantial amounts of pollutants which can be harmful to human health and the environment. The estimated carbon monoxide emissions are 76 070 kg/year, NMVOC 96 715 kg/year and Benzene emissions are 2 879 kg/year from the 107 operational landfills located within KZN.

Waste Burning

Every year, approximately 1 426 116 tonnes of waste from uncollected household waste are burnt within the province. The Zululand, uMkhanyakude, King Cetshwayo, uMgungundlovu, and Ugu district municipalities have the highest waste-burning emissions. CO (32 515 442 kg/year) is the main criteria pollutant generated by waste burning.

Wastewater Treatment Plants

The total volume of wastewater treated at KZN WWTW is 407 947 031.50 m^3/year and VOC emissions from WWTW are estimated to be 436 503 kg per year in total. The WWTW in the eThekwini Municipality emit most of the VOC emissions per year.

Emissions Inventory Summary of Findings

There are many uncertainties about the true extent of air quality impacts in the KZN. Limited data is available, and emissions are extrapolated from areas that might have some variation. Industries, biomass burning, mines, quarries and vehicles dominate the quantified emissions by total mass of pollutants emitted. Waste burning and residential fuel burning raise concerns in terms of potential health impacts.

- By mass, CO is the largest pollutant emitted within KZN followed by PM_{10}.
- Particulate matter is largely emitted from mines and quarries (53%).
- Vehicles emit 58% of the NO_X emissions; followed by Biomass Burning (27%).
- Biomass burning emissions contribute the most to CO emissions.
- Vehicles emit 58% of the VOC emissions in KZN followed by listed activities (33%).
- Listed activities account for the highest SO_2 emissions.

Gap and Capacity Analysis

- The KZN emissions inventory had limitations in terms of data availability and subsequently also their usability.
- The human resources capacity in KZN is limited and comprises of one Air Quality Officer and one Environmental Compliance Officer. To adequately manage air quality, it is necessary to fill the vacant AQMP positions and expand the team.

- There is currently no continuous ambient air quality monitoring within the uThukela and Harry Gwala, district, therefore a screening process should be undertaken to assess whether there is a need for Ambient Air Quality Monitoring Stations in these districts.

Proposed Interventions

Interventions for the various emission sources have been proposed for implementation. The two main sources of emissions were identified as industry and biomass burning. The key interventions proposed for these sources include:

Listed Activities

- Investigate opportunities to market waste as raw material inputs to other industries e.g., discard coal.
- Investigate the feasibility of renewable energy.
- Motivate for and undertake research to improve abatement technology and reduce retrofitting costs.
- Investigate mechanisms to regulate newly identified technologies.
- Identify any Listed and Controlled Activities currently operating without emissions licences.
- Develop and enforce emission reduction plan/measures for controlled emitters.

- *Biomass burning*

- Develop fire early warning systems and maintain fire services to assist in air pollution control.
- Partner with system operators (e.g., the CSIR, ARC, etc.) to quantify emissions from biomass burning to assist in the management of biomass burning.
- Identify areas prone to fire and evaluate the role of fire and the removal of landcover in those areas.
- Establish a buffer zone between residential and high-risk vegetation areas to develop fire breaks.
- Engage the public through awareness programmes about the health risk associated with fires and get them to participate in reporting illegal fires and assist in the combat of veld fires.

- The two main sources of emissions with potentially the greatest health impact were identified as residential fuel burning and waste burning. The key interventions proposed for these sources include:
- *Residential fuel burning*
- Develop a residential fuel burning emissions inventory to more accurately quantify the spatial impact of this source.
- Identify and prioritise the residential areas using fossil fuels that require installation of air quality monitoring equipment.
- Develop a residential fuel burning strategy.
- Initiate an awareness campaign to educate people on the negative health impacts of residential fuel burning and the financial benefits of using alternative options.
- Implement electrification in informal settlements.
- Introduce energy efficiency measures into low-cost housing, such as insulated ceilings, solar water heaters, wall insulation, replacing old stoves with new smokeless stoves and energy efficient lighting.

Waste burning

- Keep records at official landfills to facilitate planning around air quality issues.
- Manage official landfills to prevent burning of the waste.
- Identify and quantify the extent of waste burning occuring outside of landfills in the district to evaluate the true impact of this source on air quality.
- Develop a waste burning prevention strategy.
- Minimise waste by implementing the Regional Recycling Project.
- Raise public awareness about the dangers associated with uncontrolled waste burning and the implications for air quality and human health.

Implementation Plan

Short medium- and long-term targets were drawn up for the KZN province based on the mission, vision and goals for air quality management as set out in this document.

Actions that need to be implemented in the immediate to short-term period are:

- Implementing the Air Quality Management Plan within the KZN.
- Integrating the AQMP into the province's strategic developmental plan.
- Motivating for a dedicated, full time air quality officer in the province.
- Assigning clear responsibilities and functions for air quality management.
- Training of air quality personnel at the provincial and district level.
- Reporting and submitting online emissions inventory data into the South African Atmospheric Emission Licencing and Inventory Portal (SAAELIP).
- Developing electronic databases of emission sources in KZN that are not yet required to be reported on the National Atmospheric Emission Inventory System (NAEIS).
- Developing an electronic complaints response database.
- Obtaining the necessary resources and funding for air quality management.
- Compliance monitoring and enforcement of air quality legislation, policies and regulations.
- Assessing the contribution of various activities/sources to ambient air quality and establishing measures to control emissions from these sources.
- Implementing community awareness programmes.

Table Of Contents

List Of Figures

List Of Tables

List Of Abbreviations

°C	Degrees Celsius
AAQM	Ambient Air Quality Monitoring
AAQMS	Ambient Air Quality Monitoring Station
AEL	Atmospheric Emissions Licence
AELO	Atmospheric Emissions Licensing Officer
AQM	Air Quality Management
AFIS	Advanced Fire Information System
AQM	Air Quality Management
AQMP	Air Quality Management Plan
AQO	Air Quality Officer
C_6H_6	Benzene
CO	Carbon Monoxide
D-COGTA	Department of Cooperative Governance and Traditional Affairs
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry and Fisheries
DFFE	Department of Forestry, Fisheries and the Environment
DM	District Municipality
DoE	Department of Energy
DWS	Department of Water and Sanitation
ECO	Environmental Compliance Officer
ECMO	Environmental Compliance Monitoring Officer
EEA	European Environment Agency
EHP	Environmental Health Practitioner
EIA	Environmental Impact Assessment

EIP	Environmental Implementation Plan
EMEP	European Monitoring and Evaluation Programme
EMI	Environmental Management Inspector
FAO	Food and Agriculture Organization of the United Nations
FSSA	Fertilizer Society of South Africa
GHG	Greenhouse Gas
GIS	Geographic Information Systems
IDP	Integrated Development Plans
IPCC	Intergovernmental Panel on Climate Change
km^2	Square Kilometres
KZN	Kwa-Zulu Natal Province
KZN EDTEA	Kwa-Zulu Natal Department of Economic Development, Tourism and Environmental Affairs
m	Metres
mm	Millimetres
NAAQS	National Ambient Air Quality Standards
NAEIS	National Atmospheric Emission Inventory System
NEM: AQA	National Environmental Management Air Quality Act
NFAQM	National Framework for Air Quality Management
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compound
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
N_2O	Nitrous Oxide
O_3	Ozone
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 µm

$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 µm
SAAELIP	South African Atmospheric Emission Licencing and Inventory Portal
SAAQIS	South African Air Quality Information System
SO_2	Sulphur Dioxide
t	Tonne
Tonne	1 000 kilograms
VOC	Volatile Organic Compound
WHO	World Health Organization
WWTW	Wastewater Treatment Works

1 Introduction

The KwaZulu-Natal Province (hereinafter referred to as KZN), is a coastal province situated in the south-east of South Africa. It encompasses one metropolitan municipality, ten district municipalities and 43 local municipalities.

The Constitution of South Africa (South Africa, 1996) entitles everyone to an environment that is not harmful to their health or well-being, and an environment that is protected for the current and future generations (Section 24). The environment includes air quality, which is governed under the National Environmental Management Air Quality Act (herein referred to as the NEM: AQA), Act 39 of 2004 and subordinate legislation. Section 15(1) of the NEM: AQA requires provinces to develop Air Quality Management Plans (AQMPs) that seek to improve air quality by identifying and addressing emissions that are harmful to human health. Provinces are further required to include their AQMP as part of their environmental implementation plan.

The KZN AQMP is based on guidelines outlined in the 2017 National Framework for Air Quality Management in the Republic of South Africa (NFAQM) (Government Notice No. 1144, 2018) and the Air Quality Management Plan Guideline Documents (DEA, 2012) provided by the Department of Environmental Affairs. The main aims of the KZN AQMP are:

- To develop medium to long term plans for the practical implementation of the NEM: AQA.
- To ensure sustainable implementation of air quality standards within the KZN.
- To comply with the Bill of Rights as enshrined in the Constitution of South Africa (South Africa, 1996) of every citizen having the right to live in an environment that is free of harmful pollution.
- To recommend the methodology and processes for the monitoring of air pollution consistent with national, provincial and local norms and standards.
- To establish an emissions inventory of the study area by identifying sources, quantifying pollution and capturing these in Geographic Information Systems (GIS).
- To ensure the provision of sustainable air quality management support and services to all stakeholders within KZN.
- Promote sustainable economic development that is not detrimental to communities and the environment.

To meet these aims, the immediate objectives are:

- To conduct an Air Quality Baseline Assessment to determine pollution sources, ambient concentrations and the potential for human health effects within KZN.

1.1 Geographic Overview

The KwaZulu-Natal Province, situated along the Indian Ocean coastline, is one of the nine provinces in South Africa. It shares its borders with the Eastern Cape, Mpumalanga, and Free State Provinces. It also shares its western borders with Lesotho and northern borders with Eswatini and Mozambique. The KwaZulu-Natal Province covers an area of 94 361 km^2 and accounts for 7.7% of the total land surface of the country (Figure 1). The area is divided into one metropolitan municipality (eThekwini), and ten district municipalities namely Amajuba, Harry Gwala, iLembe, King Cetshwayo, Ugu, uMgungundlovu, uMkhanyakude, uMzinyathi, uThukela, and Zululand. The district municipalities are subdivided into 43 local municipalities. Pietermaritzburg is the provincial capital, and the municpality headquarters are located in eThekwini, the provincial metroplitian area.

The region is renowned as the "garden province" and encompasses pristine beaches, mountains, and indigenous forest regions along the coast (EDTEA, 2017). KZN is in a subtropical to temperate climate region, characterised by high humidity levels. It has a complex topography that is divided into three distinct geographic areas – the lowlands, midlands and the escarpment (Figure 2). The lowland areas, situated in the eastern part of the province along the Indian Ocean, are mainly characterised by the grassland, thicket, savanna and marine biomes (South, North and Elephant coast), while the inland and central areas of the province are dominated by the grassland, thicket and savanna biomes (Figure 3). Across the province there are areas of forest which grow in the higher rainfall areas and coastal areas. The Pietermaritzburg area is part of the central midlands which comprises of grassland and hills and stretches to the foothills of the Drakensberg in the west. The escarpment areas form part of the Drakensberg Mountain Range (EDTEA, 2017). The Drakensberg area is the source of the Tugela River; considered as KZN's largest river with the Tugela Falls being the second-highest terrestrial waterfall in the world after the Angel Falls in Venezuela (World's Tallest Waterfalls, 2022).

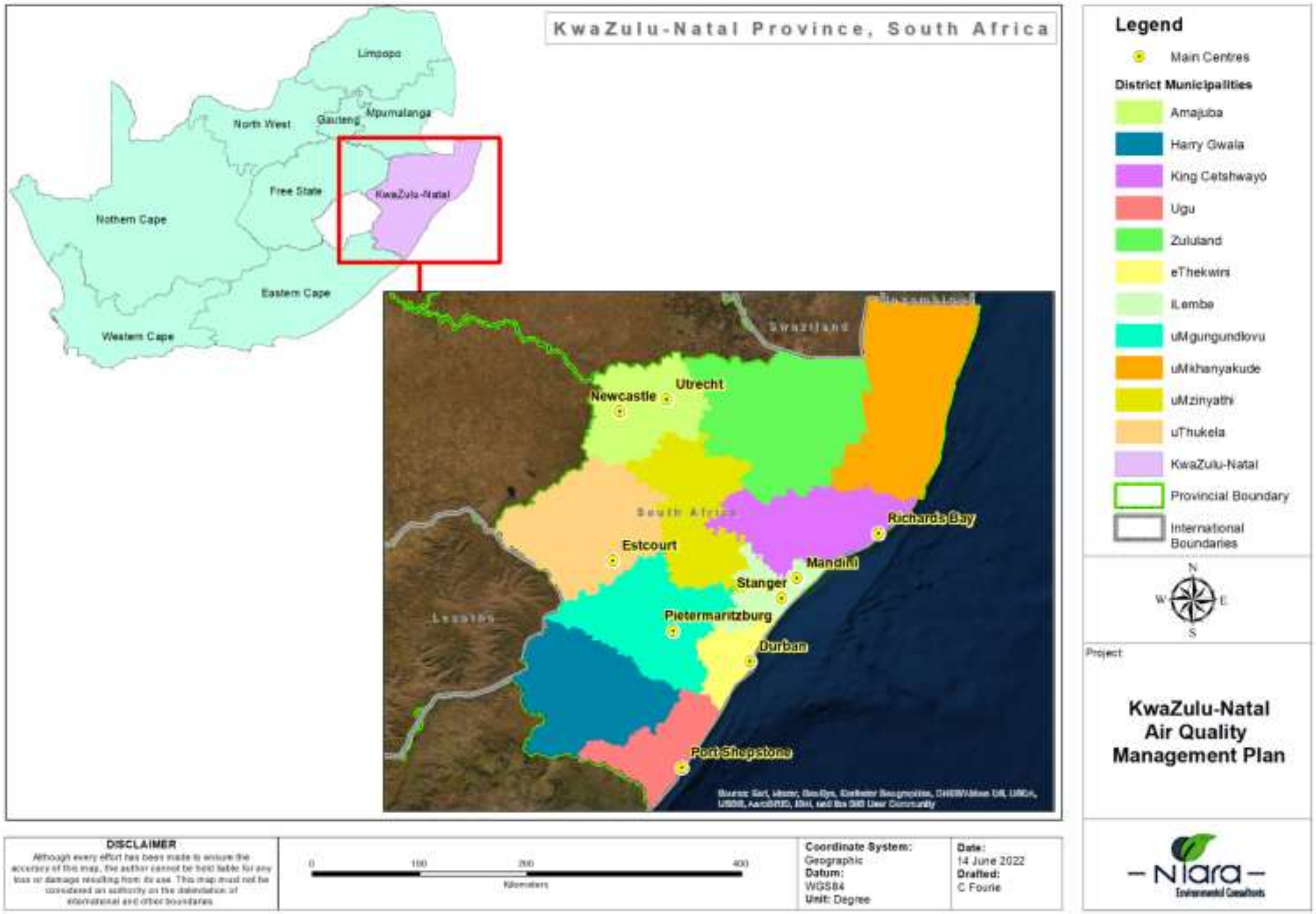


Figure 1: Location of KZN and its district municipalities

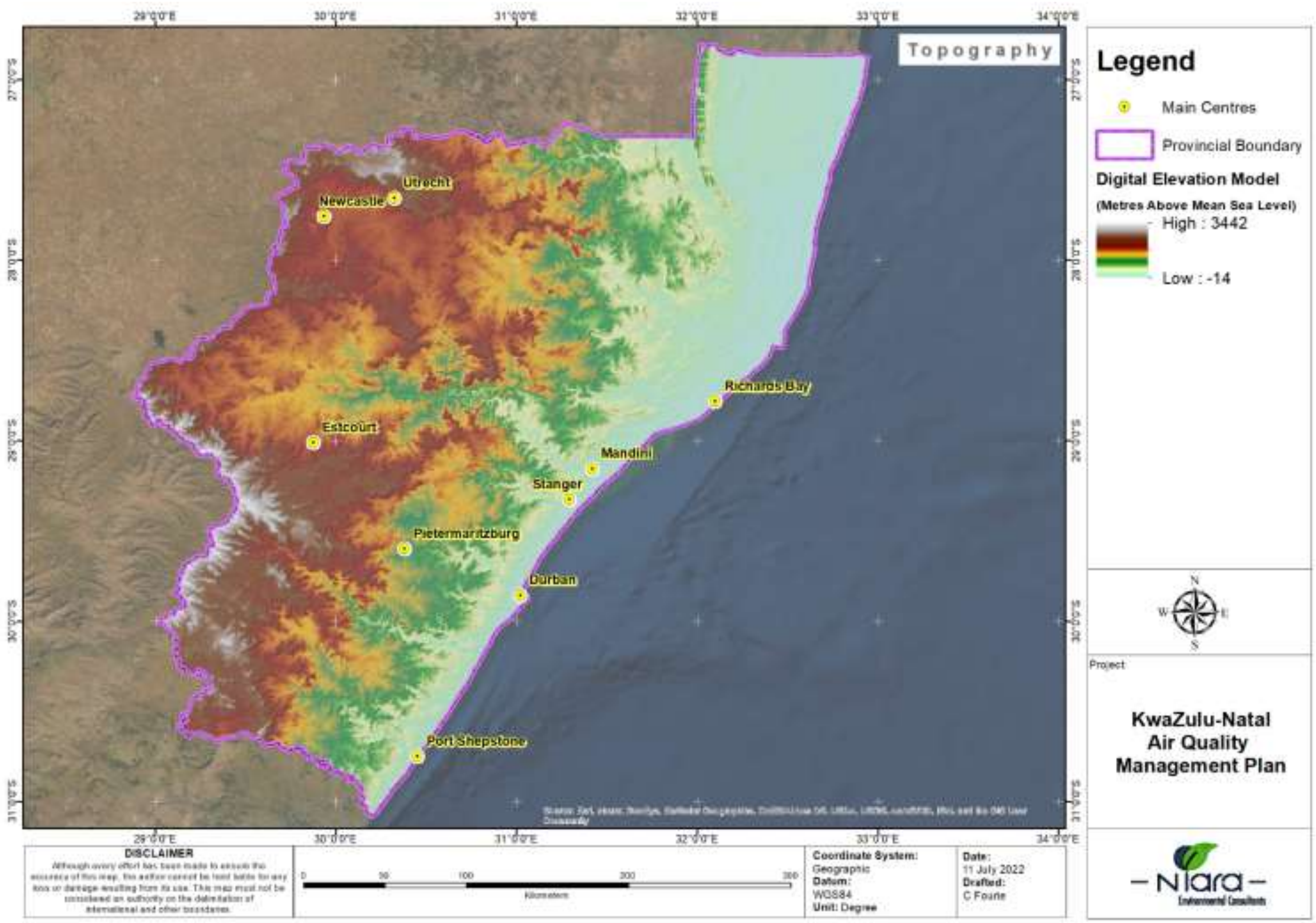


Figure 2: Topography of KZN

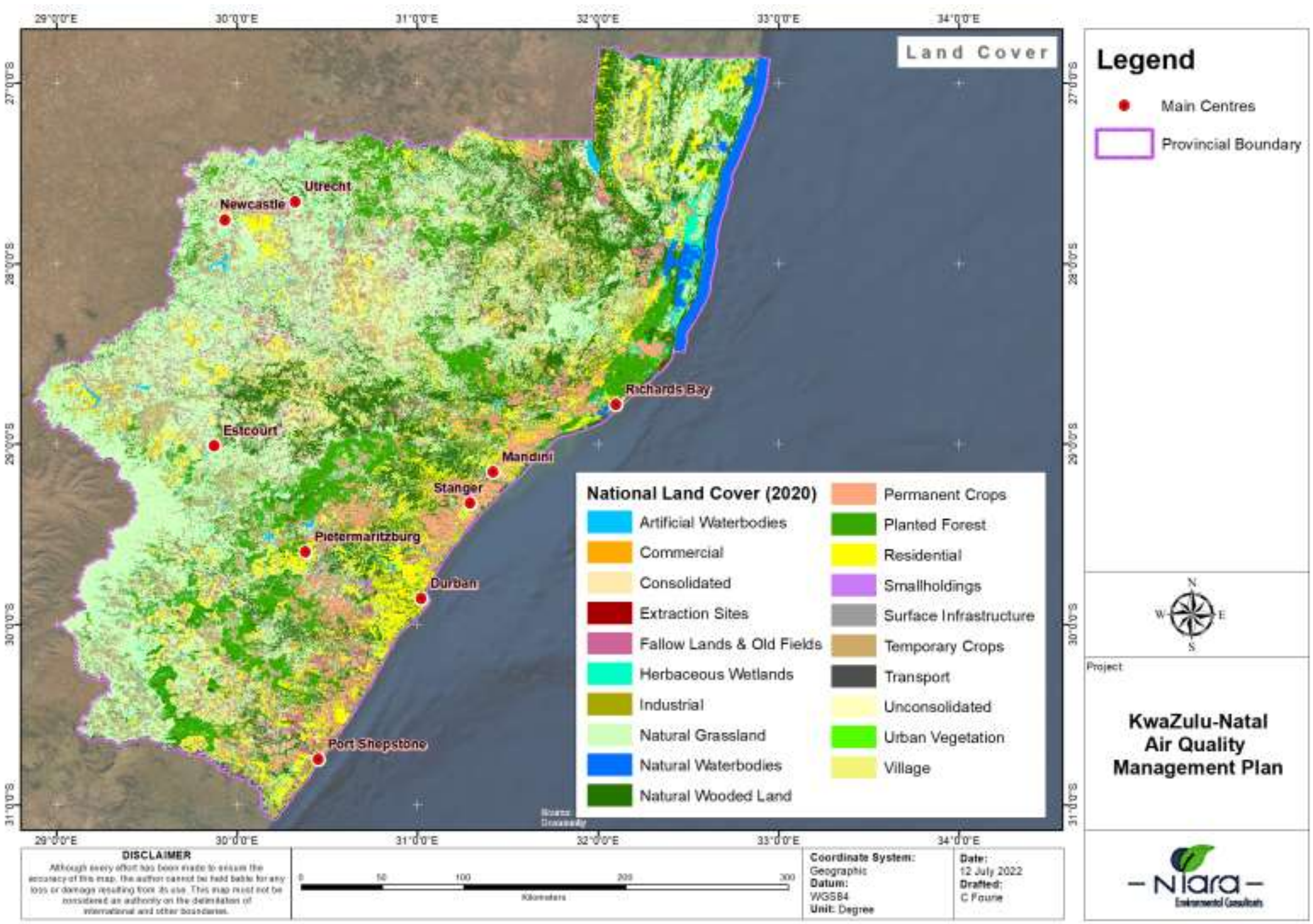


Figure 3: Landcover and land uses of KZN

1.2 Socio-Economic Description

A socio-economic description of an area is a combination of demographics, education, income and employment, social support, safety and other factors that contribute to its socio-economic status. This section was compiled using the latest available provincial statistics with the country currently updating their statistics from the 2022 population census.

KwaZulu-Natal's economic sectors are characterised by various activities contributing to the province's economic performance, with manufacturing representing 16%, agriculture 3%, construction 4% and mining 2% (StatsSA, 2016). Tourism, representing 9.5% of the province's economy, is also one of the economic sectors which contributes to the province's economic growth due to a variety of tourist attractions (top-rated national parks, beaches, and cultural heritage sites) which benefits the province's Gross Domestic Product (GDP), employment, and investments. KZN has the country's largest port in Durban, which contributes 11% to the province's economic performance, and Richards Bay, which has the largest coal export terminal in the world. In Durban, sugar refining is the main industry, and Newcastle's main industrial products are rubber and chrome chemicals. Other industries located mainly in and around Durban and Richards Bay include textiles, clothing, fertiliser, paper (including paperboard and tissue), vehicle assembly, food processing plants, oil refineries and coal mining. KZN's economy is concentrated mostly in the eThekwini Metro, with an estimated Real Gross Domestic Profit (GDP-R) contribution of 59.6% in 2019, followed by districts with urban settings namely, uMgungundlovu (11%) and King Cetshwayo (7.1%). Districts that are characterised by rural settings such as uMzinyathi (1.5%), Harry Gwala (1.8%), and uMkhanyakude (2.1%) contribute the least toward the GDP-R due to limited economic activities and low employment rates. Overall, the province contributes 16% towards the country's GDP (KZN Provincial Treasury, 2021).

KZN had a population of 11 065 240 (Table 1) in 2016 (StatsSA, 2016) making it the second-largest province. The population increased at a 1.7% annual growth rate between 2011 and 2016. According to the most recent update, the total population of KZN in 2020 was 11 531 628 (StatsSA, 2020). Based on the overall population of KZN, Africans are the largest group with a percentage of 87.6 followed by Asians at 6.9%, Whites at 4.1%, and Coloureds at 1.4% (StatsSA, 2020). Children under the age of 14 account for around 32.2% of the population, with youth (15–34 years) accounting for 35.2% (StatsSA, 2020). Therefore, youth and children represent approximately 67.4% of the total provincial population. Approximately 42.4% of the KZN youth is unemployed, with the 35-44 year age group accounting for

19.5% followed by those in the age range of 45 to 54 (12.6%) and above 55 years old (5.8%). In terms of gender, the province's female unemployment rate was slightly higher in 2019, at 25.1%, than for males, at 25% (KZN Provincial Treasury, 2021).

Table 1: Population Growth per District Municipality between 2011 and 2016 (StatsSA, 2016).

District Municipalities	Total Population (2011)	Total Population (2016)	Growth Rate (%)
Ugu	689 051	753 336	2.03
uMgungundlovu	1 007 806	1 095 865	1.90
uThukela	668 072	706 588	1.27
uMzinyathi	514 028	554 882	1.74
Amajuba	500 615	531 327	1.35
Zululand	803 575	892 310	2.28
uMkhanyakude	625 846	689 090	2.19
King Cetshwayo	907 519	971 135	1.54
iLembe	606 809	657 612	1.83
Harry Gwala	467 292	510 865	2.03
eThekwini	3 476 686	3 702 231	1.43
KwaZulu-Natal	**10 267 300**	**11 065 240**	**1.70**

KwaZulu-Natal Province had the largest proportion of households living in formal dwellings compared to those living in other types of housing in 2016 (Table 2). The eThekwini Metropolitan Municipality has the largest percentage of formal residences at the district level (81.5%), followed by the uMgungundlovu DM (76.7%). Harry Gwala DM has the largest percentage of traditional homes, at 53.0%, while eThekwini Metropolitan Municipality has more prevalent informal homes, at 13.3%, followed by uMgungundlovu District Municipality at 7.4%.

Table 2: Distribution of households by type of main dwelling (StatsSA, 2016).

District Municipalities	Formal Dwelling	Traditional Dwelling	Informal Dwelling	Other	Total
Amajuba	98 987	10 828	6 153	1 288	117 256

District Municipalities	Formal Dwelling	Traditional Dwelling	Informal Dwelling	Other	Total
eThekwini	917 812	50 430	149 662	7 760	1 125 664
Harry Gwala	51 564	65 544	6 353	245	123 705
iLembe	141 383	32 114	16 170	1 679	191 347
King Cetshwayo	159 371	58 094	7 466	867	225 797
Ugu	102 651	54 011	16 344	2 140	175 146
uMgungundlovu	228 768	45 826	22 243	1 569	298 405
uMkhanyakude	106 090	38 306	4 964	1 876	151 236
uMzinyathi	59 558	62 476	4 423	335	126 791
uThukela	112 979	44 914	2 169	1 727	161 788
Zululand	110 906	57 702	9 221	681	178 510
KwaZulu-Natal Total	**2 090 067**	**520 244**	**245 167**	**20 166**	**2 875 645**

Although the province is the second largest contributor to South Africa's GDP with a diverse economic base (KZN Provincial Treasury, 2021), it still faces social challenges such as poverty. Poverty can consist of one or more of the following: lack of income and employment; inequality; little or no access to livelihood; and social isolation. Stats SA was officially tasked by government to establish a threshold that could be used in standardising a money-metric measurement of poverty for the country, which is updated every year. They developed a 'food poverty line' and an 'upper poverty line'. The food poverty line refers to the amount of money that an individual's need to afford the minimum required daily energy intake. This is also commonly referred to as the 'extreme' poverty. The upper poverty line refers to the food poverty line plus the average amount derived from non-food items of households whose food expenditure is equal to the food poverty line. In 2019 the province had approximately 38% of the population living below the food poverty line and 68% living below the upper poverty line. Social grants have made a substantial contribution towards reducing food poverty in KZN. The province has approximately 4.04 million grant recipients, and it was ranked as the province with the largest share of social grants in the country (KZN Provincial Treasury, 2021).

Health is essential to the global objective of poverty reduction and to achieving the Sustainable Developmental Goals. Socially disadvantaged people have less access to health resources, which compounds to the inequality issues in the province. According to StatsSA (2022), in 2017, TB remained the leading cause of death in KZN at the rate of 7.4%, followed by Diabetes 6,8% and HIV 6.5%. The global pandemic (COVID-19) has also been one of the leading causes of death.

Education is important in increasing economic efficiency and social well-being. It is an investment in human capital, as it provides the trained workforce and skilled professionals required to achieve a country's socio-economic developmental goals. In 2019 South Africa's overall literacy rate was 85.7% which is slightly higher than the KZN literacy rate that improved from 76.8% in 2009 to 83.7% in 2019. The province's level of education has improved over the ten years with only 6.8% of their 20+ age group without formal education. Between 2009 and 2019 the number of people within the highest educational attainment category of 'matric only' increased from 27.3% to 32% followed by an increase from 9% to 10.7% of people who attained higher degree qualifications. This indicates a slight increase of 5% of matriculants and 1.7% of post-matric qualifications in the province over the ten-year period (KZN Provincial Treasury, 2021).

2 Policy and Regulatory Requirements

The Bill of Rights contained in the Constitution protects the civil, political, and socio-economic rights of all people in South Africa. The importance of the environment and air quality is highlighted in Section 24 of the Bill of Rights, which states that everyone has the right:

- To an environment that is not harmful to their health or wellbeing; and
- To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:
    - Prevent pollution and ecological degradation.
    - Promote conservation.
    - Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development (South Africa, 1996, pp. 1251-1252).

The Constitutions' emphasis on environmental rights facilitated the development of the National Environmental Management Act, Act 107 of 1998 (NEMA) (Act No. 107, 1998). Specific Environmental

Management Acts (SEMAs) were developed to form the legislated framework for different environmental aspects namely:

- The National Environmental Management: Protected Areas Act, Act 57 of 2003 (NEM: PAA).
- The National Environmental Management: Biodiversity Act, Act 10 of 2004 (NEM:BA).
- The National Environmental Management: Air Quality Act, Act 39 of 2004 (NEM: AQA).
- The National Environmental Management: Integrated Coastal Management Act, Act 24 of 2008 (NEM: ICM).
- The National Environmental Management: Waste Act, Act 59 of 2008 (NEM: WA).

Only the NEM: AQA and legislation pertinent to the implementation of the NEM: AQA is discussed hereafter. However, the other SEMAs through enforcement of their legislation may consequentially promote improved air quality.

2.1 National Environmental Management: Air Quality Act 39 of 2004

Air quality in South Africa is governed under the NEM: AQA. The main objective of the Act is to ensure the protection of the environment and human health through reasonable measures of air pollution control within the sustainable economic, social, and ecological development framework.

Various activities have been identified that, due to their processes, may result in air pollution that is detrimental to health and the environment. In terms of Section 21 of the NEM: AQA, a list of these activities was first published in 2010 (Government Notice No. 248, 2010). It was repealed in 2013 (Government Notice No. 893, 2013), and the 2013 list was amended in 2015 (Government Notice No. 551, 2015), 2018 (Government Notice No. 1207, 2018), 2019 (Government Notice No. 687, 2019) and 2020 (Government Notice No. 421, 2020). This legislation specifies minimum emission standards (the permissible amount, volume, emission rate or concentration that may be emitted) in respect of substances or a mixture of substances resulting from a listed activity. It also specifies the manner in which measurements of such emissions must be carried out. All listed activities must obtain an atmospheric emissions licence (AEL) in order to operate. The issuing of AELs is the responsibility of the metropolitan and district municipalities; however, the province may be delegated this responsibility. A provincial Air Quality Officer (AQO) is required to be appointed who will be responsible for coordinating air quality management requirements and the issuing of AELs (if a Metro/District has delegated its function to the Provincial Organ of the State in terms Section 238 of the Constitution;

whenever a licensing authority fails to take a decision on an application for an atmospheric emission licence; and if a municipality applies for an atmospheric emission licence).

The NEM: AQA also shifted some of the approach of air quality management from source-based control to receptor-based control. With receptor-based control the ambient air quality of receptors is the factor which is used to determine the compliance of the emission source. The measured, or expected, ambient air quality of receptors is compared to National Ambient Air Quality Standards (NAAQS). These standards prescribe the maximum ambient concentrations of pollutants permitted (and the number of exceedances allowed) during a specified time period in a defined area (Table 3). If the air quality standards are exceeded, the ambient air quality is poor and the potential for health effects is greatest. The NAAQS, therefore, provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants of air that are known, or likely, to be hazardous to human health and wellbeing (WHO, 2000). The South African NAAQS for criteria pollutants were published in 2009 (Government Notice No. 1210, 2009) in terms of Section 9(1) of the NEM: AQA. The criteria pollutants include benzene (C_6H_6), carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}), ozone (O_3) and sulphur dioxide (SO_2). In 2012, particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) was also promulgated as a criteria pollutant (Government Notice No. 486, 2012). Provincial government may introduce more stringent Air Quality Standards than the NAAQS, and similarly, local government may introduce more stringent Air Quality Standards than the Provincial Air Quality Standards.

Table **3**: National Ambient Air Quality Standards for Criteria Pollutants **(Government Notice No. 1210, 2009; Government Notice No. 486, 2012)**.

Pollutant	Averaging Period	Concentration (µg/m^3)	Concentration (ppb)
SO_2	10-minute running average	500	191
	1-hr average	350	134
	24-hr average	125	48
	Annual average	50	19
NO_2	1-hr average	200	106
	Annual average	40	21
CO	1-hr average	30 mg/m^3	26 ppm

	8-hourly running average	10 mg/m^3	8.7 ppm
O_3	8-hourly running average	120	61
PM_{10}	24-hr average	75	-
	Annual average	40	-
$PM_{2.5}$	24-hr average	40	-
	Annual average	20	-
Pb	Annual average	0.5	-
C_6H_6	Annual average	5	1.6

The NEM: AQA provides for additional measures to be implemented, including the declaration of controlled emitters (Sections 23 to 25), controlled fuels (Sections 26 to 28), priority air pollutants (Section 29), and measures for dust, noise and offensive odours (Section 32, 34, and 35, respectively). Regulations for controlled emitters have been established for small boilers (Government Notice No. 831, 2013), temporary asphalt plants (Government Notice No. 201, 2014) and small-scale char and charcoal plants (Government Notice No. 602, 2015). No regulations for controlled fuels have been legislated to date. Greenhouse Gases were legislated as priority air pollutants in 2017 (Government Notice No. 710, 2017). Any industries or industrial sectors that emit these priority pollutants are required to implement a Pollution Prevention Plan (Government Notice No. 712, 2017).

The National Dust Control Regulations of 2018 (Government Notice No. 517, 2018) have been developed as a measure for dust, applicable to all entities nationwide (Table 4). The 2017 NFAQM has listed provincial government as having principal responsibility, together with metropolitan and district municipalities, for monitoring compliance with the requirements of the National Dust Control Regulations for listed activities.

Table 4: Acceptable dustfall rates (Government Notice No. 517, 2018).

Restriction Areas	Dustfall Rate (D) (mg/m^2/day) (30-day average)	Permitted Frequency of Exceeding Dustfall Rate
Residential Areas	D < 600	Two within a year, not sequential months.
Non-Residential Areas	600 < D < 1,200	Two within a year, not sequential months.

The standard test method to be used for measuring dustfall rate and the guideline for locating sampling points shall be ASTM D1739. The latest version of this method shall be used.

The NEMA defines essential principles for environmental decision-making; the principles pertaining to air pollution are that pollution and environmental degradation must be avoided, and where they cannot be prevented, a life cycle assessment should be undertaken where waste is minimized and re-used or whenever feasible recycled, or disposed of responsibly.

The NEM: AQA introduced the compulsory monitoring of ambient air quality. The NFAQM legislates protocols, standards, and methodologies for monitoring (Government Notice No. 1144, 2018).

The NEM: AQA requires relevant national departments, provinces, and municipalities to introduce Air Quality Management Plans (AQMPs) that set out what will be done to achieve the prescribed air quality standards. Metropolitan, district, and local municipalities are required to include an AQMP as part of their Integrated Development Plans and provinces to develop an AQMP as part of their Environmental Implementation Plans.

In terms of the NEM: AQA, local government is responsible for air quality management, control and enforcement. This includes the control of all major sources, including mining, industrial, vehicle and residential sources, in terms of ambient air concentrations. District and Metropolitan Municipalities are the licensing authorities. Provincial government is also responsible for ambient monitoring and ensuring municipalities fulfil their legal obligations.

National government is primarily the policy maker and co-ordinator. A summary of the functions and responsibilities of National, Provincial and Local Government, as informed by the NEM: AQA and the NFAQM are provided in (**Table 5**).

Table 5: Air quality responsibilities and functions of National, Provincial, and Local Government **(Government Notice No. 1144, 2018).**

National Government	Provincial Government	Local Government
Establish the NFAQM.		
Appoint a national air quality officer.	Appoint a provincial Air Quality Officer.	Appoint a municipal Air Quality Officer.
Identify substances/mixture of substances that pose a threat to human health/well-being.	Establish provincial emission standards.	Establish municipal standards for emissions from point, non-

National Government	Provincial Government	Local Government
		point, and mobile sources in a municipality, in terms of its by-laws.
Set procedures for the measurement and reporting of emissions from point and non-point sources.		
Set procedures for the measurement and reporting of ambient air quality.		
Be the Atmospheric Emissions Licensing Authority. Issue AELs whenever a licensing authority fails to take a decision on an AEL application.	Perform the functions of the Atmospheric Emissions Licensing Authority if a Metro/District has delegated its function or fails to take a decision on an AEL application or if a municipality is the AEL applicant.	Metropolitan and District Municipalities perform the functions of the Atmospheric Emissions Licensing Authority
Prepare a National AQMP.	Prepare a Provincial AQMP as a component of their EIP and review the AQMPs received from the municipalities.	Develop an AQMP as part of their IDP.
Prepare an annual report regarding the implementation of the AQMP.	Prepare an annual report regarding the implementation of the AQMP.	Prepare an annual report regarding the implementation of the AQMP and compliance.
Publish and maintain a national list of activities which results in atmospheric emissions.	Publish and maintain a provincial list of activities which result in atmospheric emissions.	

National Government	Provincial Government	Local Government
Execute overarching auditing function to ensure that adequate air quality monitoring occurs.	Ambient air quality monitoring.	Ambient air quality monitoring.
Enforce compliance with the NEM: AQA, the NFAQM and any other relevant legislation.		Enforce and ensure compliance with the requirements of the regulations developed in terms of the AQA.
Review the impact on air quality of all government policies, strategies, plans, programmes and actions.		
Ensure that air quality information is accessible to all stakeholders using various channels such as AQ management websites and newsletters.	Keep stakeholders informed about ongoing and planned Air Quality management projects and decision-processes and public participation opportunities.	Keep stakeholders informed about ongoing and planned Air Quality management projects and decision-processes public participation opportunities.
Establish a national Air Quality Advisory Committee to advise the Minister on the implementation of AQA.		.
Declare national priority areas.	Declare provincial priority areas.	
Prepare a national priority areas AQMP.	Prepare provincial priority areas AQMPs in consultation with the AQOs in the affected municipalities.	

National Government	Provincial Government	Local Government
Prescribe regulations for implementing and enforcing the priority area AQMP.	Prescribe regulations for implementing and enforcing the priority area AQMP.	
Declare controlled emitters.	Declare controlled emitters.	
Declare and set requirements for controlled fuels.	Declare and set requirements for controlled fuels.	
Declare any substance contributing to air pollution as a priority air pollutant.	Declare any substance contributing to air pollution as a provincial priority air pollutant	
Set requirements for pollution prevention plans.	Establish a programme of public recognition of significant achievement in air pollution prevention.	Require the appointment of an Emission Control Officer in a given company who is responsible for the company's emissions control.
Prescribe measures for the control of dust, noise and odours.	Prescribe measures for the control of dust, noise and odours.	Monitor compliance with the requirements of the National Dust Control Regulations
Investigate and regulate transboundary pollution.		
Investigate potential international agreement contraventions.		
Issue an integrated environmental authorisation for activities identified in NEMA.		
Make regulations regarding any matter necessary to give		

National Government	Provincial Government	Local Government
effect to the Republic's obligations and information relating to energy that is required for compiling atmospheric emission reports.		

2.2 Legislation for Government

The Local Government: Municipal Systems Act, (Act No. 32, 2000), together with the Municipal Structures Act, (Act No. 117, 1998), establishes local government as an autonomous sphere of government with specific powers and functions as defined by the Constitution. Section 155 of the Constitution provides for the establishment of Category A, B and C municipalities; each having different levels of municipal executive and legislative authorities. According to Section 156(1) of the Constitution, a municipality has the executive authority in respect of, and has the right to, administer the local government matters (listed in Part B of Schedule 4 and Part B of Schedule 5) that deal with air pollution. Section 156(2) makes provision for a municipality to make and administer by-laws for the effective administration of any matters that it has the right to administer, provided it does not conflict with national or provincial legislation. The Municipal Systems Act, in conjunction with the Municipal Financial Management Act, (Act No. 56, 2003), requires municipalities to budget for and provide basic municipal services, that would *"ensure an acceptable and reasonable quality of life and which, if not provided, would endanger public health or safety of the environment"* (Act No. 56, 2003, p. 15). In terms of the National Health Act, Act 61 of 2003 (Act No. 61, 2004), municipalities are required to appoint a health officer who is required to investigate any state of affairs that may lead to a contravention of Section 24(a) of the Constitution, where Section 24(a) states that each person *"has the right to an environment that is not harmful to their health or well-being"* (South Africa, 1996, p. 1251).

The Promotion of Access to Information Act, (Act No. 2, 2000), in conjunction with Section 32 of the Constitution, entitles everyone to the right of access to any information held by government and private individuals that is required for the exercise or protection of any rights. The relevance of the right to information is that government, industries, and private individuals can be compelled, through court proceedings if required, to make information available regarding the state of the atmosphere and pollution. The Promotion of Administrative Justice Act, (Act No. 3, 2000), which was introduced by the State to give effect to Section 33 of the Constitution, provides everyone with the right to administrative action that is lawful, reasonable and procedurally fair, and the right to be given written reasons when rights have been adversely affected by administrative action.

The NFAQM provides a detailed table of National Legislation that has links, direct or indirect, to air quality management. The relevance of the links may improve communication, access to information, or the provision of measures to manage air quality (to name a few examples), or the links may be prohibitive, for instance, information is denied using the Protection of Information Act. The full list of direct and indirect legislation is provided hereafter (Table 6) as it appears in the NFAQM (Government Notice No. 1144, 2018).

Table 6: List of National legislation with direct or indirect links to air quality management in South Africa.

Legislation	Air quality management links	Relevance
National Key Points Act, 1980 (Act No. 102 of 1980)	• Provides for the protection of significant State or private assets, relative to national security. • Regulates the flow of information regarding Key Point activity. • Allows for measures to be implemented to maintain the security of a Key Point.	Many significant emitters have been classified as National Key Points, and the Act is used to regulate access to information.
Protection of Information Act, 1982 (Act No. 84 of 1982)	• Covers the protection of information related to defence, terrorism and hostile organisation. • Information regarding these activities in any form is prohibited access and cannot be disseminated. • Prohibited places can be declared, which also fall under this protection.	Can be used to regulate access to information on air quality.

Legislation	Air quality management links	Relevance
Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983)	• Regulates burning of veld, except in state forests. • Allows for control and prevention of veld fires through prescribed control measures. • Allows for control measures to be prescribed regarding the utilisation and protection of veld that has been burned.	Addresses controlled burning, which directly impacts on ambient air quality.
Local Government Municipal Structures Act, 1998 (Act No. 117 of 1998)	• Establishes municipal categories. • Designates functions and powers of municipalities.	Specifies that responsibility for integrated development planning, within which air quality management plans must reside, rests with district municipalities.
National Veld and Forest Fires Act, 1998 (Act No. 101 of 1998)	• Purpose is to combat and prevent veld, forest and mountain fires. • Fire Protection Agency can be designated for control and has power to conduct controlled burning with respect to conservation of ecosystems and reduction of fire danger. • Lighting, maintenance and using of fires is regulated.	Addresses controlled burning, which directly impacts on ambient air quality.
National Water Act, 1998 (Act No. 36 of 1998)	• Establishes strategy to address management of water resources including protection and use of water. • Establishes management agencies. • Provides for pollution prevention and remediation, including land-based sources.	Pollution sources from land-based activities that impact on water resources.

Legislation	Air quality management links	Relevance
	• Addresses emergency incidents, including land-based pollutant sources.	
Local Government Municipal Systems Act, 2000 (Act No. 32 of 2000)	• Provides a framework for planning by local government. • Describes contents of an integrated development plan and the process to be followed.	Air quality management plans are to be incorporated into integrated development plans.
Occupational Health and Safety Act, 1993 (Act No. 85 of 1993)	• Provides for the health and safety of persons at work, including atmospheric emission from workplaces. • Sets out certain general duties of employers and to their employees. • Empowers the Minister of Labour to make regulations regarding various matters. • Further require any employer to ensure that their activities do not expose non-employees to health hazards.	The air emissions from the workplace environment has atmospheric quality implications.
Promotion of Access to Information Act, 2000 (Act No. 2 of 2000)	• Facilitates constitutional right of access to any information whether held by State or another person (if it is related to exercise or protection of a right). • Details the means to access records, whether public or private. • Does not detract from provisions in the NEMA Section 1 and Section 2. • Allows for denial of access based on defence, security or international relations.	Promotes access to information, including air quality information, although it has provisions for refusing access.

Legislation	Air quality management links	Relevance
Promotion of Administrative Justice Act, 2000 (Act No. 3 of 2000)	• Details the administrative procedure to be followed when carrying out an administrative action, and the process of review.	Formal interactions between government departments, the public and other stakeholders by informing due process in decision-making.
International Trade Administration Act, 2002 (Act No. 71 of 2002)	• Establishes the International Trade Administration Commission as an administrative body. • Regulates the import and export of controlled substances.	Import and export control related to ozone-depleting substances through the declaration of controlled substance.
Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)	• States that environmental authorisation is required for obtaining prospecting and mining right. • For environmental authorisations, scoping, EIA, specialist reports (including air quality specialist report), and EMP are needed. The Act states that it is necessary to submit an environmental management programme if applying for a mining right, and an environmental management plan if applying for reconnaissance permission. • The Minister is required to consult with any state department which administers any law relating to matters that affect the environment and must request the comments of that department on the environmental plan or programme being considered.	Grants the decision-making power on matters potentially affecting the air environment to the Minister of Minerals and Energy in the case of mining activities but includes the obligation to comply with the AQA.

Legislation	Air quality management links	Relevance
	• Provisions are made for monitoring and auditing of environmental performance. • Regulation 64 of MPRDA regulations stipulates that, the holder of a mining right or permit must comply with laws relating to air quality management and control. • Stockpiles require compliance monitoring and decommissioning. • Closure certificate authorisation is dependent on approval from other environmental departments that potential environmental impacts have been addressed.	
National Health Act, 2003 (Act No. 61 of 2003)	• Makes reference to the performing of environmental pollution control by municipalities. • Municipal health services are defined as including the responsibility for environmental pollution control. • The responsibility for municipal health services rests with metropolitan and district municipalities. • National and provincial departments of health have the duty to perform environmental pollution control.	Air quality management falls within environmental pollution control.

Legislation	Air quality management links	Relevance
Intergovernmental Relations Framework Act, 2005 (Act No. 13 of 2005)	• Determines a framework to facilitate interaction and coordination, in the implementation of legislation, between spheres of government. • Principles of participation, consultation and consideration are included. • Establishes structures for coordination at different spheres of government. • Establishes an implementation protocol mechanism as a tool for coordination. • Provides mechanisms for conflict resolution, including the appointment of a facilitator.	Provides mechanisms for coordination and conflict resolution across spheres of government in aspects of legislative implementation.
National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)	• Promotes cleaner technology, cleaner production and consumption practices for pollution minimisation. • Addresses impacts of waste disposal on the environment, including air. • Provides for numerous measures related to waste disposal including standards, integrated waste management planning, municipal waste management, priority wastes, licensing, waste management information system.	Closely linked through issues of emissions to the air from thermal treatment activities and landfill sites.
Disaster Management Act, 2002 (Act No. 57 of 2002)	• Provides for the declaration of certain areas as disaster areas. • Disaster is defined as including the damage to the environment. • Provides for an integrated and co-ordinated disaster management policy that focuses on preventing or reducing the risk of disasters,	Certain air pollution episodes can be disastrous. Inversely, certain disasters result in air pollution.

Legislation	Air quality management links	Relevance
	mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post-disaster recovery. • Provides for the establishment of national, provincial and municipal disaster management centres.	
Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice, 2006 (Act No. 19 of 2006)	• Provides national and international recognition of the reliability of data produced by conformity assessment bodies involved in air quality management.	An accreditation service can be used to provide confidence to stakeholders regarding the reliability of data produced by conformity assessment bodies.

2.3 Local Air Quality By-Laws

Section 156(2) of the Constitution of the Republic of South Africa allows Local Municipalities to make and administer by-laws for the effective administration of the matters that it has the right to administer, provided that the by-laws do not conflict with National or Provincial legislation.

In the Kwa-Zulu Natal Province, only four municipalities out of a total of 54 have Air Quality By-laws that have been officially published for implementation. These municipalities include eThekwini Metropolitan, City of UMhlatuze LM, Ugu DM, and uMgungundlovu DM. Two district municipalities, namely Kings Cetshwayo DM and Amajuba DM, have Air Quality By-laws in the draft stage. On the other hand, the remaining 48 municipalities in the province either have outdated Air Quality By-laws or no By-laws at all.

By-laws pertaining to air quality have been established at local level for the uMhlatuze (Air Quality bylaws to be effective once council adopts the bylaws), Mkhambathini (Mkhambathini Municipal

Council, 2011), Msunduzi (City of Pietermaritzburg, 1968; The Msunduzi Municipality, 2012) and Richmond (Richmond Municipal Council, 2010) Local Municipalities and for the eThekwini Metropolitan Municipality (eThekwini Municipality, 2020). These bylaws regulate:

These bylaws regulate:

- Lighting of fires.
- Air pollution and smokeless control zones.
- Smoke emissions from premises other than dwellings.
- Smoke emissions from dwellings.
- Smoke emissions from open burning.
- Emissions that cause a nuisance.
- Smoke emissions from compressed ignition.

2.4 International Policies

Over and above the National, Provincial, and Local legislation including by-laws, South Africa is committed through the ratification of several international agreements that relate to air quality. The main obligations relate to greenhouse gases (GHG), stratospheric ozone depletion, and persistent organic pollutants (POPs) (Government Notice No. 1144, 2018). The international policies include:

- The United Nations Framework Convention on Climate Change (UNFCC).
- The Vienna Convention for the Protection of the Ozone Layer.
- The Montreal Protocol on Substances that deplete the Ozone Layer.
- The Stockholm Convention on Persistent Organic Pollutants.
- The Basel Convention on the Control of Transboundary Movements of hazardous wastes and their disposal.

The implementation of these policies is guided by the broader NEM: AQA and climate change related legislation. These policies and the implementation are not discussed in this AQMP; however, the continued contribution of South Africa towards these international policies can assist in improving air quality at Provincial, District and Local Municipal levels. The NFAQM provides a more detailed discussion on how South Africa contributes towards international policies (Government Notice No. 1144, 2018).

3 Health and Environment Impacts Associated with Criteria Air Pollutants

Air pollution is one of the major environmental risks to health. According to the Global Burden of Disease Study, air pollution is ranked among the top five out of 87 risk factors, competing with significant global health risks (GBD 2019 Risk Factors Collaborators, 2020). Deteriorating urban air quality has implications for human health, climate, the environment, and visibility. An overview of the human health and environmental impacts associated with air pollutants are discussed in the section below.

Some air pollutants, called criteria pollutants, are known to be hazardous to human health and wellbeing. The South African national ambient air quality standards (NAAQS) (Government Notice No. 1210, 2009; Government Notice No. 486, 2012) provide a basis for protecting public health from some of the adverse effects of these pollutants. These standards prescribe the maximum ambient concentrations permitted during a specified time period in a defined area. If the air quality standards are exceeded, there is an icreased health risk. The criteria pollutants are $PM_{2.5}$, PM_{10}, SO_2, NO_2, O_3, C_6H_6, Pb and CO.

Dust is also an air pollutant with legislated control. The National Dust Control Regulations (Government Notice No. 517, 2018) set acceptable dustfall rates for residential and non-residential areas. The coarsest fractions of dust have an impact on visibility and on plants flourishing in areas close to the source. The finer fractions (PM_{10} and $PM_{2.5}$) have health impacts.

3.1 Health Studies in KZN

Health studies in relation to air quality in the province have been developed in the Durban, eThekwini metropolitan region. The one study examines respiratory outcomes in association to ambient air quality among school children at primary schools located in two regions: the highly industrialised (Durban South) areas and non-industrialised (Durban North) areas (Naidoo RN, Robins TG, Batterman S, Mentz G, and Jack C., 2013). The study examined concentrations of PM, SO_2, CO and NO_X. The outcome of the study indicates that poor respiratory health was more common in children from the Durban South region than from the North region. In the population-based sample, 32.1% of participants had asthma of some severity, 12.0% had persistent asthma, of which 4.0% had moderate to severe symptoms, and

7.8% had marked airway hyperreactivity AHR. Asthma diagnosis by a doctor was much less common (14.8%). The South region participants were noted to have prevalent cases of severe symptoms of asthma. The results indicate that 12.2% of South region participants had moderate to severe persistent asthma compared to the Northern region participants (9.6%). In addition, the objective measure of AHR was also high (8.1% in the South versus 2.8% in the North). They concluded that their findings strongly suggested that the adverse respiratory symptoms were increased by industrial pollution (Naidoo RN, Robins TG, Batterman S, Mentz G, and Jack C., 2013).

3.2 Human Health Impacts

3.2.1 Particulate Matter

Particles can be classified by their aerodynamic properties into coarse particles (2.5 – 10 μm), fine particles (<2.5 μm) and ultrafine particles (<0.1 μm). The coarse particles contain earth crust materials, fugitive dust from roads and industries, desiccated cellular debris, spores, and pollen. The fine particles contain combustion particles, the secondarily formed aerosols such as sulphates and nitrates, coagulation of ultrafine particles and recondensed organic and metal vapours. Ultrafine particles are produced mainly by combustion and contain organic carbon, refractory metals (added to or naturally present in fuels), and vapor condensation products (Phalen, 2004). In terms of health effects, particulate air pollution is associated with respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms, and an increase in hospital admissions. Inhalable particulate matter (PM) also leads to increased mortality from cardiovascular and respiratory diseases and from lung cancer (WHO, 2013). Particle size is important for health because it controls where in the respiratory system a given particle deposits. Fine particles have been found to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles (Pope & Dockery, 2006). Larger particles are deposited into the extrathoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2005).

In the middle decades of the twentieth century, daily particulate concentrations in urban centres were in the range of 100 to 1000 μg/m^3 (Fowler, et al., 2020) whereas in more recent times, daily concentrations are between 10 and 100 μg/m^3. Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (WHO, 2000).

Short-term exposure

There is good evidence that short-term exposure to particulate matter is associated with health effects (WHO, 2013). Studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 µg/m^3). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function (Scapellato & Lotti, 2007). Susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable. For example, exposure to particulate matter affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function (WHO, 2011). There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur (WHO, 2013)

Long-term exposure

Long-term exposure to low concentrations (~10 µg/m^3) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2005). Studies have indicated an association between lung function, chronic respiratory disease, and airborne particles. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10 µg/m^3 increase in annual average particulate concentrations (WHO, 2000). Based on studies conducted in the USA, Europe and Canada, mortality is estimated to increase by 0.2–0.6% per 10 µg/m^3 of PM_{10} (WHO, 2005; Samoli, et al., 2008). $PM_{2.5}$ is a higher risk factor than the coarse part of PM_{10} (particles in the 2.5–10 µm range), particularly with long-term exposure. Long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 µg/m^3 of $PM_{2.5}$ (Pope, et al., 2002; Beelen, et al., 2008; Krewski, et al., 2009). Those most at risk include the elderly, individuals with pre-existing heart or lung disease, asthmatics, and children.

3.2.2 Sulphur Dioxide

SO_2 originates from the combustion of sulphur-containing fossil fuels in applications such as residential heating, industries, stationary power generation, ships and motor vehicles, and is a major air pollutant in many parts of the world. Health effects associated with exposure to SO_2 are mainly associated with the respiratory system. Being soluble, SO_2 is readily absorbed in the mucous membranes of the nose and upper respiratory tract (Witschi & Last, 2001).

Short-term exposure

The effects of short-term exposure to SO_2 include reductions in ventilatory capacity, increases in specific airway resistance, and symptoms such as wheezing or shortness of breath (WHO, 2005). Most information on the acute effects of SO_2 is derived from short-term exposure in controlled chamber experiments. These experiments have demonstrated a wide range of sensitivity amongst individuals. Acute exposure of SO_2 concentrations can lead to severe bronchoconstriction in some individuals, while others remain completely unaffected. Response to SO_2 inhalation is rapid with the maximum effect experienced within a few minutes. Continued exposure does not increase the response. The effects are, however, increased by exercise that increases the amount and depth of inhalation, and breathing through the mouth. Effects of SO_2 exposure are short-lived with lung function returning to normal within a few minutes to hours (WHO, 2000; WHO, 2005).

Exposure over 24 hours

The effects of exposure to SO_2, averaged over a 24-hour period, are derived from epidemiological studies in which the effects of SO_2, particulates and other associated pollutants are assessed. Studies of the health impact of emissions from the inefficient burning of coal in domestic appliances have shown that when SO_2 concentrations exceed 250 μg/m^3 in the presence of particulate matter (as sulphates), an exacerbation of symptoms are observed in selected sensitive patients. More recent studies of health impacts in ambient air polluted by industrial and vehicular activities have demonstrated, at low levels, effects on mortality (total, cardiovascular and respiratory) and increases in hospital admissions. In these studies, no obvious SO_2 threshold level was identified (WHO, 2005).

Long-term exposure

Long-term exposure to SO_2 has been found to be associated with an exacerbation of respiratory symptoms and a small reduction in lung function in children in some cases. In adults, respiratory symptoms such as wheezing, and coughing are increased. The Hong Kong "intervention" study (Hedley, et al., 2002) indicated significant health benefits, both immediate and long-term, in reducing SO_2 from a daily average of 44 μg/m^3 to 21 μg/m^3.

3.2.3 Nitrogen Oxides

Nitric oxide (NO) is a primary pollutant emitted from combustion at stationary sources (heating, power generation, industrial incinerations) and from motor vehicles. Nitrogen dioxide (NO_2) is formed through the oxidation of nitric oxide. Oxidation of NO by O_3 occurs rapidly, even at low levels of reactants present in the atmosphere. As a result, this reaction is regarded as the most important route for nitrogen dioxide production in the atmosphere. Health effects of NO_2 gas are related to its ability to dissolve in the moisture on any moist tissue surfaces to form nitric acid which can burn delicate tissues. As such, NO_2 is an irritant asphyxiant gas which can produce severe irritation in the air passages and lungs (Queensland Government, 2017).

Nitrogen dioxide is an important gas, not only because of its health effects, but because it (a) absorbs visible solar radiation and contributes to visibility impairment, (b) could have a potential role in global climate change if concentrations were to increase significantly, (c) is a chief regulator of the oxidizing capacity of the free troposphere by controlling the build-up and fate of radical species, including hydroxyl radicals and (d) plays a critical role in determining ozone concentrations.

Short-term exposure

Experimental toxicology indicates that nitrogen dioxide is a toxic gas (in short-term concentrations exceeding 200 μg/m^3) with significant health effects (WHO, 2005). However, short-term concentrations of NO_2 greater than 1 880 μg/m^3 (i.e., concentrations which are higher than those normally found in ambient air) are required to bring about changes in the pulmonary function of healthy adults (WHO, 2000). Normal healthy people exposed at rest or with light exercise for less than 2 hours to concentrations above 4 700 μg/m^3 (2 500 ppb), experience pronounced decreases in pulmonary function. Asthmatics are potentially the most sensitive subjects although various studies of the health effects on asthmatics have been inconclusive. The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30 – 110 minutes to 565 μg/m^3 (301 ppb) during intermittent exercise (WHO, 2005)

Long-term exposure

Animal studies have shown that exposure to 1 880 μg/m^3 over a period of several weeks to months, causes effects in the lungs and other organs such as the spleen and liver. Structural changes include a change in cell type in the tracheo-bronchial and pulmonary regions to emphysema-like effects. NO_2 concentrations as low as 940 μg/m^3, can also increase the lung's susceptibility to bacterial and viral infections (WHO, 2000). It is known that these toxic effects of NO_2 might occur in humans, but because of differences in species sensitivity, the effects that are caused by a specific inhaled concentration of NO_2 cannot be deduced with any level of confidence (WHO, 2005).

It is very difficult to differentiate the effects of nitrogen dioxide from those of other pollutants in outdoor epidemiological studies. This is because the complex gas-particle mixture of NO_2, organic and elemental carbon, inorganic acids, $PM_{2.5}$ and ultrafine particles all usually come from the same combustion sources (WHO, 2005).

Epidemiological studies have been undertaken on the indoor use of gas cooking appliances and health effects. Studies on adults and children under 2 years of age found no association between the use of gas cooking appliances and respiratory effects. Children aged 5 – 12 years have a 20% increased risk for respiratory symptoms and disease for each increase of 28 $\mu g/m^3$ (15 ppb) NO_2 concentration, where the weekly average concentrations are in the range of 15 – 128 $\mu g/m^3$ (8 – 68 ppb) (WHO, 2005).

Outdoor studies consistently indicate that children with long-term ambient NO_2 exposures exhibit increased respiratory symptoms that are of a longer duration. However, no evidence is provided for the association of long-term exposures with health effects in adults (WHO, 2005).

3.2.4 Ozone

Ozone in the atmosphere is a secondary pollutant formed through a complex series of photochemical reactions between NO_2 and VOCs in the presence of sunlight. Sources of these precursor pollutants include motor vehicles and industries. Atmospheric background concentrations are derived from both natural and anthropogenic sources. Natural concentrations of O_3 vary with altitude and seasonal variations (i.e., summer conditions favour O_3 formation due to increased insolation). Diurnal patterns of O_3 vary according to location, depending on the balance of factors affecting its formation, transport, and destruction. From the minimal levels recorded in the early morning, concentrations increase because of photochemical processes and peak in the afternoon. During the night, O_3 is scavenged by nitric oxide. Seasonal variations in O_3 concentrations also occur and are caused by changes in meteorological conditions and insolation. Quarterly mean (arithmetic average of daily values for a calendar quarter) O_3 concentrations are typically highest in summer (WHO, 2005).
Ozone is a powerful oxidant and can react with a wide range of cellular components and biological materials. Health effects and the extent of the damage associated with O_3 exposure is dependent on O_3 concentrations, exposure duration, exposure pattern and ventilation (WHO, 2005)

Short-term exposure

Short-term effects include respiratory symptoms, pulmonary function changes, increased airway responsiveness and inflammation. Field studies in vulnerable persons (children, adolescents, young adults, elderly, and asthmatics) have indicated that pulmonary function decrements can occur because of short-term exposure to O_3 concentrations in the range 120 – 240 µg/m^3 (61 – 122 ppb) and higher. Ozone exposure has also been reported to be associated with increased hospital admissions for respiratory causes and exacerbation of asthma (WHO, 2005).

Long-term exposure

There is limited information linking long-term O_3 exposure to chronic health effects, however, there are suggestions that cumulative O_3 exposures may be linked with increasing asthma severity and the possibility of increased risk of becoming asthmatic (Katsouyanni, 2003).

Evidence provided by studies of health effects related to chronic ambient O_3 exposure is consistent in indicating chronic effects on the lung. Some studies have shown that long-term exposure to concentrations of O_3 in the range 240 – 500 µg/m^3 (122 – 255 ppb) causes morphological changes in the region of the lung resulting in a reduction in lung function (Katsouyanni, 2003).

3.2.5 Carbon Monoxide

Carbon monoxide (CO) is one of the most common and widely distributed air pollutants. CO is a tasteless, odourless, and colourless gas, which has a low solubility in water. In the human body, after reaching the lungs it diffuses rapidly across the alveolar and capillary membranes and binds reversibly with the haem proteins. Approximately 80 – 90% of CO binds to haemoglobin to form carboxyhaemoglobin which is a specific biomarker of exposure in blood. The affinity of haemoglobin for CO is 200 – 250 times that for oxygen. This causes a reduction in the oxygen-carrying capacity of the blood which leads to hypoxia as the body is starved of oxygen.

Anthropogenic emissions of CO originate from the incomplete combustion of carbonaceous materials. The largest proportion of these emissions is produced from exhausts of internal combustion engines, in particular petrol vehicles. Other sources include industrial processes, coal power plants and waste incinerators. Ambient CO concentrations in urban areas depend on the density of vehicles and are influenced by topography and weather conditions. In the streets, CO concentrations vary according to the distance from the traffic. In general, the concentration is highest at the leeward side of the ‘street canyon’ with a sharp decline in concentration from pavement to rooftop level (Schwela, 2000).

Short and Long-term exposure

The adverse health effects of CO vary, depending on the concentration and time of exposure. Clinical symptoms range from headaches, nausea and vomiting, muscular weakness, and shortness of breath at low concentrations (10 ppm) to loss of consciousness and death after prolonged exposure or after acute exposure to high CO concentrations (>500 ppm). Poisoning may cause both reversible, short-lasting neurological deficits and severe, often delayed, neurological damage. Neurobehavioural effects include impaired co-ordination, tracking, driving ability, vigilance, and cognitive ability at carboxyhaemoglobin levels as low as 1.5 – 8.2% (WHO, 2005).

High risk patients with regards to CO exposure include persons with cardiovascular diseases (especially ischaemic heart disease), pregnant mothers and the foetus and new-born infants. Epidemiological and clinical studies indicate that CO from smoking and environmental or occupational exposures may contribute to cardiovascular mortality (WHO, 2005).

3.2.6 Benzene

Benzene is a volatile organic compound (VOC). VOCs are organic chemicals that easily vaporise at room temperature and are colourless. Benzene in air exists predominantly in the vapour phase, with residence times varying between a few hours and a few days, depending on the environment, climate, and the concentration of other pollutants. The only benzene reaction, which is important in the lower atmosphere, is the reaction with hydroxy radicals. The products of this reaction are phenols and aldehydes, which react quickly and are removed from the air by rain.

Benzene is a natural component of crude oil, and petrol contains 1 – 5% by volume. Benzene is produced in large quantities from petroleum sources and is used in the chemical synthesis of ethyl benzene, phenol, cyclohexane, and other substituted aromatic hydrocarbons. Benzene is emitted from industrial sources as well as from combustion sources such as motor engines, wood combustion and stationary fossil fuel combustion. The major source is exhaust emissions and evaporation losses from motor vehicles and during the handling, distribution, and storage of petrol.

Information on health effects from short-term exposure to benzene is fairly limited. The most significant adverse effects from prolonged exposure to benzene are haematotoxicity, genotoxicity and carcinogenicity. Chronic benzene exposure can result in bone marrow depression expressed as leukopenia, anaemia and/or thrombocytopenia, leading to pancytopenia and aplastic anaemia. Based on this evidence, C_6H_6 is recognized to be a human and animal carcinogen. An increased mortality from leukaemia has been demonstrated in workers occupationally exposed (WHO, 2005).

3.2.7 Lead

Lead is a naturally occurring element found in the Earth's crust. Properties including softness, malleability, ductility, poor conductibility and resistance to corrosion have made its use popular. Important sources of environmental contamination include mining, smelting, manufacturing, and recycling activities. More than three quarters of global lead consumption is used in the manufacture of lead-acid batteries for motor vehicles (WHO, 2019). There are a wide range of sources of lead in South Africa that put particular groups of people at high risk of lead exposure (Mathee, 2014). For example, lead-based paint was used in most houses in South Africa as well as on playground equipment and toys. In some subsistence fishing communities, lead is melted to craft fishing sinkers (Mathee, 2014). Due to its non-biodegradable nature and continuous use, lead concentrations accumulate in the environment with increasing hazards (Wani, Ara, & Usmani, 2015). Significant reductions in the levels of air-borne lead were achieved over recent years as a result of national legislation which came into effect in 2006 to ban lead in petrol and the promulgation in 2010 of legislation to control the use of lead in paint.

It does not matter if a person breathes-in, swallows, or absorbs lead particles, the health effects are the same; however, the body absorbs higher levels of lead when it is breathed in (CDC, 2018). Once taken into the body, lead distributes throughout the body in the blood and is accumulated in the bones. There is almost no function in the human body which is not affected by lead toxicity. Lead toxicity disrupts the functions of the digestive system, nervous system, respiratory system, reproductive system, etc. In addition, lead prevents enzymes from performing their normal activities. Lead even disrupts the normal DNA transcription process and causes disability in bones (Wani, Ara, & Usmani, 2015).

Infants and young children are especially sensitive to lead exposures. Lead can affect children's brain development resulting in reduced intelligence quotient (IQ) and can cause behavioural changes such as reduced attention span and increased antisocial behaviour. Lead exposure also causes anaemia, hypertension, renal impairment, immunotoxicity and toxicity to the reproductive organs. Lead in bone is released into blood during pregnancy and becomes a source of exposure to the developing foetus. There is no level of exposure to lead that is known to be without harmful effects (WHO, 2019).

3.3 Environmental Impacts

3.3.1 Acid Rain

Environmental impacts associated with criteria air pollutants include the loss of biodiversity and damage to sensitive environments due to acid rain. Acid rain is a general term referring to a combination of wet and dry deposition from the atmosphere containing elevated amounts of sulphuric and nitric acid. Acid rain occurs when SO_2 and NO_x are emitted into the atmosphere, undergo chemical transformation, and are absorbed by water droplets in clouds. The droplets then fall to earth as rain, snow, mist, dust, hail, or sleet.

Direct impacts of acid rain include visible damage to leaves. Direct effects on vegetation are most likely to occur where plants are frequently exposed to polluted cloud or fog water under conditions where direct capture of water droplets is efficient. For these reasons forests in upland areas exposed to wind driven cloud are likely to be the most sensitive receptors (UK DETR, 1996).

The indirect, but grave ecological effects of acid rain are most clearly seen in aquatic environments, such as streams, lakes, and marshes where it can be harmful to fish and other wildlife (Rutherford, 1984). Acidic rainwater leaches aluminium from soil clay particles as it flows through the soil, depositing aluminium into streams and lakes. The more acid that is introduced to the ecosystem, the more aluminium is released (US EPA, 2019). Some types of plants and animals are able to tolerate acidic waters and moderate amounts of aluminium. Others, however, are acid-sensitive and will be lost as the pH declines. Excess nitrogen in the water also may cause eutrophication – a dense growth of plant life resulting in the depletion of dissolved oxygen (hypoxia), which stresses or kills aquatic life.

The major effects of acid rain on terrestrial ecosystems are indirect, through soil acidification. Acid rain may suppress microbiological decomposition and nitrification processes, thus influencing the nutrient status of soils. It has also been found that soil organic matter is less soluble in more acid solutions (Van Loon, 1984). The resulting reduction in the availability of essential soil nutrients may result in reduced plant growth, changes in the quantity and quality of crops, reduced seed production and increased vulnerability to frost, drought, pests, and diseases (Mills, et al., 2017). Increased solubility of potentially toxic elements such as aluminium may also occur from soils which have been exposed to acidified rainfall (Van Loon, 1984). These are very harmful to trees and plants, even if contact is limited.

At the ecosystem level, sulphur dioxide impacts on biodiversity by eliminating more sensitive species. Even if a species of fish or animal can tolerate moderately acidic water, the animals, or plants it eats might not. This alters trophic relationships which have far-reaching implications for the animal and microbial populations in the community (Varshney 2009).

3.3.2 Fugitive Dust

Fugitive dust is described as dust emanating from open sources through mechanical disturbance or wind erosion (US EPA, 1995 c13s2). This differentiates fugitive dust from dust particles that are discharged through stacks or similar confined flow streams. Common sources of fugitive dust include entrained dust from vehicles moving on unpaved roads, loading, and unloading of aggregate storage piles, heavy construction operations and wind erosion from denuded land.

The impact of fugitive dust sources on air pollution depends on the quantity and drift potential of the dust particles released into the atmosphere. Large dust particles settle out near the source often creating a local nuisance problem. Particles larger than ~100 µm are likely to settle out within 6 to 9 metres from the point of emission. Depending on the extent of atmospheric turbulence, particles that are 30 to 100 µm in diameter are likely to settle within approximately 90 metres from the source. Fine particles, on the other hand, particularly inhalable particles, disperse over much greater distances from the source (US EPA, 1995 c13s2). The health impacts of these inhalable particles have been discussed in the section on particulate matter.

Implementing dust control (dust suppression) and preventative measures is critical to reduce fugitive emissions. Dust suppression measures include but are not limited to watering, chemical stabilisation, the reduction of surface wind speed using windbreaks/source enclosures or a combination of measures. Preventive measures for the control of fugitive dust include the reduction of the extent of the source of dust, process modification and/or adjusting work practices (US EPA, 1995 c13s2).

There are many reasons for controlling dust emissions. These reasons include legislative requirements, site specific conditions and the proximity of sensitive receptors to the sources of dust. Understanding these requirements is essential to ensure sufficient environmental planning is conducted in order for dust control to be effective (Annegarn 1993). The following effects of the dust emissions bear consideration:

- The acute and / or chronic toxicity to humans, animals or plants.

- The aesthetic nuisance value.
- Soiling.
- Damage to machinery.
- Quality impairment by deposition on fruit and leaf crops.
- Soil modification.
- Accumulation of dust on pasture.
- Smothering of plants.
- Visibility impairment in pristine sites.
- Significant deterioration of existing air quality.

Legislative requirements in South Africa are structured to reduce the potential negative impact on people. The dust control regulations, therefore, distinguish between residential and non-residential areas. Consideration of sensitive receptors, such as schools, hospitals, etc. are required to understand the potential impact of dust emissions from specific sources on health.

3.3.3 Odour

According to the National Environmental Management: Air Quality Act, Act 39 of 2004 (NEM: AQA) offensive odour means any smell which is considered to be malodorous or a nuisance to a reasonable person. Waste disposal industries and operations at risk of gas explosion hazards where methane gas can reach concentrations between 5% and 15% of atmospheric gas composition are sources of distinctive and unpleasent odours. Sources of offensive odour are common in operations that emit above average ambient levels of sulphur dioxide and hydrogen sulphide which are common for strong odour.These sources, when they are situated within 250 m of residential or other structures (commercial areas, schools and hospitals, etc), are found to represent a potential safety hazard or odour issues (Department of Water Affairs & Forestry, 1998). The specified activities are required to implement gas monitoring and a management plan for the control/preventation of offensive odours emanating from their premises as outlined in the NEM: AQA Section 35. Repeated exposure to nuisance levels of odour can cause annoyance as well as physiological and psychological health impacts such as stress, headaches, nausea, shortness of breath or aggravating asthma symptoms and interferenace with a person's capacity to work (EPA, 2023). Health impacts in relation to offensive odour is dependent on the frequency of the occurence, intensity, duration of exposure and the individual's sensitivity (EPA, 2023).

4 Meteorological Overview

An overview of the macroscale and mesoscale atmospheric circulations influencing airflow and the subsequent dispersion and dilution of pollutants is discussed. The local meteorological conditions in the province are evaluated using surface meteorological data from selected ambient air quality monitoring stations (AAQMS) with meteorological sensors reported on SAAQIS.

4.1 Macroscale Air Circulation

The mean circulation of the atmosphere over southern Africa is anticyclonic throughout the year due to the dominance of three semi-permanent, subtropical high-pressure cells. Seasonal changes in the intensity and position of the high-pressure cells, together with the influence of the easterlies in the north and westerlies in the south, control the climate of southern Africa (Tyson, Garstang, & Swap, 1996).

The presence and strengthening of an anticyclone centred over the subcontinent in winter is associated with subsidence of air which produces clear, dry, stable conditions. Subsidence associated with anticyclones is conducive to the formation of absolutely stable layers in the troposphere that prevent the vertical transport of pollution. Over the interior plateau, three stable layers occur at 700 hPa, 500 hPa, and 300 hPa with another layer at 800 hPa between the plateau and the coast. On days when these stable layers occur, dense haze layers are evident (Tyson, Garstang, & Swap, 1996). Absolutely stable layers at the surface in the form of surface inversions develop due to cooling during the night. Surface inversions prevent the vertical distribution of pollutants in the atmosphere which can reduce visibility during the early morning. During the day, the stable boundary layer is eroded away by heating and a mixing layer develops which may erode away the surface inversion (Tyson & Preston-Whyte, 2000). Pollutants trapped below the surface inversion are then able to rise and disperse.

In summer, the inter-tropical convergence zone moves southwards, and the subtropical anticyclonic belt is weakened. Over southern Africa, semi-stationary easterly waves form in deep easterly currents in the vicinity of an easterly jet. The waves are barotropic (axes not displaced with height) and the perturbations take the form of closed lows which are evident near the surface. Surface convergence and upper air divergence to the east of the wave trough can produce strong uplift, instability, and the potential for precipitation. Ahead of and to the west of the wave trough, surface divergence and upper air convergence occurs, ensuring clear, dry conditions. Easterly lows are deeper systems than easterly waves, with surface convergence through the 500 hPa level. Such phenomena are associated with copious rains if airflow has a northerly component emanating from the warm Agulhas Current. Tropical disturbances are mainly a summer phenomenon and peak during the summer months of December and February (Tyson & Preston-Whyte, 2000).

During winter, the high-pressure belt moves northwards, allowing circumpolar westerlies to displace the tropical easterlies. Westerly waves are baroclinic, Rossby waves and are tilted westward with height. Westerly waves are associated with surface convergence and upper-level divergence to the rear of the wave trough which produce gentle uplift of air with cloud and precipitation. Subsidence and stable conditions occur ahead of the trough. Disturbances in the westerlies include cut-off lows, southerly meridional flow, ridging anticyclones, west-coast troughs, and cold fronts, all of which can induce rainfall both over the plateau and coastal areas.

The northward positioning of the Westerlies during winter results in a succession of cold fronts associated with passing mid-latitude cyclones. This causes frontal rain over the south-western coastline of South Africa in the winter rainfall area. Cold fronts can also occur in association with depressions or cut-off lows which bring heavy rainfall over large parts of the interior particularly in spring and autumn by causing onshore flow from the warm Agulhas Current up over the eastern escarpment.

Cold fronts moving northwards and eastwards over the land occur most frequently in winter and bring cool weather due to airflow from the south and south-west. Ahead of the front, northerly airflow is associated with divergence and subsidence that brings stable, clear conditions. Behind the front, southerly airflow, associated with low-level convergence causes cool conditions and rain (Tyson & Preston-Whyte, 2000). With the passage of a cold front, wind direction changes from north-west to west and then south-west.

4.2 Mesoscale Air Circulation

Air transport near the surface can either be induced by horizontal spatial discontinuities in temperature, pressure and density fields or by topographically induced local winds such as those on slopes and in valleys. Such mesoscale circulations have implications for the transport and recirculation of pollutants in an airshed.

On slopes, differential heating and cooling of the air produces local baroclinic fields (Figure 4). During the day, the absorption of radiation by the slopes warms the air near the surface, initiating low-level, up-slope anabatic flow with an upper-level return flow to complete the closed circulation. During the night, the mechanism and the circulation are reversed as surface cooling produces down-slope katabatic flow and its return flow. The formation of frost hollows and the accumulation of fog and pollutants are associated with down-slope flow (Atkinson, 1981). The onset of the valley wind in valleys around Pietermaritzburg is shown to produce distinctive changes in the spatial variation of the wind field which are conducive to the occurrence of dynamic air pollution fumigations (Tyson P. D., 2012).

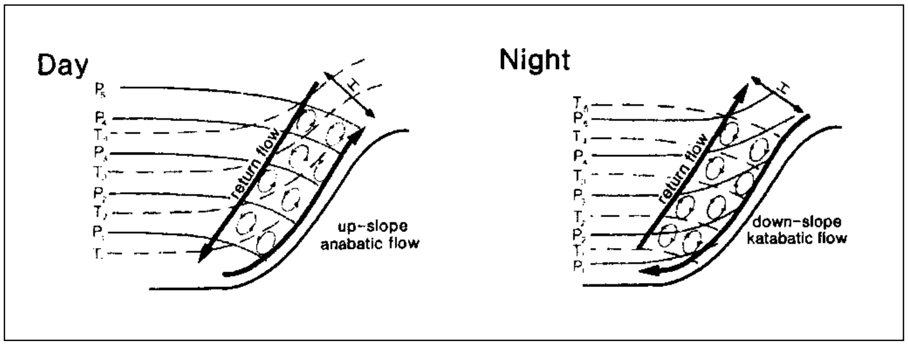


Figure 4: Diurnal variation of local winds on slopes (Tyson & Preston-Whyte, 2000)

Within valleys, local airflow is dependent on the geometry (depth and orientation) of valleys and the time of day or night (Tyson & Preston-Whyte, 2000). In valleys whose slopes are equally heated (east-west valleys), early morning circulations are up-slope and down-slope in the evening (Figure 5).

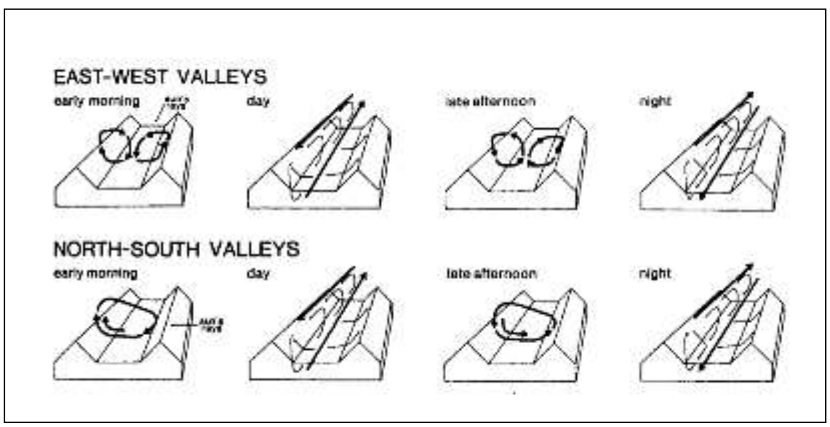


Figure 5: Diurnal variation of local winds in valleys (Tyson & Preston-Whyte, 2000)

During the day, up-valley valley winds occur with an upper-level anti-valley wind to complete the closed circulation. During the night, down-valley mountain winds and the return anti-mountain wind occur. In valleys at right angles to the rising and setting sun (north-south valleys), the flow patterns are similar except that a unicellular circulation is set up at sunrise and sunset. These wind fields control the transport and dispersion of low-level pollutants within valleys. Nocturnal mountain winds can transport pollution long distances down valleys under stable conditions while daytime valley winds can effectively disperse, and dilute pollution trapped within the valley. Valley winds dominate and are strongest in summer when heating is greatest while mountain winds dominate and are strongest in winter when cooling is strongest (Tyson & Preston-Whyte, 2000).

4.3 Wind Field

Characterization of the wind fields in KZN was undertaken using surface meteorological data from the ambient air quality monitoring stations (AAQMS) in eThekwini (Wentworth Reservoir AAQMS), uMgungundlovu (Edendale AAQMS) and King Cetshwayo (Richards Bay CBD AAQMS) all of which report on the South African Air Quality Information System (SAAQIS) (Table 7). A data recovery of 50% is required for the determination of wind analysis and wind roses. Wind roses for the district municipalities that had less than 50% data recovery were compiled using Weather Research and Forecasting Model (WRF) data on a 5km grid processed for dispersion modelling. The modelled wind roses and analysis are provided in APPENDIX 1:

Table 7: Meteorological stations.

Station Name	Wentworth operated by eThekwini Metropolitan
Latitude	-29.934094°S
Longitude	30.988622°E
Station Name	**Edendale operated by Msunduzi Local Municipality**
Latitude	-29.637968°S
Longitude	30.344507°E
Station Name	**Richards Bay CBD operated by Richards Bay Clean Air Association**
Latitude	-28.744719°S
Longitude	32.054805°E

Wind roses graphically present wind conditions over a period of time at a specific location, representing their strength, direction and frequency. Annual wind roses for eThekwini, uMgungundlovu and King

Cetshwayo are presented below. The wind rose are calculated using hourly averages wind data (wind speed and wind directions) for the 2019-2021 period, where available. In the wind roses, the length of each spoke represents the percentage of time that the wind blew from that direction during the period. The percentage scale is presented on the concentric grey lines (each dotted circle within the wind rose represents a 5% frequency of occurrence in the relevant period). Each spoke is divided by colour into wind speed ranges. Wind speed classes are based on the Beaufort Scale (World Meteorological Organization 2012) as follows:

1. Calm (> 0 and <= 0.5 m/s),
2. Light air (> 0.5 and <= 1.5 m/s; dark blue),
3. Light breeze (> 1.5 and <= 3.1 m/s; light green),
4. Gentle breeze (> 3.1 and <= 5.1 m/s; dark green),
5. Moderate breeze (> 5.1 and <= 8.2 m/s; pink),
6. Fresh breeze (> 8.2 and <= 10.8 m/s; red),
7. Strong breeze (> 10.8 and <= 13.9 m/s; yellow),
8. Near gale (> 13.9 and <= 17 m/s; orange),
9. Gale (> 17 and <= 20.6 m/s; purple),
10. Strong gale (> 20.6 and <= 24.2 m/s; brown),
11. Storm (> 24.2 and <= 28.3 m/s; khaki),
12. Violent storm (> 28.3 and <= 32.4 m/s; grey), and
13. Hurricane (> 32.4 m/s; black).

The predominant winds, as measured at the Wentworth Reservior AAQMS in eThekwini, for the period from 2019 to 2021, are from a north-easterly direction for approximately 23% of the time, followed by a west-south-westerly direction (11.8%) and an east-north-easterly direction (10.3%). The dominant wind directions as measured at the Edendale AAQMS in uMgungundlovu, for the same period, are from an easterly (22.4%), east-north-easterly (15%), east-south-easterly (13.9%) and south-westerly (11.5%) direction. The Richards Bay CBD AAQMS in the King Cetshwayo District, measured winds predominantly from the north-north-east (22.7%), while winds from all other directions occurred with less than a 10.0% frequency (Figure 6 to Figure 8). The average hourly wind speed is approximately 4 m/s in eThekwini, 1.7 m/s in uMgungundlovu and 3.3 m/s in King Cetshwayo. The highest wind speeds (strong breezes between 10.8 and 13.9 m/s) occurred in eThekwini for 0.5% of the time from the south-south-westerly and south-westerly directions, and for 0.03% of the time in uMgungundlovu from the north-easterly direction. Calm conditions (wind speeds below 0.5 m/s) are experienced approximately 2.3% of the time in eThekwini, 9.2% of the time in uMgungundlovu and 2.1% of the time in King Cetshwayo.

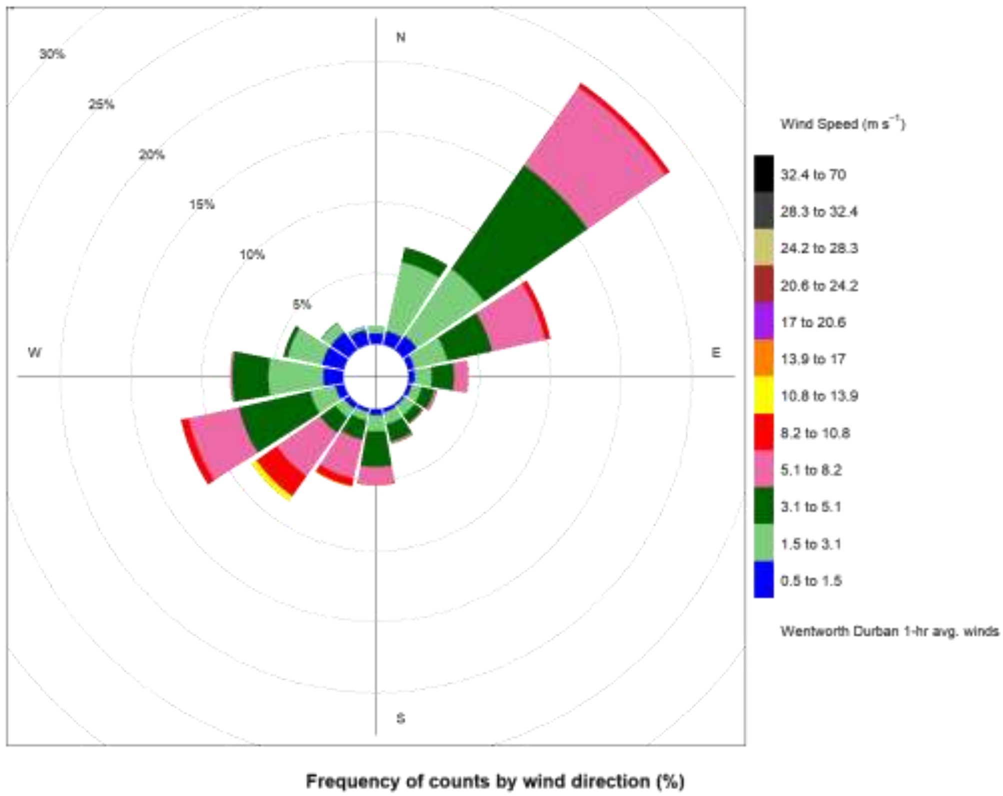


Figure 6: Wind roses of the average hourly winds measured at the Wentworth Reservoir AAQMS for the years 2019-2021.

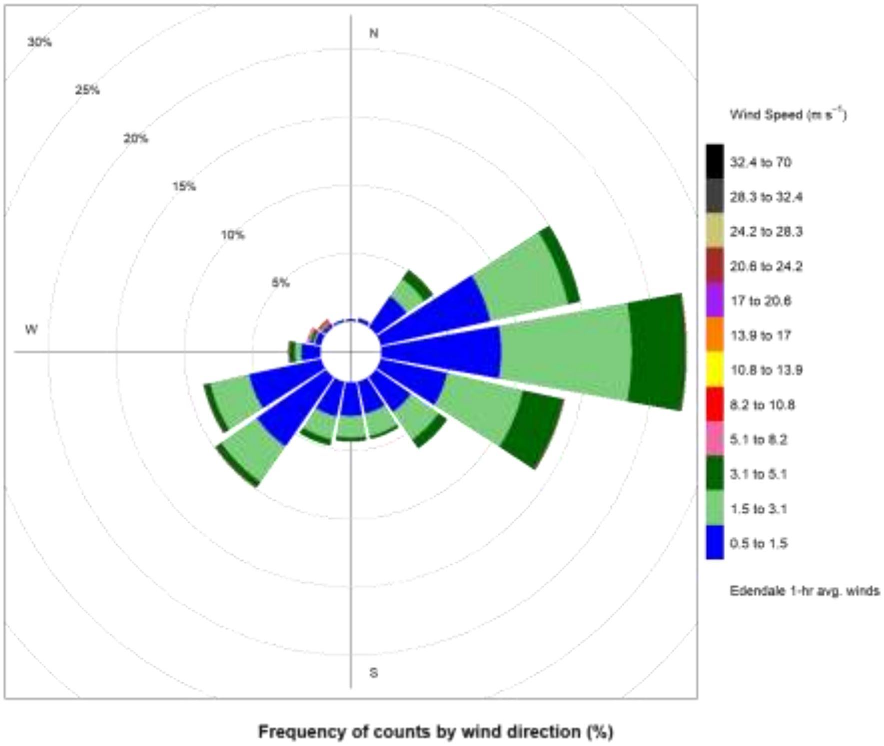


Figure 7: Wind roses of the average hourly winds measured at the Edendale AAQMS for the years 2019-2021.

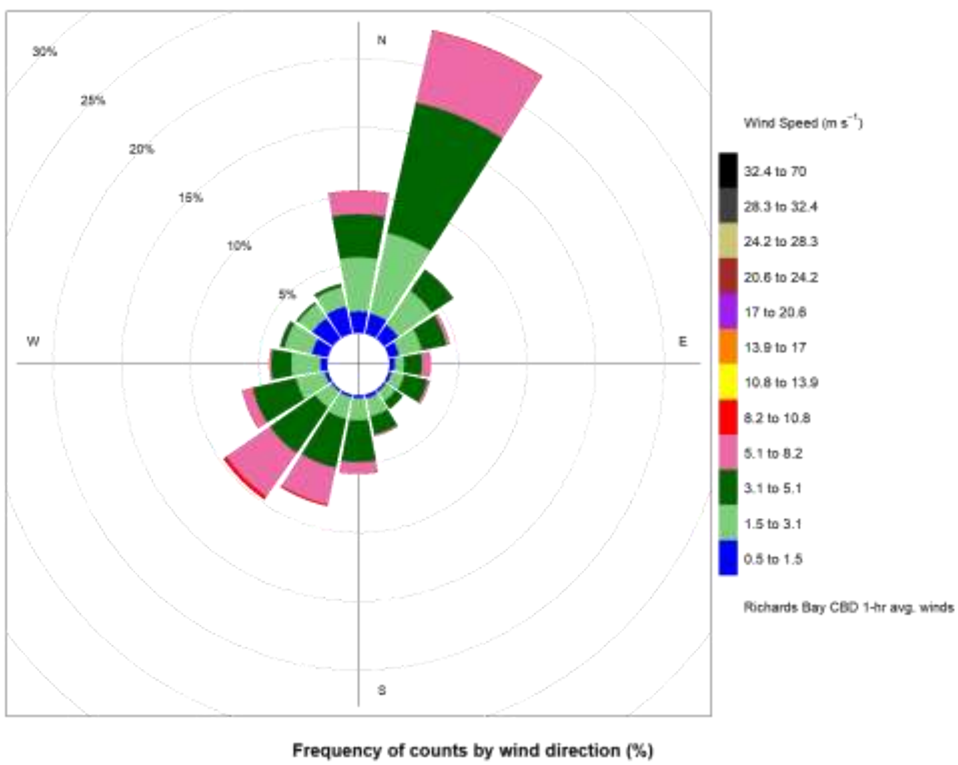
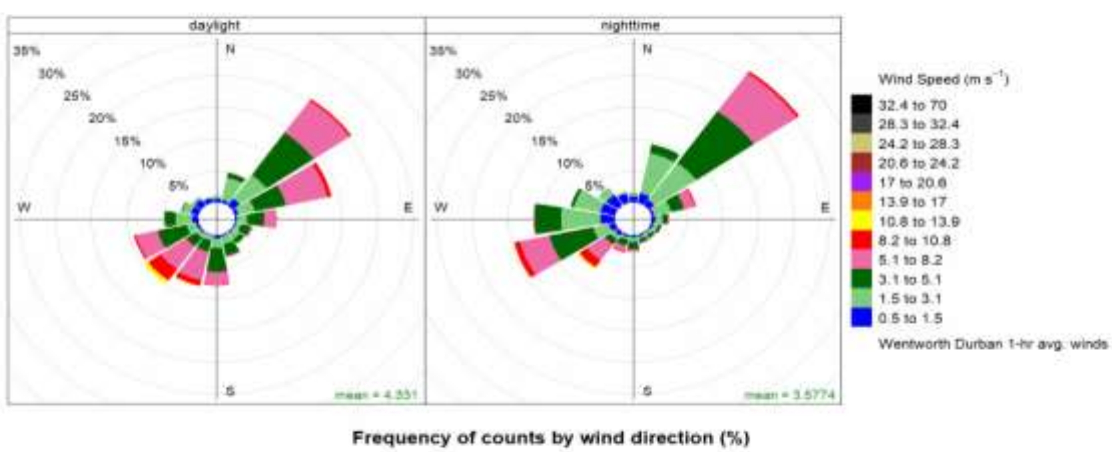


Figure 8: Wind roses of the average hourly winds measured at the Richards Bay CBD AAQMS for the years 2019-2021.

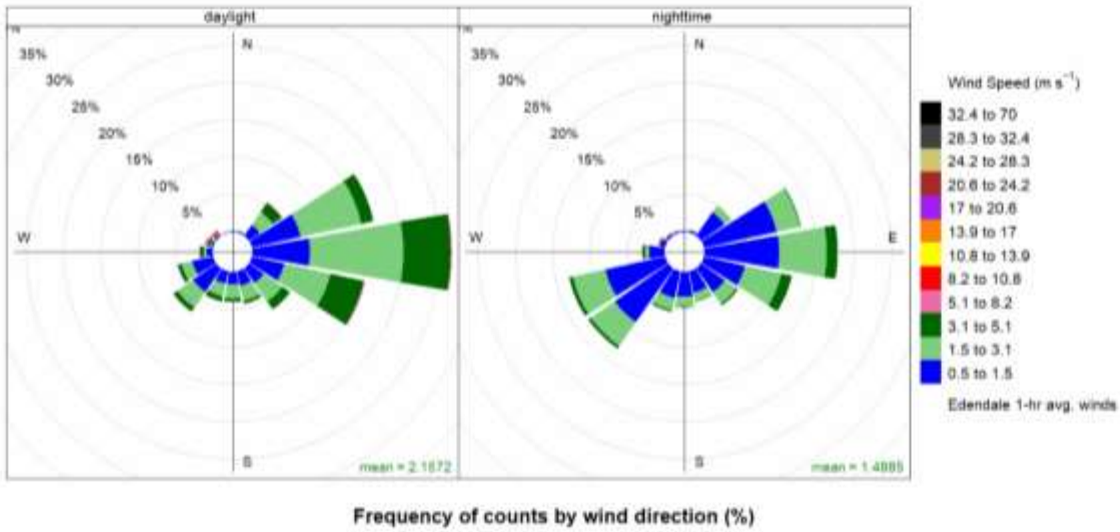
The diurnal variation in wind direction is more evident in eThekwini and uMgungundlovu than in King Cetshwayo. In eThekwini, most of the daytime winds are from the north-east, east-north-east, south-west and west-south-west, while night-time winds are mainly from the north-east, west-south-west and west. Average wind speeds are higher in the day (4.3 m/s) than during the night (3.6 m/s). In uMgungundlovu, winds originating from the east, east-north-east and east-south-east are the most common during the day, while at night, additional south-westerly and west-south-westerly directions are dominant. Average wind speeds are higher in the day (2.2 m/s) than during the night (1.5 m/s). In King Cetshwayo both the day and night-time have dominant winds originating from the north-north-east and north. The average windspeeds are slightly higher (3.8 m/s) in the day than during the night (3.2 m/s) however, the difference is less marked than for eThekwini and uMgungundlovu.

In eThekwini the most frequent winds with speeds above 8.2 m/s (strong breezes) are expected from the south-west quadrant both during the day and during the night (Figure 9). In uMgungundlovu, most winds above 3.1 m/s tend to blow from the east and east-south-east during both the day and night, with a small fraction of winds above 8.2 m/s originating from the north-west during the day (Figure 10). The predominant winds with speeds above 8.2 m/s in King Cetshwayo occurred from the south-west and south-south-west during the day and from the south-west during the night (Figure 11).



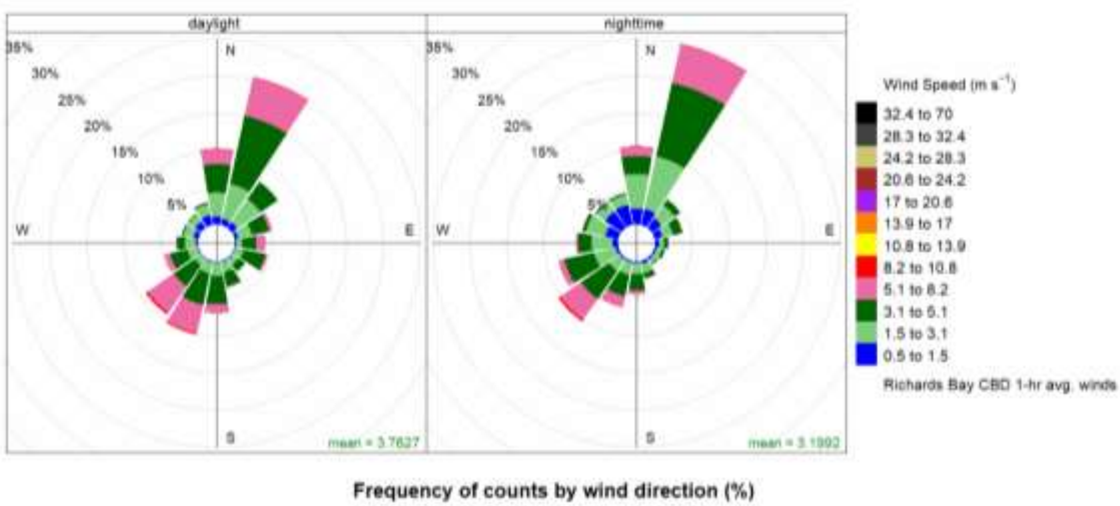
Wentworth Reservoir (eThekwini)

Figure 9: Diurnal wind roses of the average hourly winds measured at the Wentworth Reservoir in eThekwini for **the years 2019-2021.**



Edendale (uMgungundlovu)

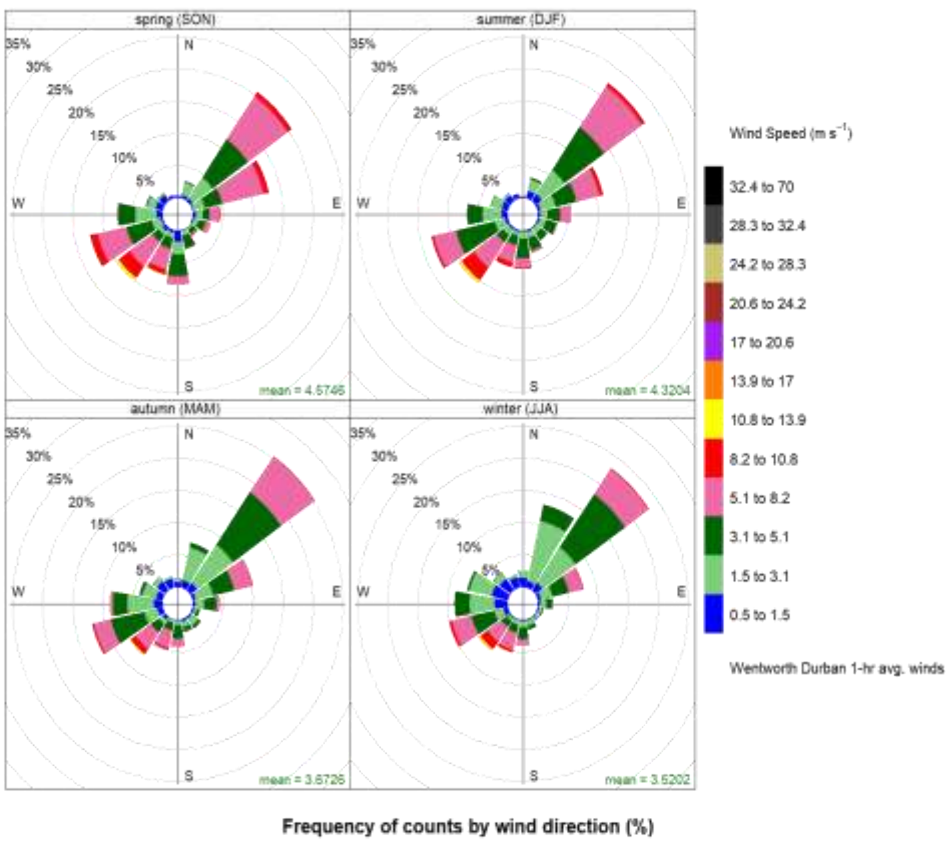
Figure **10**: Diurnal wind roses of the average hourly winds measured at the Edendale AAQMS in uMgungundlovu **for the years 2019-2021.**



Richards Bay (King Cetshwayo)

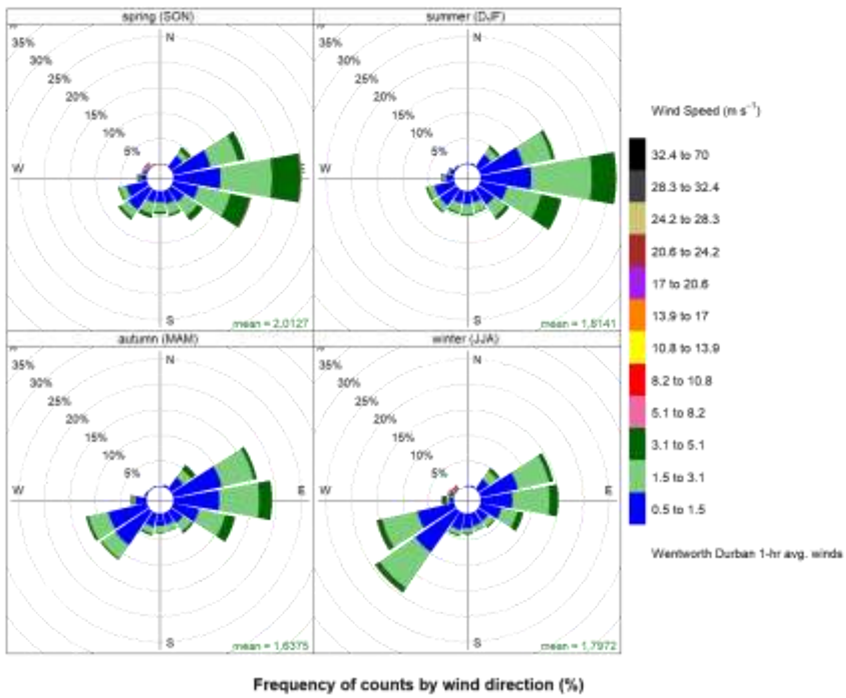
Figure 11: Diurnal wind roses of the average hourly winds measured at the Richards Bay CBD AAQMS in King **Cetshwayo for the years 2019-2021.**

The seasonal variations in wind direction and speed for eThekwini, uMgungundlovu, and King Cetshwayo are illustrated in Figure 12 to Figure 14. In eThekwini, winds from a north-easterly direction are the most common throughout the year, however, winds with the highest speeds tend to blow from the south-westerly quadrant. In uMgungundlovu, the predominant wind direction for spring, summer and autumn is from the east, whereas in winter, the predominant wind direction is from the south-west. The highest wind speeds are evident in spring and winter. In spring these winds originate from the east, east-south-east west-north-west and north-west. In winter, winds with the highest speeds originate from the west-north-west, north-west and south-west. In King Cetshwayo, winds from the north-north-east are the most dominant throughout the year. In autumn and winter the second-most dominant wind direction is from the north, whereas in spring and summer the second-most dominant wind direction is from the south-west. In eThekwini average wind speeds are the highest in spring, followed by summer then autumn and winter. In both the King Cetshwayo and uMgungundlovu, average wind speeds are the highest in spring, followed by summer, then winter and autumn.



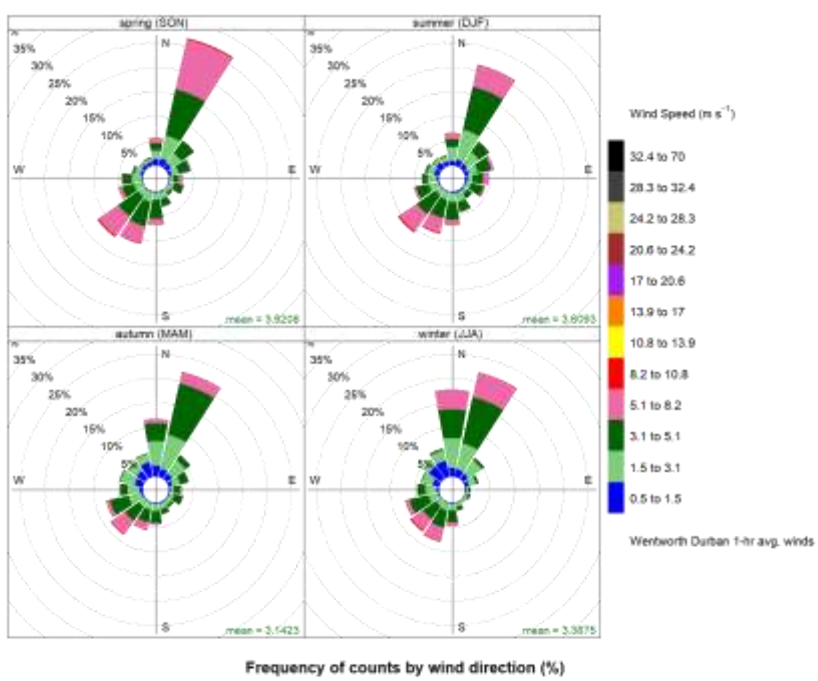
Wentworth Reservoir (eThekwini)

Figure 12: Seasonal wind roses of the average hourly winds measured at the Wentworth Reservoir AAQMS in eThekwini for the years 2019-2021.



Edendale (uMgungundlovu)

Figure **13**: Seasonal wind roses of the average hourly winds measured at the Edendale AAQMS in uMgungundlovu **for the years 2019-2021.**



Richards Bay (King Cetshwayo)

Figure **14**: Seasonal wind roses of the average hourly winds measured at the Richards Bay AAQMS in King Cetshwayo **for the years 2019-2021.**

4.4 Temperature

KZN has a varied climate with temperatures averaging at 23 ˚C in summer and 17 ˚C in winter (Table 8). The seasonal averages were calculated from hourly average temperatures measured at the selected KZN AAQMS located in eThekwini, uMgungundlovu and King Cetshwayo.

Table 8: The eThekwini, uMgungundlovu and King Cetshwayo seasonal temperature averages (2019-2021).

Monitoring Station	Seasonal Average (˚C)			
	Summer (Dec - Feb)	Autumn (Mar – May)	Winter (Jun – Aug)	Spring (Sept – Nov)
Wentworth Reservoir (eThekwini)	23.55	22.10	18.20	18.25
Edendale (uMgungundlovu)	21.57	20.40	13.95	18.27
Richardsbay (King Cetchwayo)	24.20	21.57	18.10	20.77

4.5 Precipitation

Daily precipitation averages were calculated using hourly data recorded at AAQMS with rain sensors in KZN (Figure 15) sourced from SAAQIS. The average data recovery from these stations was 50%, with eSikhaleni AAQMS recording the lowest data recovery of 5.6% for the period of 2019-2021. Richard Bay CBD AAQMS (180 mm), Pietermaritzburg and Pietermaritzburg CBD AAQMS (108 mm) recorded the highest rainfall during the three-year period with the least rain recorded in the Edendale AAQMS (98 mm) and Most of the rainfall was experienced in September to March indicating a typical summer and autumn rainfall season.

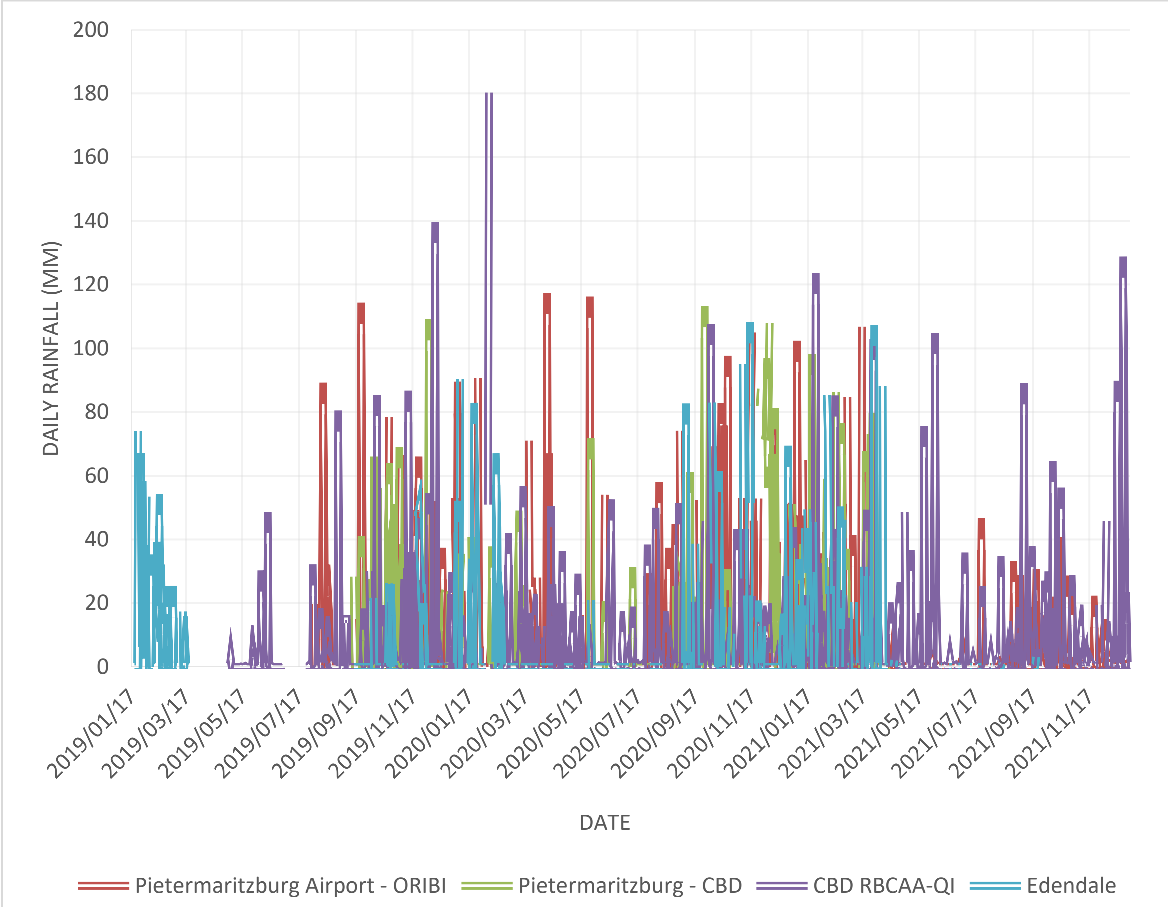


Figure 15: Daily rainfall measured at the KZN AAQMS (2019-2021).

5 Status Quo of Ambient Air Quality In KZN

5.1 Ambient Air Quality Monitoring

Ambient air quality monitoring (AAQM) data can be collected through a variety of instruments, ranging from low-cost to reference method type analysers. For purposes of this status quo assessment, only data collected from ambient air quality monitoring stations (AAQM stations) operated by DFFE are considered. AAQM stations are typically equipped with reference method analysers that have undergone stringent international approvals, such as TÜV and EPA. These approvals indicate that the uncertainty measurement of analysers has been determined in both the field and laboratory and that the performance of the analysers has been demonstrated. Currently, there are 28 AAQM stations operating in KwaZulu-Natal (SAAQIS, 2022) (Figure 16). Data from the AAQM stations was made available for three years, from 1 January 2019 to 31 December 2021. The data from these stations is representative of residential areas with high population density.

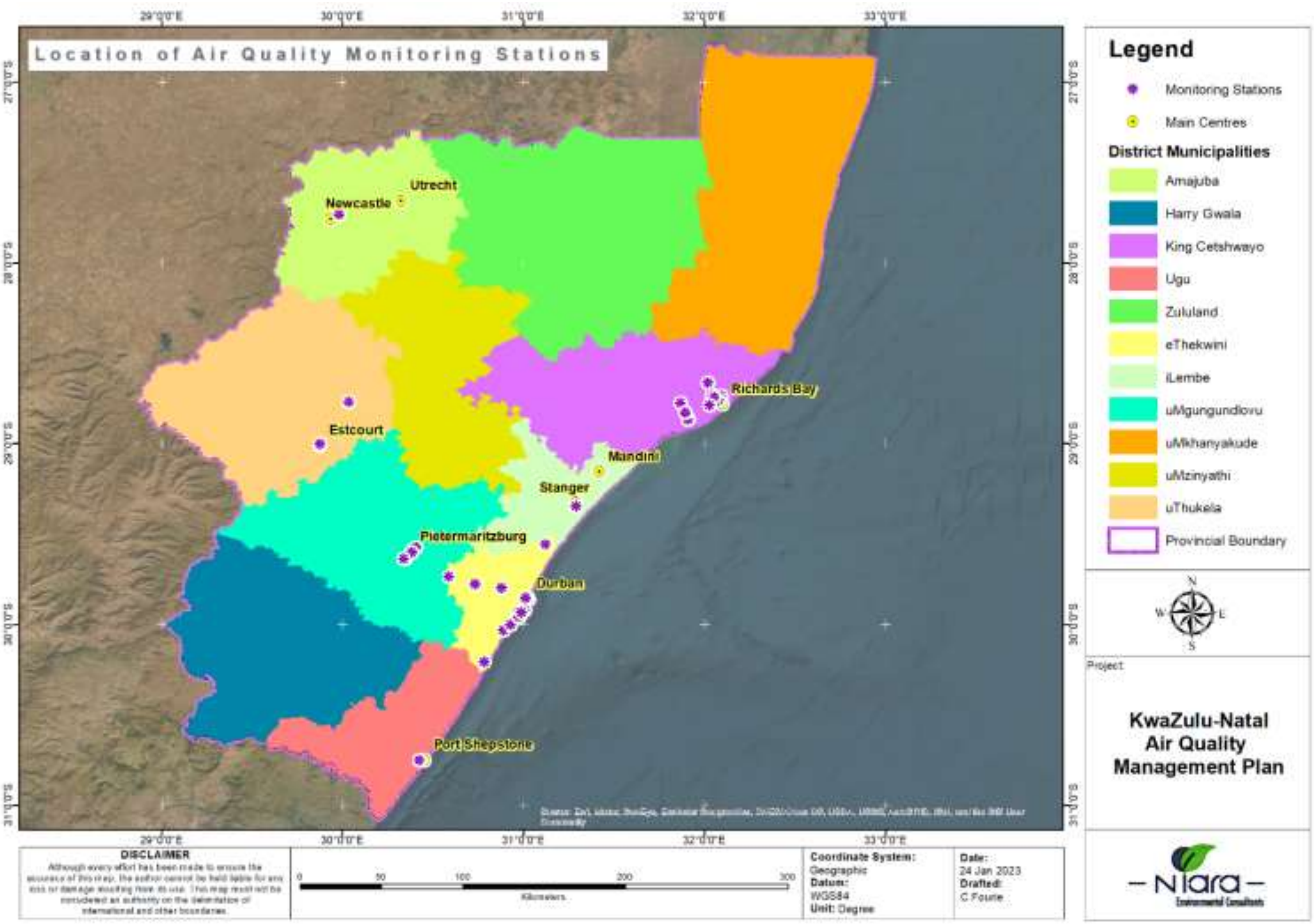


Figure 16: Location of the Air Quality Monitoring Stations in KZN

Pollutant data is presented relative to the current NAAQS limits. The NAAQS limits are represented by a horizontal red line to indicate when the pollutant concentrations either meet or exceed the relevant Standard.

Note: A data recovery of 80% is required for analysis purposes, however where 80% data recovery was not achieved, the data was still included to give the best indication of pollutant levels with the available data.

The analysis shows that out of the AAQM stations for which data was made available, only the Edendale AAQMS exceeded the SO_2 annual standard (19 ppb) in 2020 (Figure 18). The annual averages for the rest of the AAQMS remained below the annual standard for SO_2. The NO_2 annual standard is 21 ppb. Of the seven stations reporting NO_2, only Warwick exceeded the standard in both 2019 and 2020 (Figure 20 and Figure 21). Only Ganges NAQI and Pietermaritzburg Airport reported NO_2 in 2021 (Figure 22). The O_3 8-hour running average of 61 ppb was exceeded several times at the Alverstone station between 2018 and 2021 (Figure 23). The CO 8-hour runinng averages were far below the standards of 8.7ppm (Figure 24). PM_{10} showed exceedances over the three-year period with an annual standard of 40 µg/m^3. Multiple stations recorded exceedances over the three-year period with Ganges NAQI in 2019, Settlers NAQI in 2019 and 2020, Amanzimtoti in 2020 followed by Hambanathi Tongaat in 2021. $PM_{2.5}$ has an annual average standard of 20 µg/m^3 with multiple stations recording exceedances over the three-year period. In 2019 eSikhaleni, Ganges-NAQI and Settlers-NAQI exceeded the $PM_{2.5}$ standard. Amanzimtoti and Settlers - NAQI exceeded the standard in 2020. Amanzimtoti, Hambanathi Tongaat and Umkomaas exceeded the standard in 2021 (Figure 28, Figure 29 and Figure 30). Stations measuring C_6H_6 only had data for 2020 and 2021. The C_6H_6 annual average standard of 1.6 ppb, was exceeded at Umkomaas in 2021 (Figure 31).

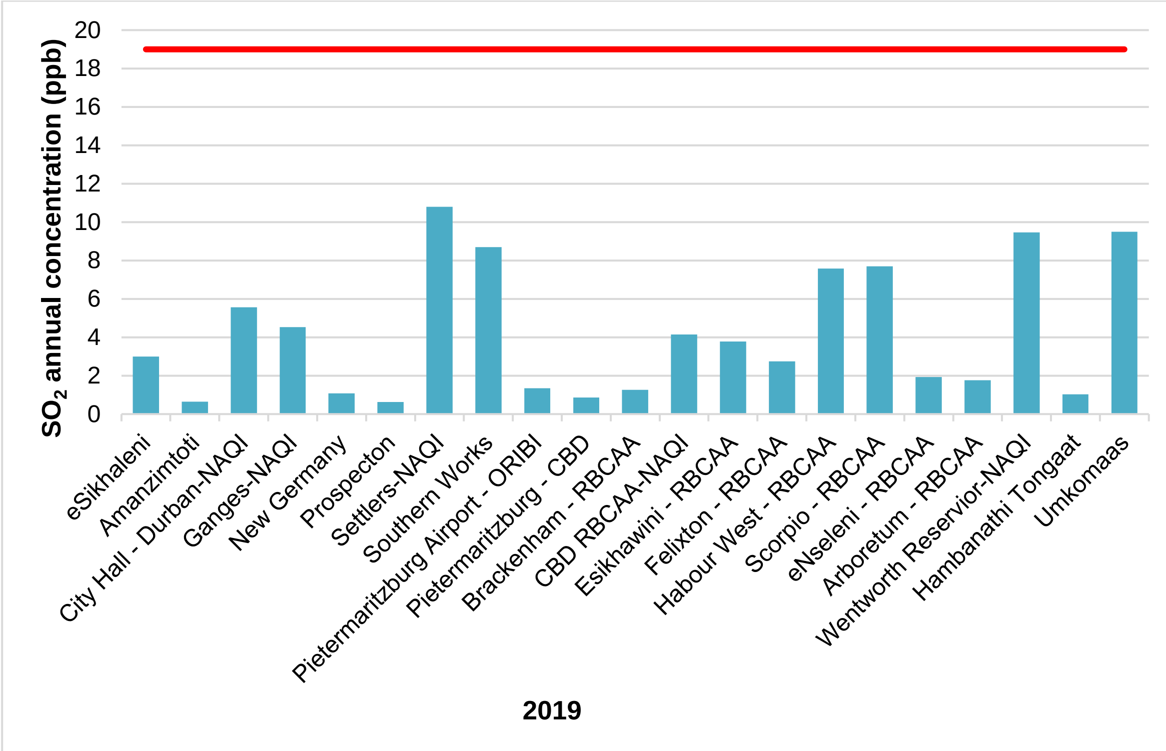


Figure 17: AAQMS 2019 Annual Average SO2 Concentrations (SAAQIS, 2022).

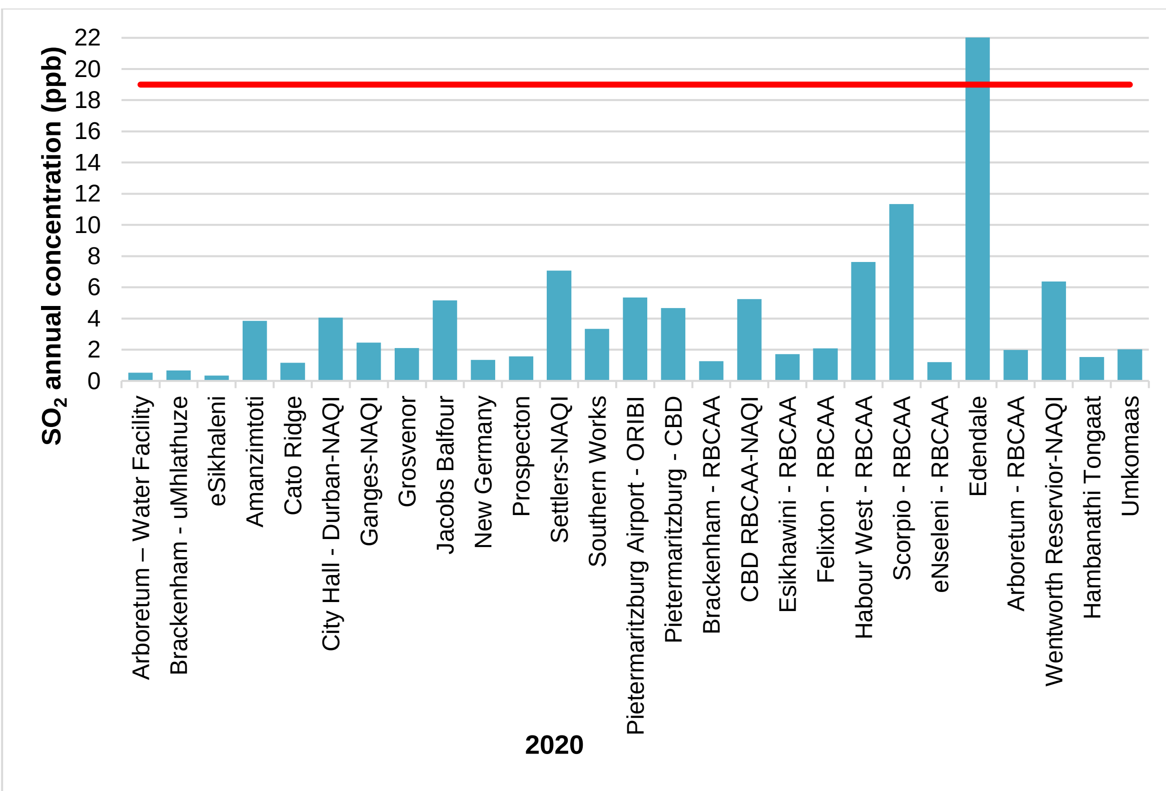


Figure 18: AAQMS 2020 Average Annual SO2 Concentrations (SAAQIS, 2022).

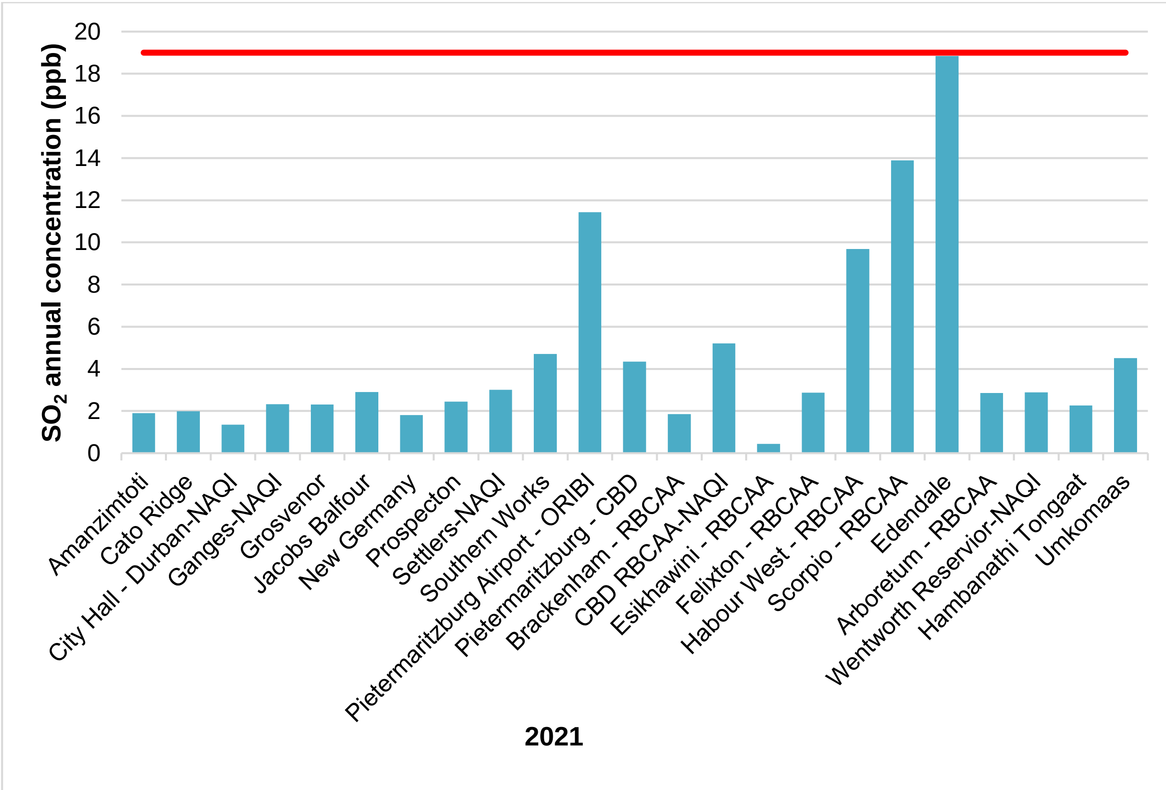


Figure 19: AAQMS 2021 Annual Average SO2 Concentrations (SAAQIS, 2022).

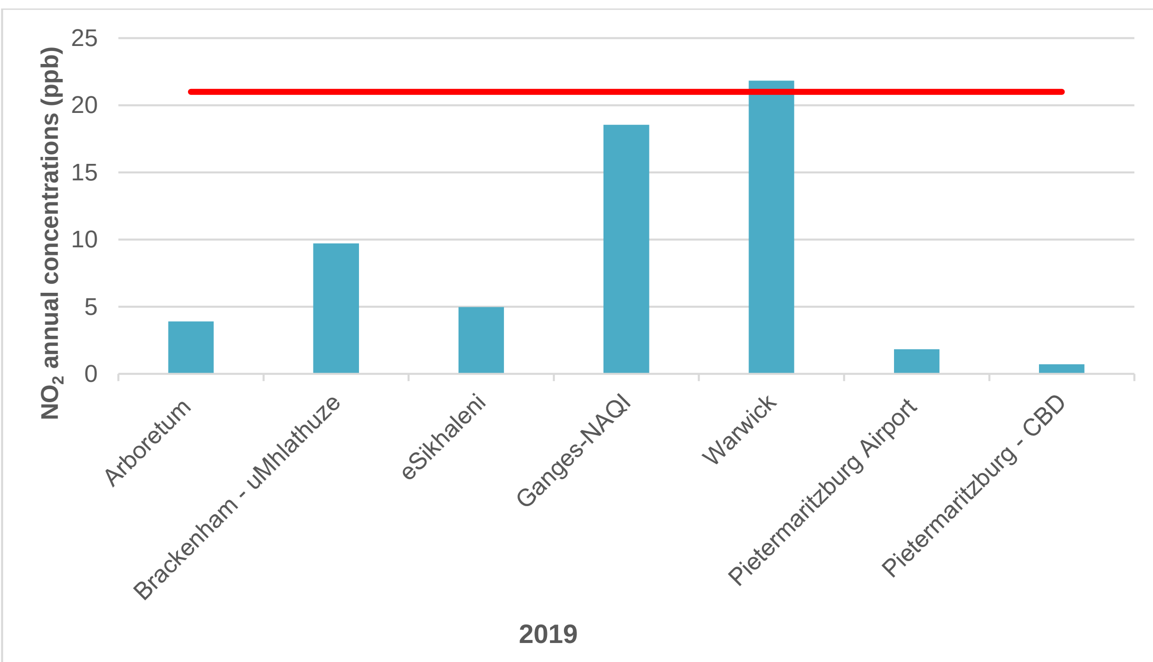


Figure 20: AAQMS 2019 Annual Average NO2 Concentrations (Eskom, 2019 - 2021a; SAAQIS, 2022).

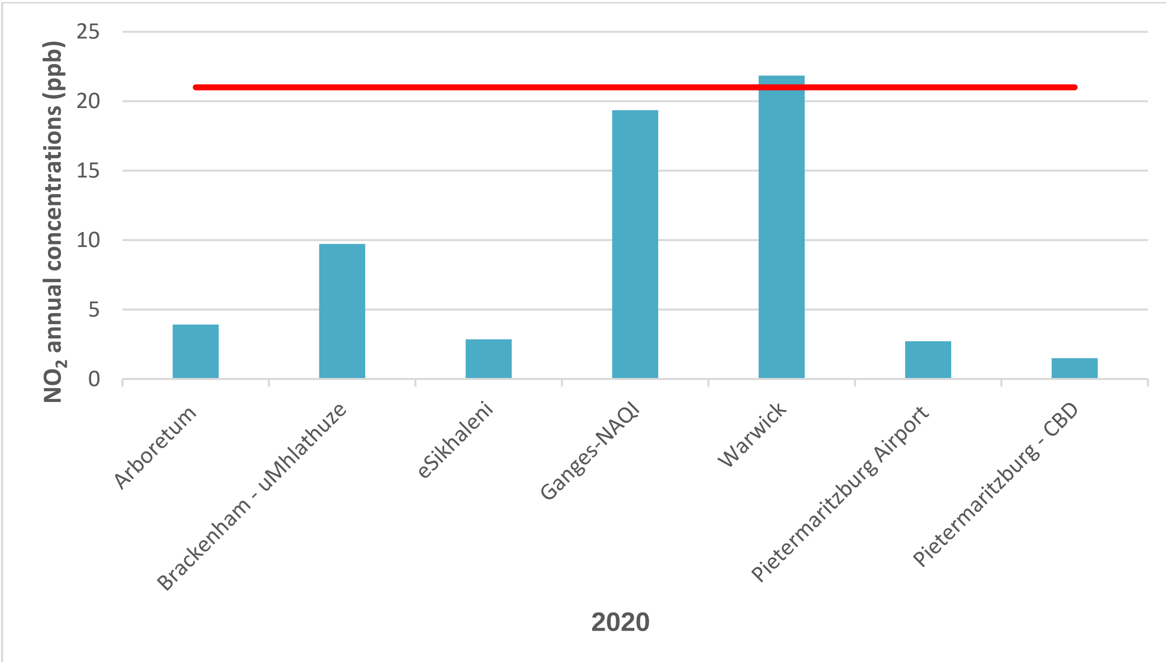


Figure 21: AAQMS 2020 Annual Average NO2 Concentrations (SAAQIS, 2022).

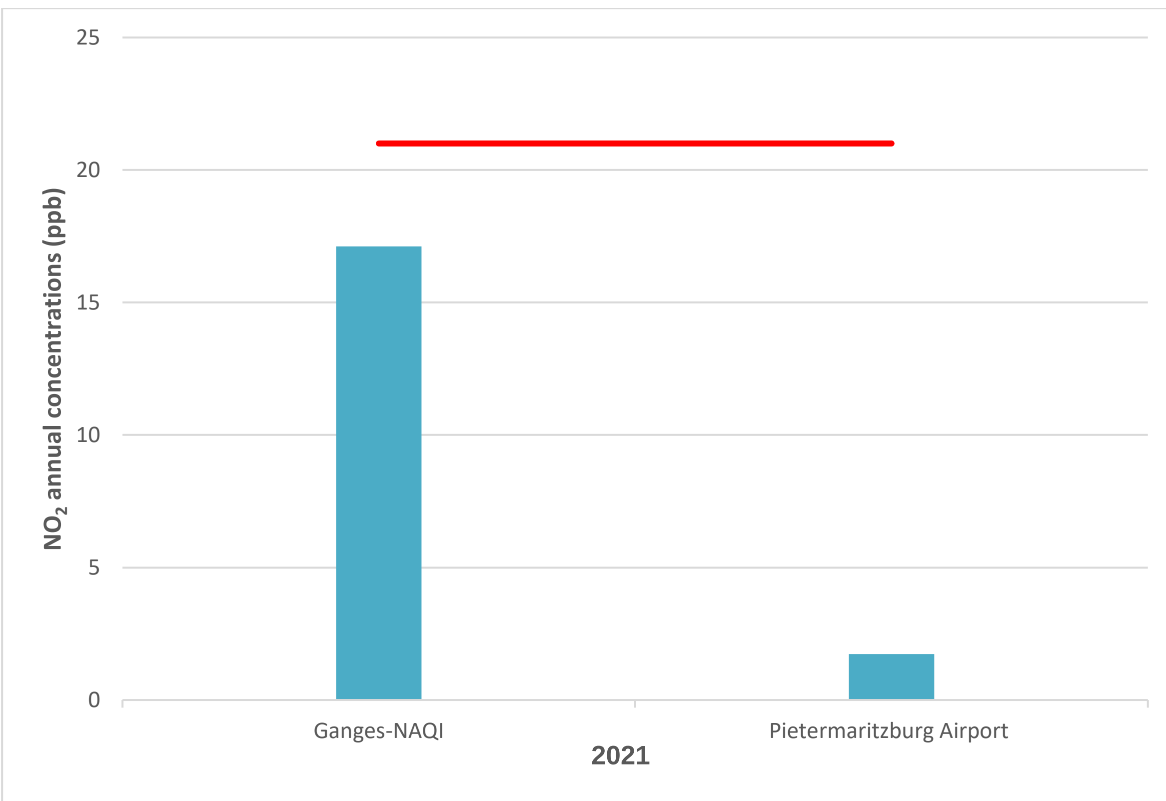


Figure 22: AAQMS 2021 Annual Average NO2 Concentrations (SAAQIS, 2022).

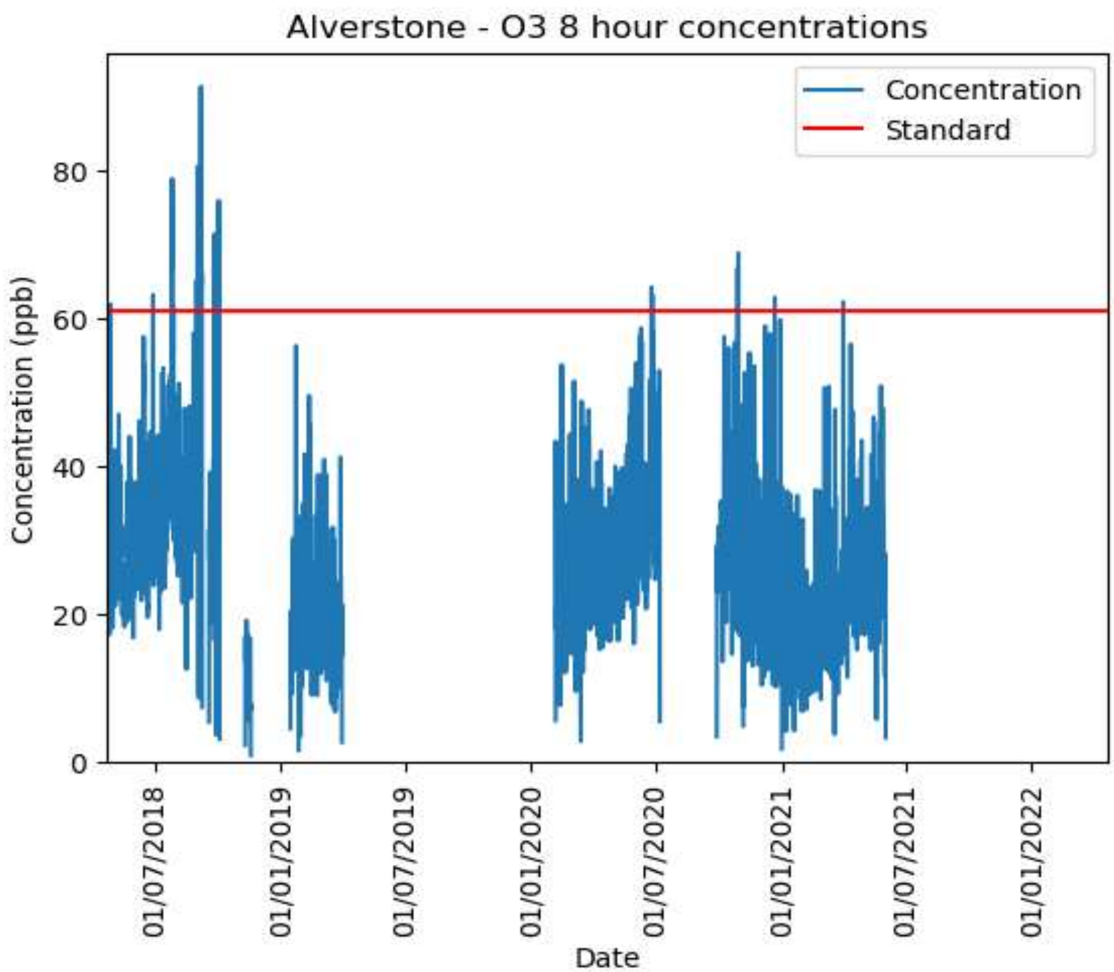


Figure 23: AAQMS 2019 - 2021 O3 8-hour Running Average (SAAQIS, 2022).

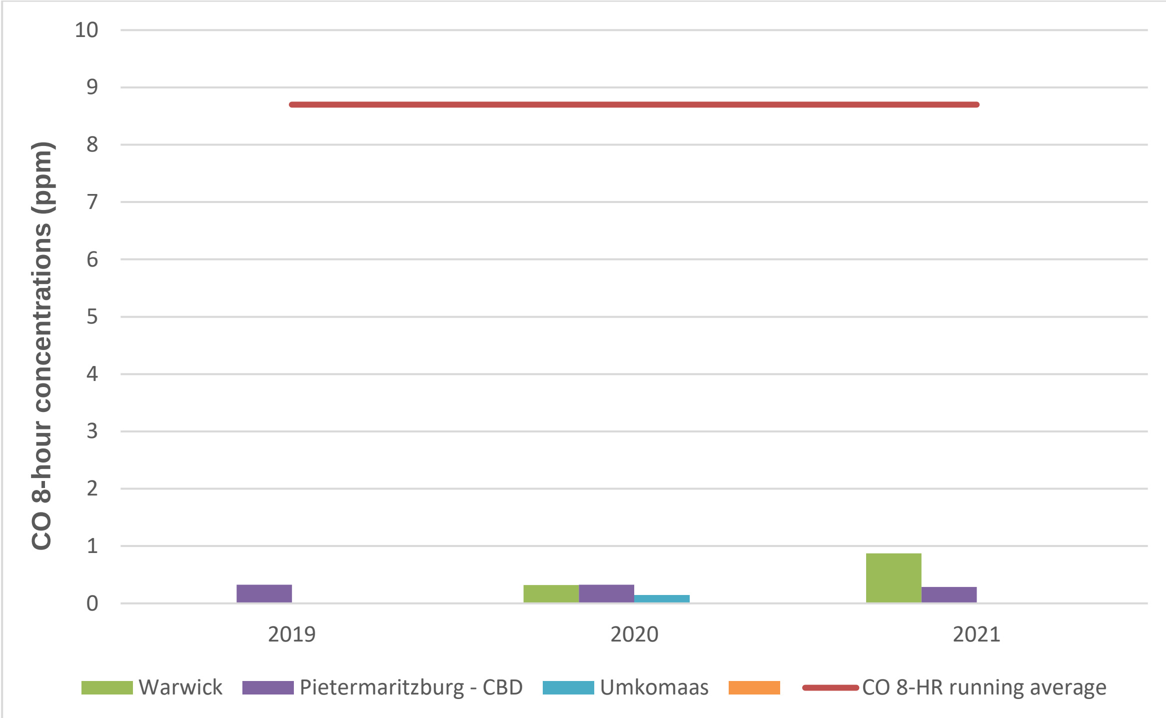


Figure 24: AAQMS 2019 - 2021 CO 8-hour Running Averages (SAAQIS, 2022).

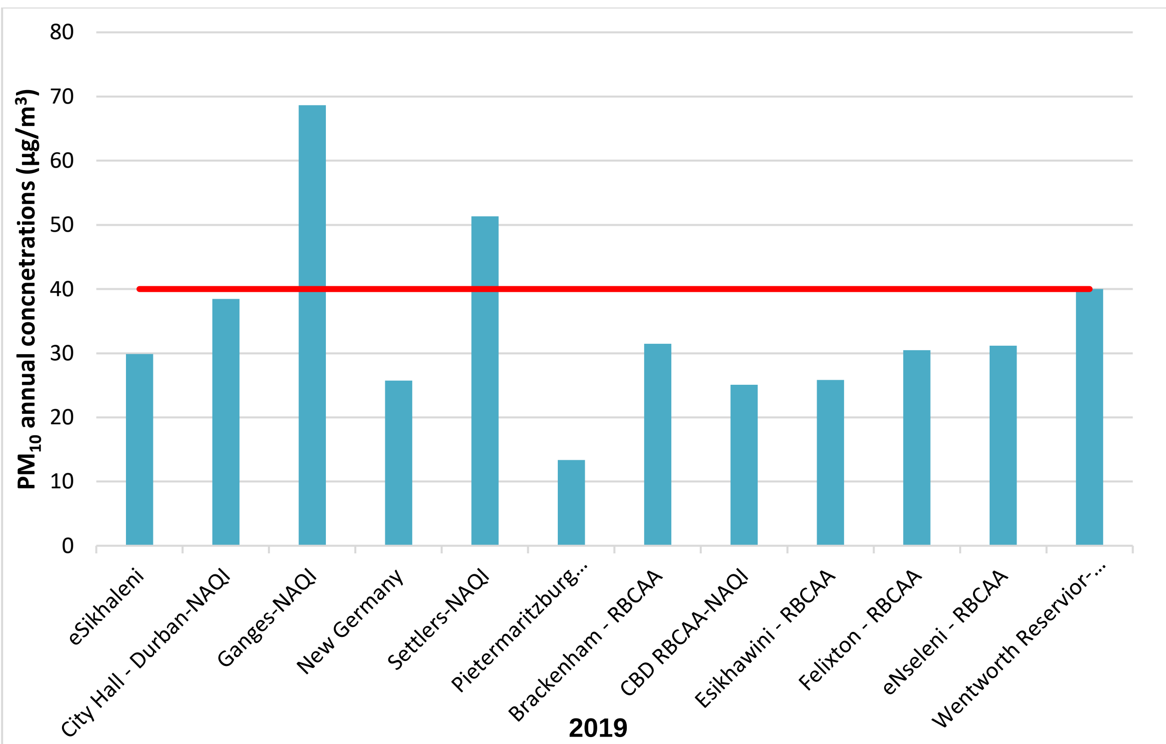


Figure 25: AAQMS 2019 Annual Average PM10 Concentrations (SAAQIS, 2022).

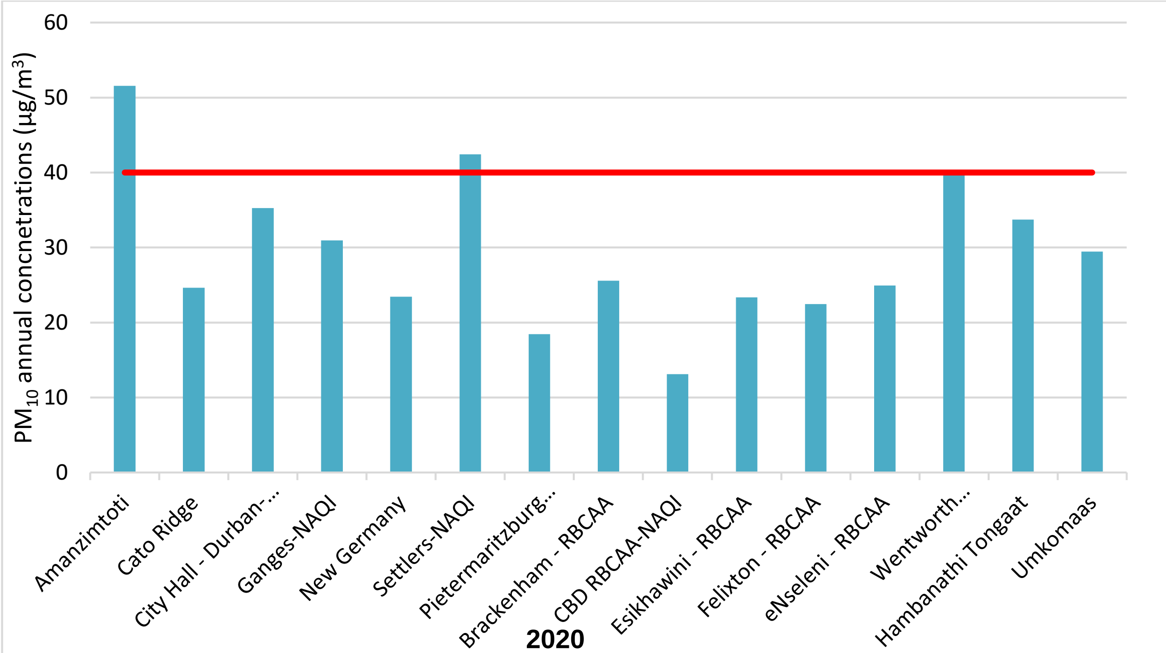


Figure 26: AAQMS 2020 Annual Average PM10 Concentrations (SAAQIS, 2022).

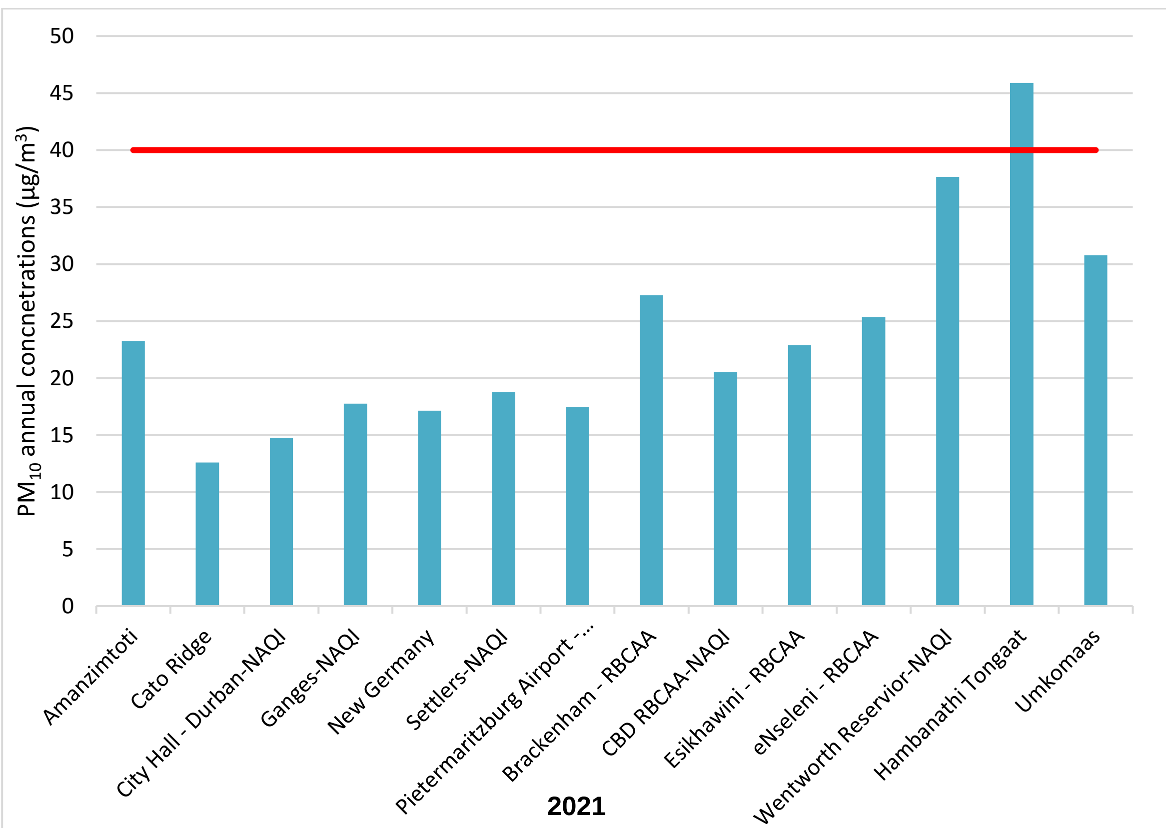


Figure 27: AAQMS 2021 Annual Average PM10 Concentrations (SAAQIS, 2022).

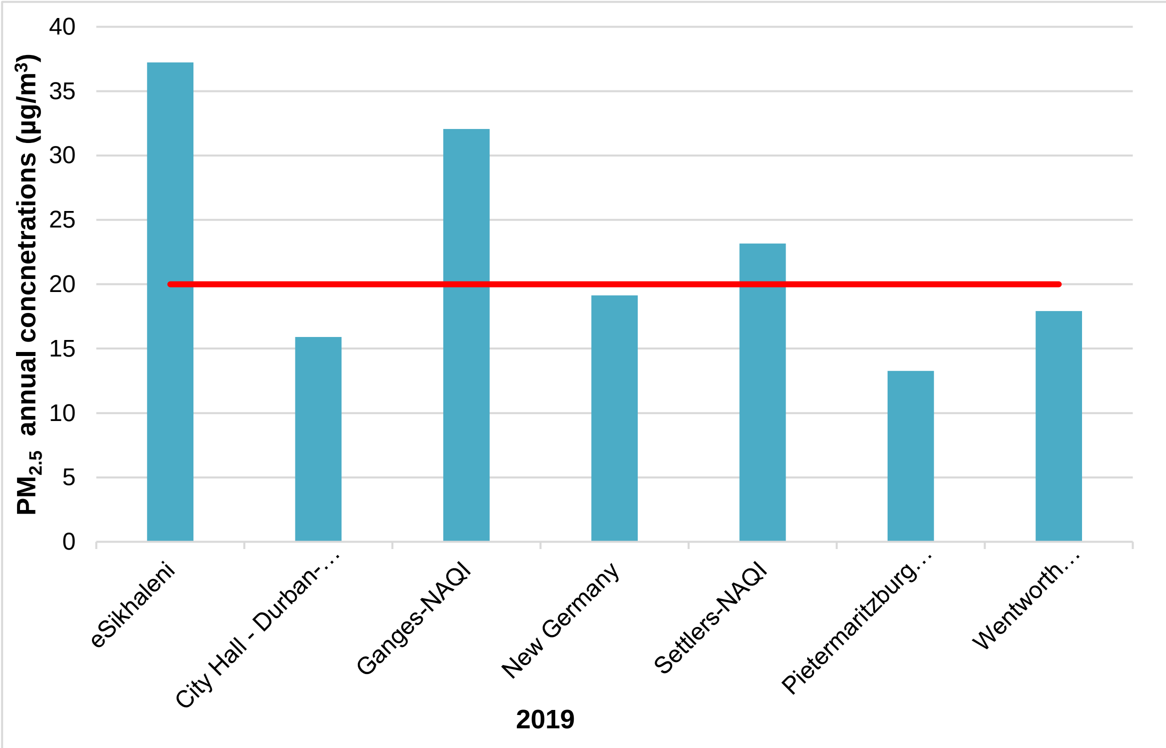


Figure 28: AAQMS 2019 Annual Average PM2.5 Concentrations (SAAQIS, 2022).

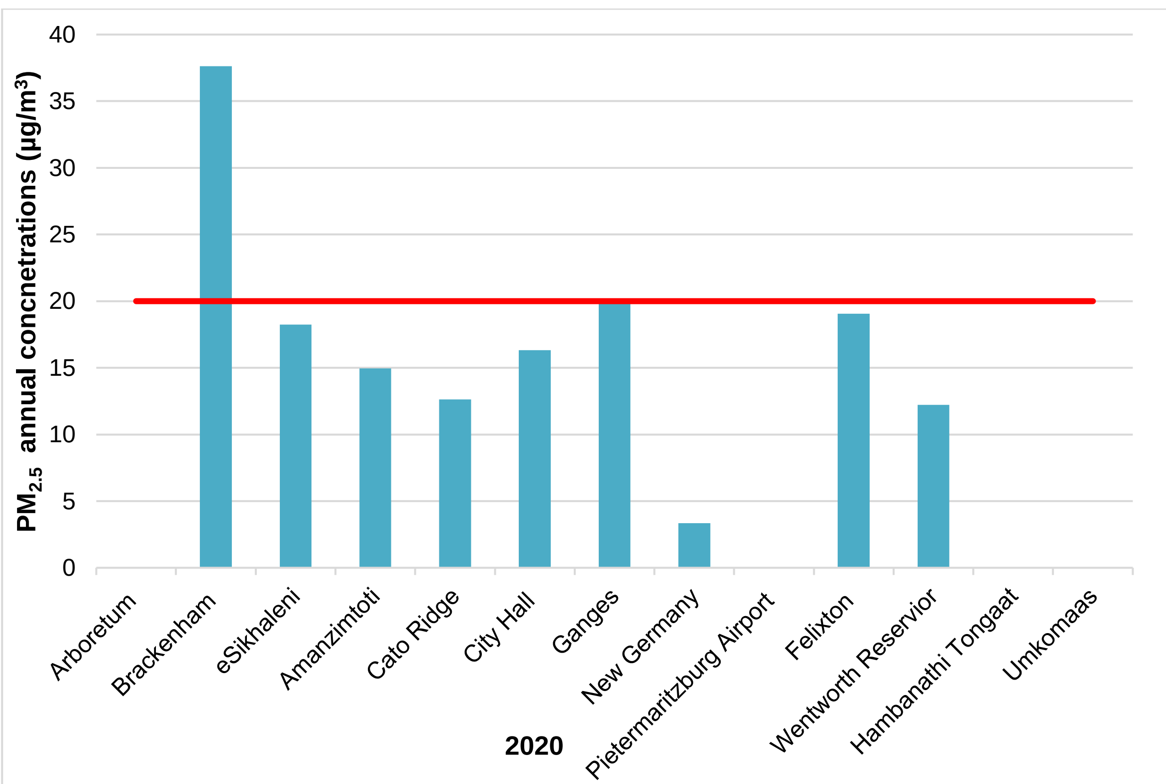


Figure 29: AAQMS 2020 Annual Average PM2.5 Concentrations (SAAQIS, 2022).

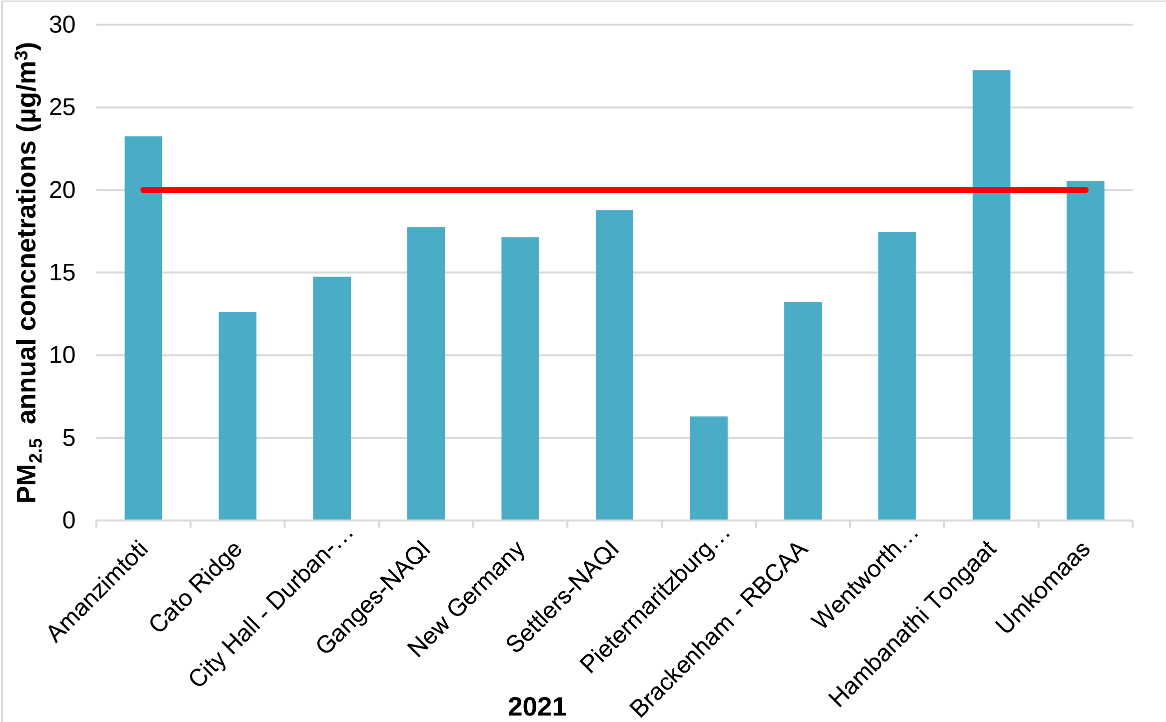


Figure 30: AAQMS 2021 Annual Average PM2.5 Concentrations (SAAQIS, 2022).

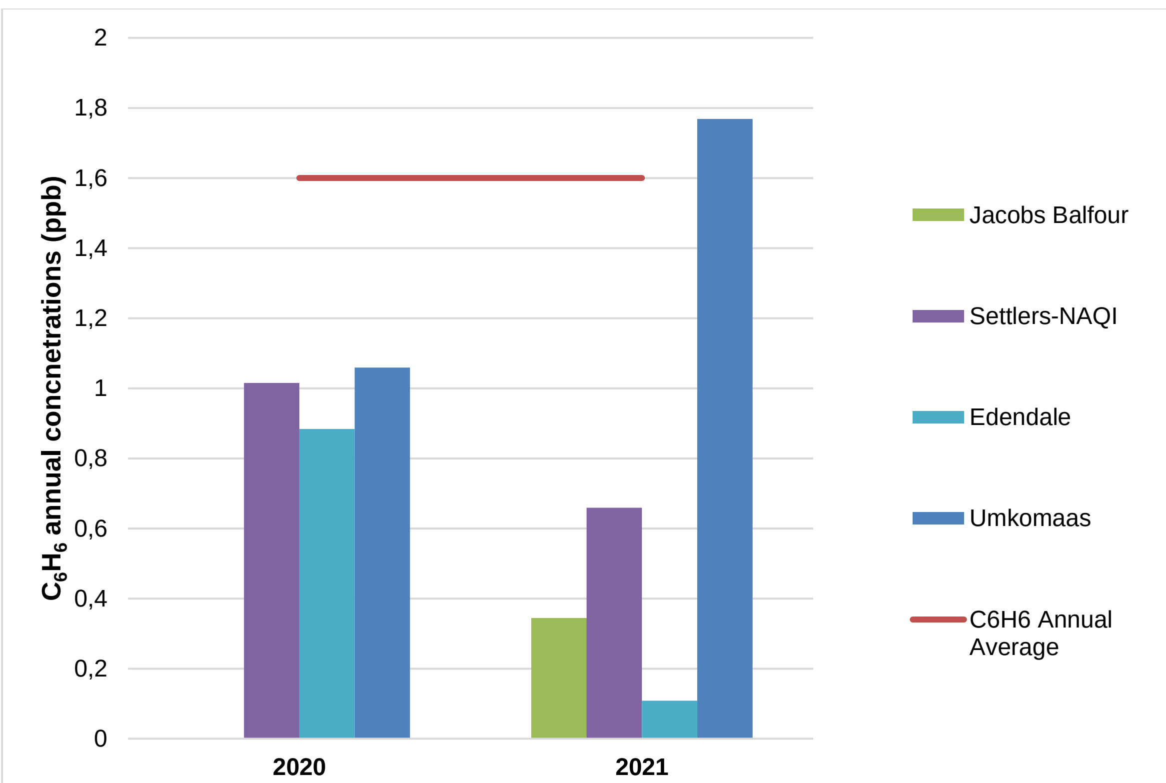


Figure 31: AAQMS Annual Average C6H6 Concentrations (SAAQIS, 2022).

6 Sources, Emissions and Proposed Management Intervention

An assessment of the current ambient air quality was undertaken through a baseline emissions inventory for the data that is available for KZN. Background information and emissions calculations for the main sectors that emit criteria pollutants are presented.

The overarching method to determine emissions from various sources is as follows:

Equation 1: Generalized Emissions Rate Calculation

$$Emission\ Rate = Emission\ Factor\ \times Activity\ Rate$$

Where:

- Emission Rates have units of (*Mass of Pollutant x Time^{-1}*).
- Emission Factors have units of (*Mass of Pollutant x Activity^{-1}*) where activity can be expressed in a variety of ways, e.g., mass of product, the mass of raw material, the area covered, the volume of material processed, etc.
- Activity Rates have units of (*Activity x Time^{-1}*).

Emission Factors are obtained from the literature such as the United States Environmental Protection Agency, AP42 documents and the Australian National Pollutant Inventory (NPI) Emission Estimation Technique Manuals. Activity rates are obtained from literature, information received directly from the sources themselves or estimated by comparison to similar sources in the literature.

6.1 Industrial Emissions

6.1.1 Background to Industrial Emissions Sources

Both large and small industries have the potential to emit pollutants, depending on their processes. South African legislation controls a large variety of industries through their classification as Listed Activities (Government Notice No. 893, 2013) as amended in 2015 (Government Notice No. 551, 2015), 2018 (Government Notice No. 1207, 2018), 2019 (Government Notice No. 687, 2019) and 2020 (Government Notice No. 421, 2020). In addition, emissions from smaller industries may be regulated by their declaration as Controlled Emitters. Small boilers were declared controlled emitters in 2013 (Government Notice No. 831, 2013), temporary asphalt plants in 2014 (Government Notice No. 201, 2014) and small-scale char and small-scale charcoal plants in 2015 (Government Notice No. 602, 2015). Small boilers are used not only by industries, but also by schools, hotels, restaurants, municipal offices, hospitals, and a variety of commercial enterprises. The location of listed activities in KZN is shown in Figure 32.

Industries that are not regulated include small brickmaking facilities which are found sparsely scattered throughout the KZN Province. Brickmaking can emit substantial amounts of black carbon and methane in localised areas, particularly if inefficient technologies such as clamp kilns are used for the firing of bricks. However, limited information regarding the production quantities and methods is available as these facilities are not registered or controlled.

6.1.2 Methodology for Quantifying Industrial Emissions

a) Listed Activities

All listed activities are required to submit an annual report of their emissions to the National Atmospheric Emission Inventory System (NAEIS) via the South African Atmospheric Emission Licence and Inventory Portal (SAAELIP). Information regarding the type and quantity of fuel used, stack height, stack temperature, stack diameter, gas exit velocity, gas volumetric flow and mitigation methods as well as emissions per year is recorded in the NAEIS through the AEL application process and subsequent reporting requirements. The information provided by the NAEIS (APPENDIX 3:) was used to summarize the emissions produced by listed industries per district municipality (Figure 33).

b) Controlled Emitters

Controlled emitters are also required to report their emissions to the NAEIS annually (Government Notice No. R283, 2015). A total of eight industries in the province reported their emissions as controlled emitters on the NAEIS small boilers inventory system. Six industries are located in the eThekwini Metropolitan Municipality, with one in the uMgungundlovu district municipality and another in the uThukela district municipality. The emissions from these industries are provided in Table 9. By mass, CO (31.2%) and NO_X (30.7%) are the highest criteria pollutants emitted by the controlled emitters; with eThekwini Metropolitan Municipality accounting for 54% of total emissions.

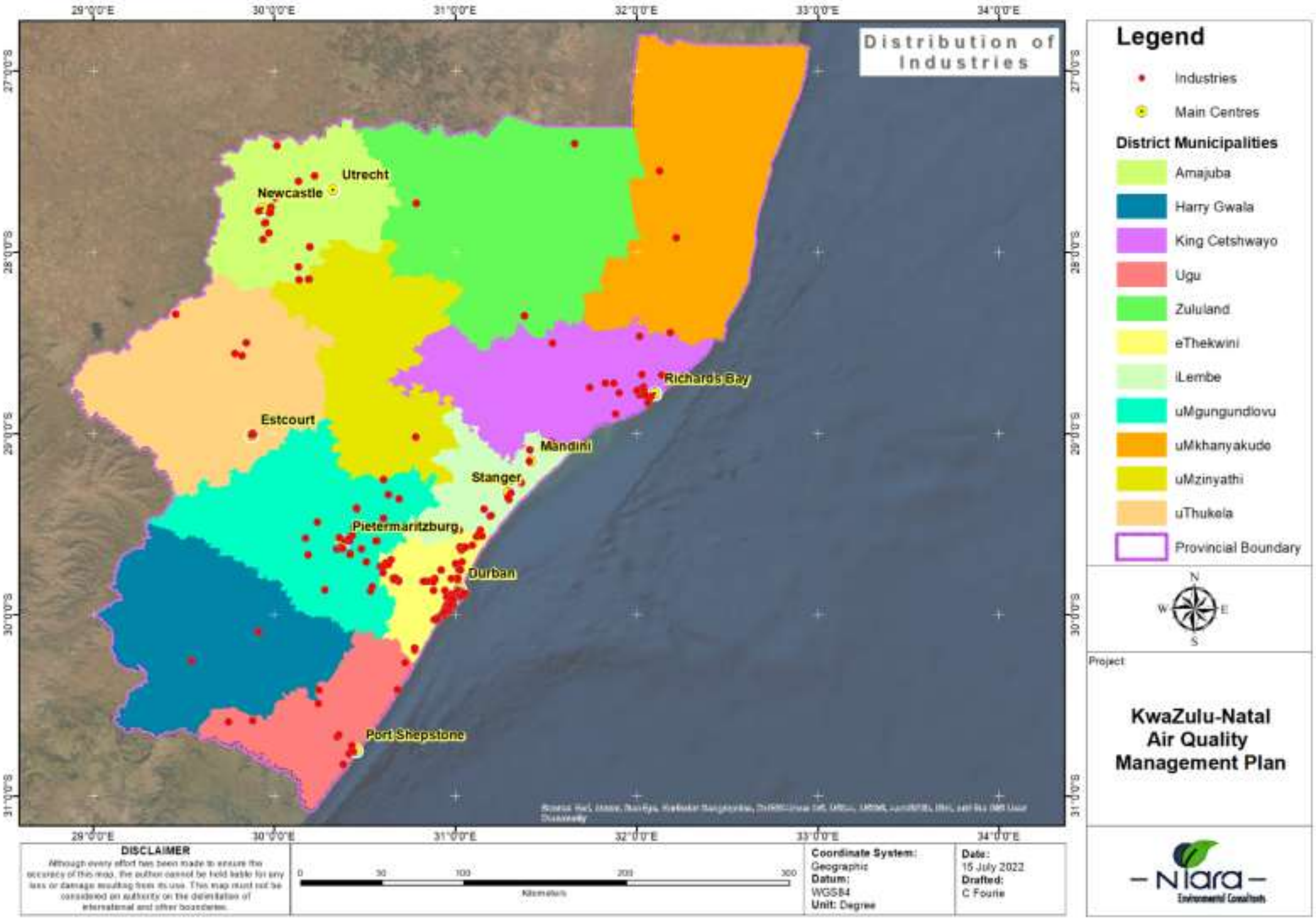


Figure 32: Location of listed activities in KZN (NAEIS, 2019).

Table 9: Total emissions from Controlled Emitters in KZN (NAEIS, 2019).

Total Emissions (Kg/annum)										
MUNICIPALITIES	FACILITY ID	Sector	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED Lead (kg/annum)	REPORTED NOX (kg/annum)	REPORTED PM10 TOTAL (kg/annum)	REPORTED SO2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
eThekwini Metropolitan Municipality	KNET084	Sulphuric Acid Production mainly. Also Paint Production on site which would be Organic Chemicals	-	1 572	3	1 965	-	69	-	18
			-	5 029	0.20	14 137	101	-	101	-
			-	2 711	0.11	7 621	54	-	54	-
	KNET092	Sugar Production	-	68 718	151	85 897	57 265	3 648	-	-
			-	78 858	173	98 572	78 858	4 186	-	-
			-	1 164	3	1 455	1 164	62	-	-
			-	2 718	6	3 397	2 718	144	-	-
			-	5 937	13	7 421	5 937	315	-	-
			-	2 157	5	2 696	2 157	115	-	-
	KNET145	Producer of Neutral Alcohol and Distillers Dried Grains with Solubles (DDGS)	-	58 716	-	10 836	84	-	84	-
			-	-	-	32 592	84	-	84	-
	KNET146	Brewery	-	59	-	6 342	1 322	-	1 322	-
			-	36	-	4 479	211	-	211	-
	KNET162	Milk Production	-	31	0.02	30	21	-	27	-
			-	20 413	10 206	18 372	7 757	91 858	8 165	-
	KNET173	Food and Beverage Production	-	9 231	0	12 287	198	44	198	-
			-	6	0	215	26	1 686	26	-
Total Emissions (Kg/annum)			**-**	**257 355**	**10 561**	**308 315**	**157 958**	**102 127**	**10 273**	**18**

Total Emissions (Kg/annum)										
MUNICIPALITIES	FACILITY ID	Sector	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED Lead (kg/annum)	REPORTED NOX (kg/annum)	REPORTED PM10 TOTAL (kg/annum)	REPORTED SO2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
uMgungundlovu District Municipality	KNUG039	Oil Processors	-	45 149	26 700	15 120	7 315	-	21 360	-
			-	40 445	26 700	20 209	9 566	-	21 360	-
			-	87 740	26 700	14 603	21 155	-	21 360	-
			-	53 400	26 700	48 060	20 292	-	21 360	-
Total Emissions (Kg/annum)			**-**	**226 734**	**106 800**	**97 992**	**58 328**	**-**	**85 440**	**-**
uThukela District Municipality	KNUH012	Beverage Production (coffee, drinking chocolate, etc.) Heat used to dry coffee	-	-	-	66 568	-	36 223	854	-
			-	475	0.24	2 558	147	11 444	147	-
			-	275	0.11	1 883	148	5 905	6 518	-
Total Emissions (Kg/annum)			**-**	**750**	**0**	**71 009**	**295**	**53 572**	**7 519**	**-**
KZN Total in Kilograms (kg)			**-**	**484 839**	**117 361**	**477 316**	**216 580**	**155 699**	**103 232**	**18**
KZN Total in Tonnes (t)			**-**	**485**	**117**	**477**	**217**	**156**	**103**	**0.02**

Note: "-" Indicate no data available

6.1.3 Industrial Emission Inventory Results

Emissions for the listed activities and controlled emitters in KZN was summarized to illustrate the total amounts of emissions in kg per district municipality per annum (Figure 33). By mass, CO (56%) is the highest criteria pollutant emitted by the listed activities, followed by SO_2 (16%) and NO_X (11%). Risk of exposure to these industrial emissions is provided in Appendix 3.

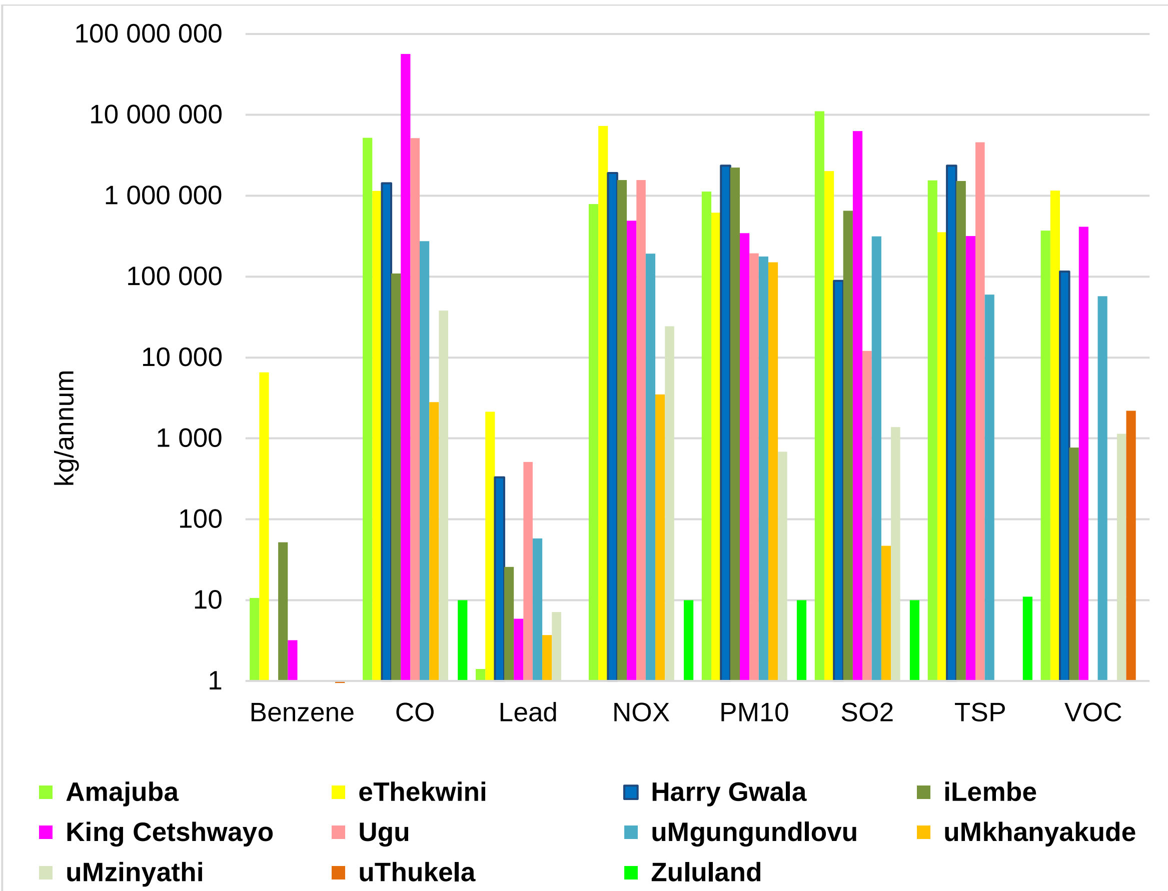


Figure 33: Total emissions from listed activities in KZN (NAEIS, 2019).

6.1.4 Industrial Emission Reduction Goals

- Equitably reduce industrial emissions to achieve compliance with ambient air quality standards and dust fallout limit values.
- Have all listed activities meet the stipulations issued in terms of the NEM: AQA, namely the Minimum Emission Standards and the emissions standards for controlled emitters.
- Reduce Metallurgical sector emissions to the extent that contributions from the sector do not cause exceedance of ambient standards at source fence line and aggregate emissions do not cause exceedance of National Ambient Air Quality Standards.
- Quantify the controlled emitter contribution to total emissions and determine their impact to air quality.
- Quantify the Petroleum sector contribution to $PM_{2.5}$ and PM_{10} through secondary particle formation and determine their impact to air quality.

6.1.5 Proposed Management Interventions

The scale of the intervention and the subsequent implementation strategy should be tailored to the size of the industry. At the 5th Annual Air Quality Governance Lekgotla a resolution was undertaken to provide a document to ensure consistent implementation of the Listed Activity regulations (DEA, 2012). Contained in the draft version of this document are mitigation methods applicable to each type of Listed Activity. An overview of these recommended interventions is given in the table in Appendix 5.

Other possible management interventions for industries and boilers include the following:

- Investigate opportunities to market waste as raw material inputs to other industries e.g., discard coal.
- Investigate the feasibility of renewable energy.
- Motivate for and undertake research to improve abatement technology and reduce retrofitting costs.
- Investigate mechanisms to regulate newly identified technologies.
- Identify any Listed and Controlled Activities currently operating without emissions licences.
- Develop and enforce emission reduction plan/measures for controlled emitters.

Vehicle Emissions

6.1.6 Background to Vehicle Emission Sources

In developing countries, such as South Africa, improved road networks can increase welfare benefits as well as growth, however, the detrimental effect on air quality and hence on human health should be taken into consideration (Berg, Deichmann, Liu, & Selod, 2016). Air pollution from traffic is known to have magnified negative impacts due to its emissions at ground level where people can be directly exposed. Vehicles have the potential to contribute significant amounts of pollutants into the atmosphere, not only in localised areas but throughout the surrounding airsheds.

Vehicle emission concentrations vary according to the vehicle's size, age, engine, fuel specification and speed travelled, with newer vehicles having significantly reduced emissions compared with vehicles manufactured in the 1980s (Burger, Stead, & Moldan, 2009). Vehicle emissions in South Africa have been identified as a growing concern, with increased emissions resulting from the increase in the number of vehicles, the age of the vehicles and the lack of emission control devices in a significant portion of South African vehicles (Burger, Stead, & Moldan, 2009). South Africa's vehicle fleet produces on average of 21% more CO_2 emissions than the European fleet, which indicates lower overall efficiency (Posada, 2017).

Increasing economic development has led to an increase in motorists on the road and an increased demand for fuel. The number of self-propelled vehicles has increased by approximately 8% in both South Africa and in the KwaZulu-Natal Province between 2017 and 2021 (eNaTIS, 2017; eNaTIS, 2021). As the number of vehicles in the area increases, the amount of air pollution caused by vehicles is expected to increase. The large demand for vehicles in South Africa is due to the dispersed nature of land-use in the country, requiring commuters to travel large distances between their residences and places of work.

KwaZulu-Natal has 25 600 km of roads in total with 6 656 km of surfaced roadways, while 18 943 km are gravel roads (KwaZulu-Natal Department of Transport, 2021). The N3 (Durban to Gauteng), N2 South (Durban to Kokstad) and the N2 North (Durban to Pongola) are the three main national routes in KZN (Figure 34). The busiest road freight corridor in South Africa is the N3 between Gauteng and the port of Durban, which transports more than 1.5 million vehicles annually on the Durban to Pietermaritzburg section. As a result of the deregulation of road transportation in 1988, together with the increase in the axle-mass loads of heavy vehicles legally permitted, and the commercialisation of rail, roads now carry the majority share of freight (75%) when compared to rail (10%) in the country. This has contributed to an increase in the number of freight vehicles (long-haul and heavy-duty trucks) on the road (Department of Transport, 2022). As a result, traffic congestion, road deterioration, and vehicle emissions have increased.

In recent years, the KwaZulu-Natal Department of Transport has placed a strong priority on the development of roads in remote rural areas and is currently upgrading several major provincial roads, including the P700 route to Ulundi and the P496 John Ross Highway from Empangeni to Richards Bay (KwaZulu-Natal Department of Transport, 2021).

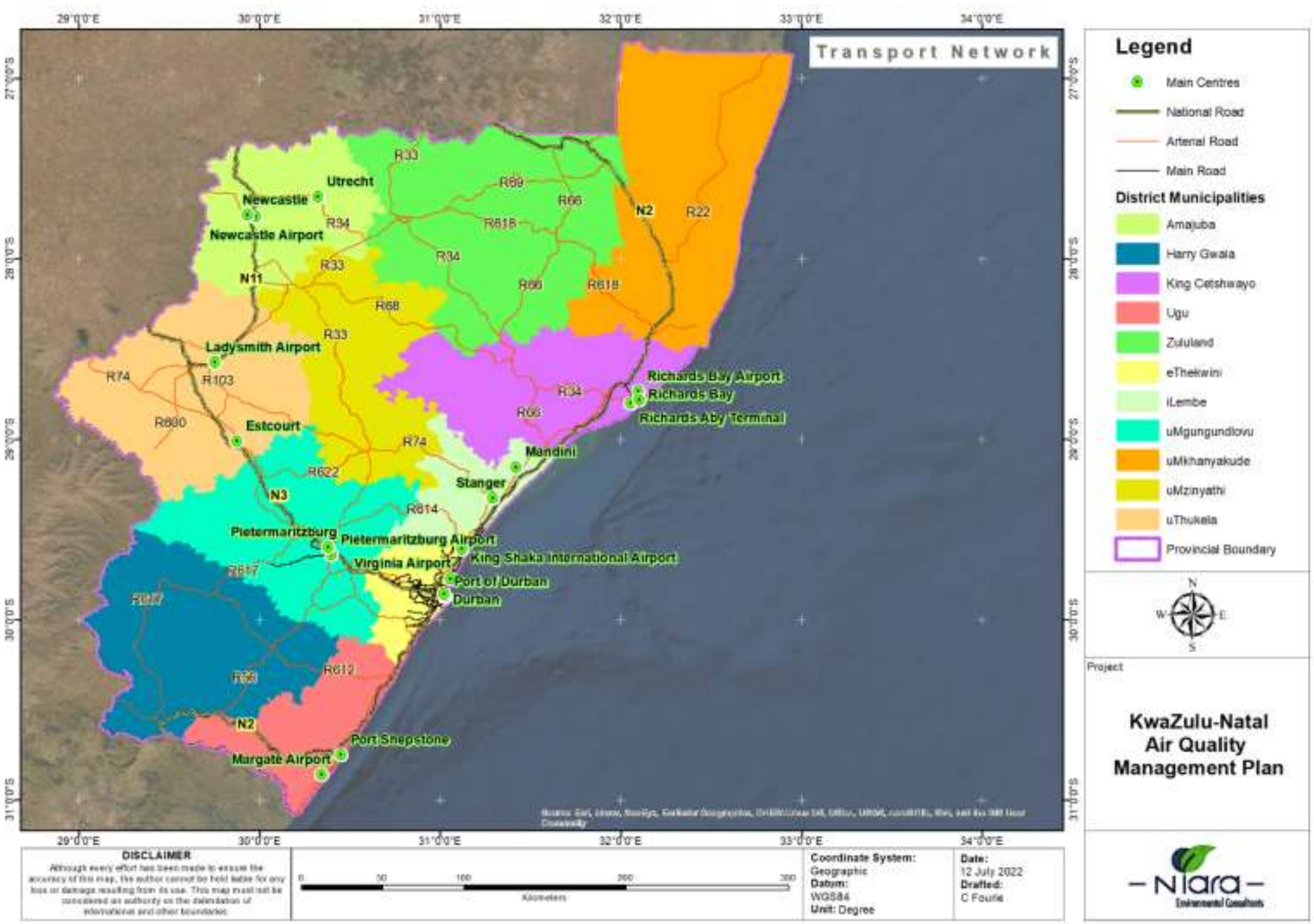


Figure 34: The KZN transport network

6.1.7 Methodology for Quantifying Emissions from Vehicles

Emissions resulting from traffic in KZN were quantified using total fuel sales statistics for towns within the province. A basic assumption of this emission calculation is that all fuel sold in the District Municipalities is combusted in the KZN airshed. This method is also inherently biased to localised areas. Interpolation for the entire region is simplistic, however, it does provide an indication of fuel-related emissions for the region.

Quarterly fuel sales statistics were obtained from the Department of Energy (DoE) (DoE, 2022) (Figure 35). Some Magisterial Districts in uMgungundlovu DM (Impendle and Richmond), Ilembe DM (Ndwendwe) and Zululand DM (Ngotshe) had no records of petrol sold for the four Quarters in 2020. Fuel sales statistics from the DoE are provided in litres of petrol and diesel. These statistics were converted from litres to tonnes based on the density of petrol and diesel provided in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2021). The density of petrol is taken as 750 kg/m^3 at 15.56°C (60°F) and the density of diesel as 840 kg/m^3. The equation used follows:

Equation 2: Fuel Sales Conversion to tonnes/year

$$Total\ Fuel\left(\frac{tons}{year}\right) = \frac{Total\ Fuel\left(\frac{kl}{year}\right) \times Fuel\ Type\ Density\left(\frac{kg}{kl}\right)}{1000}$$

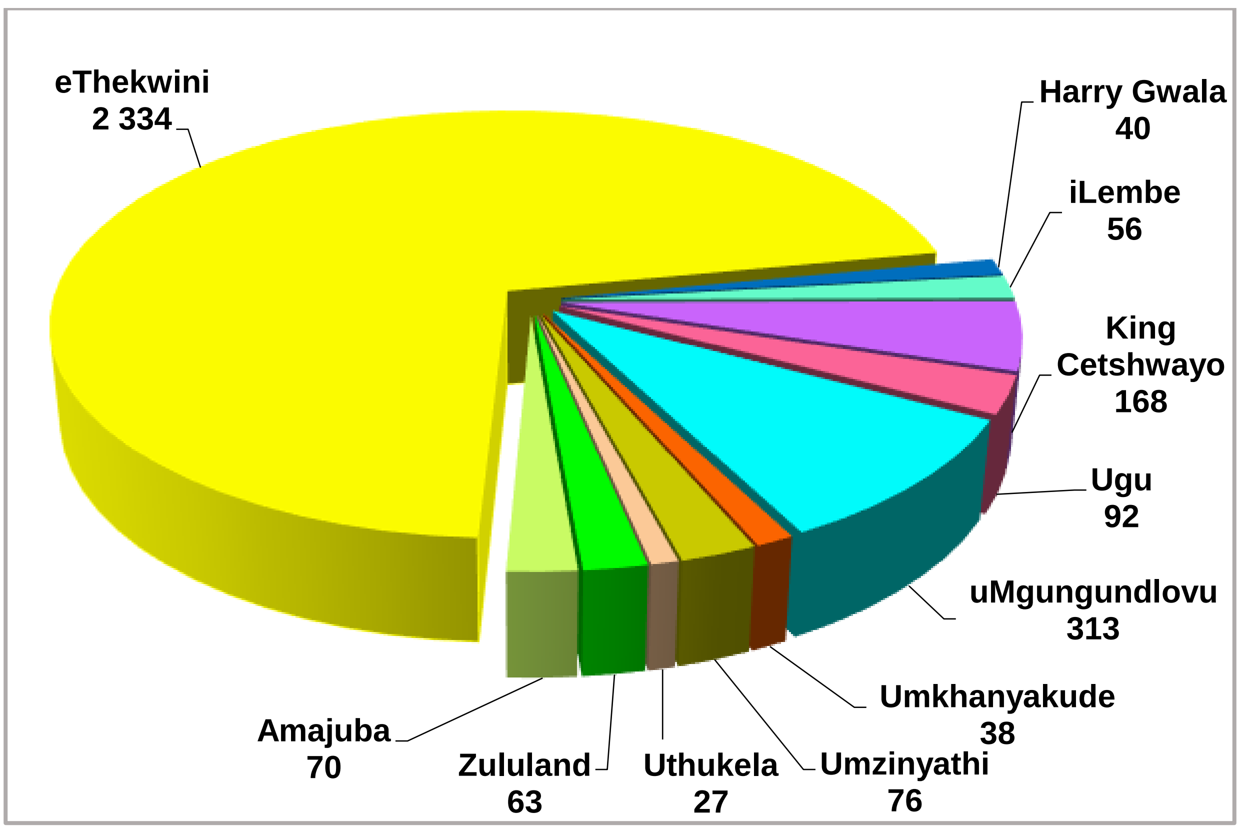


Figure 35: Fuel sales (kilotonnes per year) in KZN

Emission factors are dependent on a large number of parameters including type of vehicle (passenger cars, light duty commercial vehicles, heavy duty commercial vehicles etc.), driving conditions (travelling speeds, etc.) and even climatic conditions (temperature and humidity). This level of detail with regard to the vehicles in KZN was not available. Two different methods and sets of emission factors were used to estimate emissions from vehicles in KZN.

Method 1

Emission factors were taken from the 2021 update to the EMEP/EEA air pollutant emission inventory guidebook for Portugal which has similar climate characteristics to KZN. The average maximum and minimum temperatures and average humidity are 21.50°C, 13.20°C, and 74% for Portugal and 25.30°C, 16.60°C and 77% for KZN (https://www.worlddata.info/climate-comparison.php?r1=portugal&r2=za-kwazulu-natal). According to the guidebook, the range of application for these emission factors includes simplified inventories, where a rough estimate of the transport contribution is required. It was assumed that most vehicles using petrol are passenger vehicles, but light commercial vehicles are expected to travel over greater daily distances. Therefore, an average of the emission factors for passenger vehicles and light commercial vehicles was used for all emissions from petrol. Furthermore, it was assumed that most vehicles using diesel are commercial vehicles. Therefore, an average of the emission rates for light commercial vehicles and heavy-duty vehicles was used for all emissions from diesel. The emission factors (Table 10) were applied to the total fuel (tonnes per year) to determine the total emissions per pollutant, for petrol and diesel during 2020.

Method 2

A bottom-up emissions inventory of vehicle emissions was conducted in the eThekwini Metropolitan Municipality (eThekwini MM, 2022). The results of this study were used to calculate a second estimate of the emissions from vehicles for all the districts in KZN, also based on the proportions of fuel sold. For lack of a better alternative, it was assumed that the vehicle characteristics of all districts in KZN would be similar to that of the eThekwini Metropolitan Municipality. The vehicle emissions for eThekwini were differentiated by using separate COPERT runs for petrol and diesel. (COPERT is a **co**mputer **p**rogram that calculates **e**missions from **r**oad **t**ransport using many variables such as vehicle type, emissions regulation, vehicle kilometres travelled, trip length, average vehicle speed per road type (rural, urban and inner city), environmental conditions, fuel specifications etc. (EMEP/EEA, Update 2021)). The tonnes of pollutant per annum per vehicle category from the COPERT results were added together and divided by the litres of fuel sold in eThekwini in 2021 to produce an emission factor per tonne of fuel for each pollutant. A better method would be to calculate an emission factor per vehicle category. However, this would require the fuel used per vehicle category, and this data is not available. (The same data gap was encountered for the first emissions estimation method described above).

Table 10: Fuel emission factors (EMEP/EEA, 2021).

Fuel Emission Factor (kg/tonne)		
Pollutant	Fuel Type	
	ULP Method 1 (Method 2)	Diesel Method 1 (Method 2)
NO_X	18.60 (1.96)	24.90 (11.69)
CO	148.05 (14.33)	7.11 (2.26)
$PM_{2.5}$	0.03 (0.19)	1.11 (0.34)
PM_{10}	0.03 (0.33)	1.11 (0.46)
NMVOC	15.00 (2.86)	0.12 (0.29)

6.1.7.1 Vehicle Emission Inventory Result

Overall, the magisterial districts in the province accounted for a total of 3 277 kilotonnes of fuel sold, with diesel recording the highest sales. The district with the highest fuel usage is eThekwini (2 537 kt) (Figure 35) which, therefore, contributes significantly to overall vehicle emissions in the province.

The large difference between the emission factors (Table 10) and consequently, the total emissions estimated (Figure 36 and Table 11), can partially be ascribed to the different ages of the fleet composition used in the preparation of the emission factors. Method 1 is based on vehicles in Portugal in 2005, while method two is based on the vehicles in eThekwini in 2021. The accuracy of any vehicle emission factor deteriorates forward from the date of the vehicle fleet composition because new technologies appear and the contribution of older technologies decreases. Since the 1970s, vehicle manufacturers have continually improved engine technologies and have introduced various emission-control systems to meet the increasingly stringent legislated requirements. As a result, according to the EMEP/EEA (2021) modern vehicles have emission levels for regulated pollutants (CO, NOx, THC) which are more than an order of magnitude lower than those of vehicles entering service two decades ago. Although there are uncertainties inherent in both sets of emission factors, the second method is based on the most recent approximation of the KZN vehicle fleet and will be used in the emission summary in this report.

As a result of COPERT including emissions from tyre wear, brake wear and road abrasion in addition to vehicle exhaust emissions, PM emissions for petrol are higher. Almost all exhaust emissions of PM are in the $PM_{2.5}$ size range, and approximately three quarters of tyre wear and half of the emissions from brake wear and road abrasion are in the $PM_{2.5}$ size range.

NO_X is the main criteria pollutant emitted from the usage of diesel and CO from petrol usage. NO_X accounts for the highest mass of criteria pollutants emitted from vehicle fuel use within the province. CO values are much lower using Method 2.

Table 11: Annual Emissions from Vehicles within KZN.

District Municipality	Magisterial Districts	Fuel Usage (kilotonnes/year)		Emissions from Vehicles (tonnes/year) (Method 2)			
		Petrol	Diesel	NO_x	CO	PM_{10}	NMVOC
Amajuba	Newcastle	35	34	1 500 (469)	5 380 (575)	39 (27)	582 (109)
	Dannhauser	0	0	14 (5)	42 (5)	0 (0)	5 (1)
eThekwini	Umlazi	17	7	496 (115)	2 625 (265)	8 (9)	273 (52)
	Umbumbulu	8	6	289 (84)	1 181 (124)	7 (5)	126 (24)
	Pinetown	87	204	6 686 (2 551)	14 285 (1 703)	227 (122)	1 664 (307)
	Inanda	83	37	2 468 (596)	12 565 (1 274)	43 (44)	1 312 (248)
	Durban	468	1 374	42 928 (16 975)	79 096 (9 818)	1 530 (783)	9 477 (1 737)
	Chatsworth	32	12	883 (200)	4 766 (480)	14 (16)	495 (94)
Harry Gwala	Underberg	2	2	66	239	2	26

District Municipality	Magisterial Districts	Fuel Usage (kilotonnes/year)		Emissions from Vehicles (tonnes/year) (Method 2)			
		Petrol	Diesel	NO_x	CO	PM_{10}	NMVOC
				(21)	(26)	(1)	(5)
	Polela	1	1	58 (18)	221 (23)	1 (1)	24 (4)
	Mount Currie	10	21	717 (268)	1 641 (192)	24 (13)	189 (35)
	Ixopo	1	2	66 (21)	228 (25)	2 (1)	25 (5)
iLembe	Ndwedwe	0	0	4 (2)	1 (0)	0 (0)	0 (0)
	Lower Tugela	30	26	1 199 (360)	4 623 (488)	29 (22)	496 (93)
King Cetshwayo	Nkandla	3	2	110 (30)	484 (50)	2 (2)	51 (10)
	Mtunzini	8	6	302 (84)	1 299 (135)	7 (5)	138 (26)
	Mtonjaneni	2	2	84 (25)	327 (34)	2 (2)	35 (7)
	Lower Umfolozi	44	81	2 841 (1 036)	7 064 (812)	91 (52)	802 (149)
	Eshowe	11	8	407 (118)	1 652 (173)	9 (7)	176 (33)
Ugu	Umzinto	17	15	675 (205)	2 553 (270)	17 (12)	274 (52)
	Port Shepstone	24	31	1 221 (407)	3 840 (420)	35 (22)	422 (79)
	Alfred	3	3	121 (40)	395 (43)	3 (2)	43 (8)
uMgungundlovu	Camperdown	11	18	651 (234)	1 688 (192)	20 (12)	190 (35)
	Richmond (KZN)	0	1	23 (11)	7 (2)	1 (0)	2 (0)
	Pietermaritzburg	84	178	5 992 (2 242)	13 731 (1 609)	198 (109)	1 580 (292)
	New Hanover	1	1	50 (14)	226 (23)	1 (1)	24 (5)
	Mooirivier	2	3	122 (41)	381 (42)	3 (2)	42 (8)
	Lions River	7	6	293 (89)	1 112 (118)	7 (5)	119 (22)
	Impendle	0	0	1 (0)	0 (0)	0 (0)	0 (0)

District Municipality	Magisterial Districts	Fuel Usage (kilotonnes/year)		Emissions from Vehicles (tonnes/year) (Method 2)			
		Petrol	Diesel	NO_x	CO	PM_{10}	NMVOC
uMkhanyakude	Ubombo	6	6	263 (82)	956 (102)	7 (5)	103 (19)
	Ingwavuma	3	2	111 (32)	444 (47)	3 (2)	47 (9)
	Hlabisa	5	15	482 (190)	896 (111)	17 (9)	107 (20)
uMzinyathi	Umvoti	4	3	144 (38)	653 (67)	3 (3)	69 (13)
	Nqutu	4	2	115 (27)	600 (61)	2 (2)	63 (12)
	Kranskop	7	4	242 (64)	1 111 (114)	5 (4)	117 (22)
	Kliprivier	18	23	911 (305)	2 830 (310)	26 (17)	311 (58)
	Glencoe	0	1	26 (9)	77 (9)	1 (0)	9 (2)
	Dundee	5	5	204 (63)	745 (79)	5 (4)	80 (15)
uThukela	Estcourt	12	13	535 (172)	1 823 (196)	14 (10)	198 (37)
	Bergville	1	2	61 (20)	200 (22)	2 (1)	22 (4)
Zululand	Vryheid	17	30	1 068 (387)	2 708 (310)	34 (19)	307 (57)
	Paulpietersburg	2	0	33 (3)	262 (25)	0 (1)	27 (5)
	Nongoma	4	3	145 (40)	640 (66)	3 (3)	68 (13)
	Ngotshe	0	0	0 (0)	0 (0)	0 (0)	0 (0)
	Mahlabatini	4	3	158 (45)	663 (69)	4 (3)	70 (13)
Total		**1 085**	**2 192**	**74 767 (27 740)**	**176 259 (20 508)**	**2 449 (1 360)**	**20 193 (3 739)**

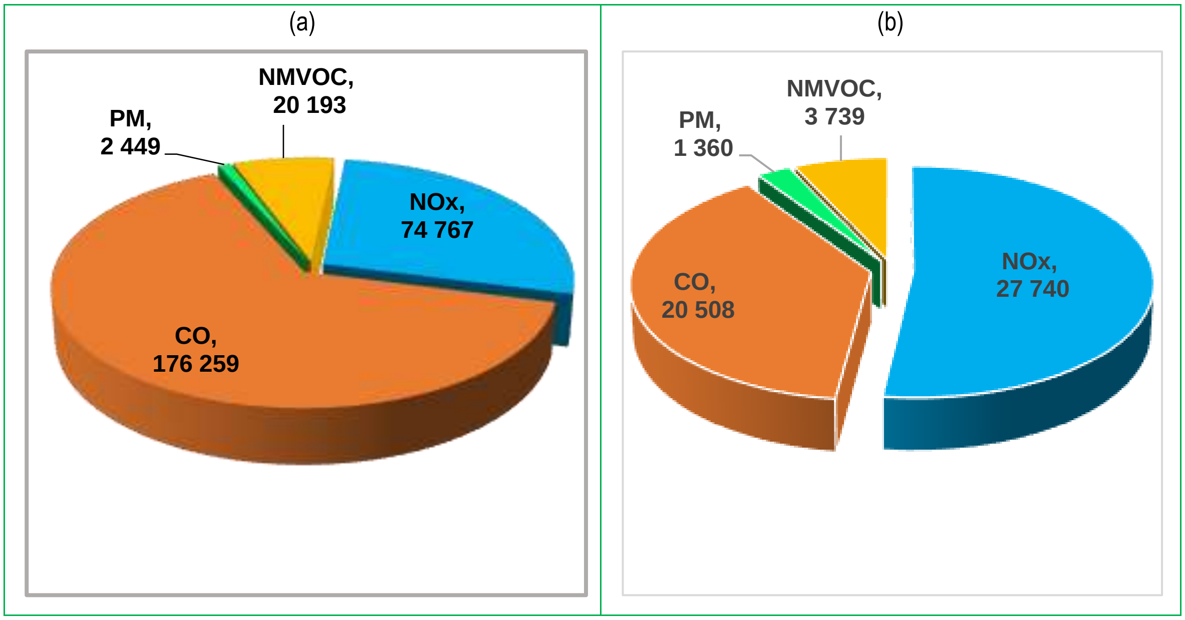


Figure 36: Emissions from vehicles (tonnes per year) in KZN (a) Method 1, (b) Method 2

6.1.8 Proposed Management Interventions

At a National Level, South Africa has identified potential mitigation measures for implementation within the transport sector to reduce emissions and contribute towards South Africa's GHG reduction targets by 2050. In 2018, the Department of Transport (DoT) published the Green Transport Strategy: 2017-2050 (DoT, 2018). As the road transport sub-sector contributes 91.2% of the sector's total emissions, mitigation of this sub-sector offers the highest potential benefits. As such, suggested strategies include integrating rail, taxi and bus services; a taxi recapitalization programme which aims to replace old, unsafe taxis with newer, more efficient vehicles; promoting cleaner fuels for the taxi industry (an efficient mitigation strategy as approximately 67% of the South African population uses mini-bus taxis); construction of low-carbon climate resilient road infrastructure including bus lanes, railways and non-motorised transport (e.g. cycling or walking) infrastructure; and incentivize the uptake of sustainable transport modes. Rail transportation infrastructure needs to be improved so as to handle freight transport and hence reduce road transport. (Government Notice No. 886, 2017).

The Air Quality Act makes provision for the Minister or Provincial MECs to declare all vehicles or vehicles falling within a specified category as a 'controlled emitter.' Emission standards, which include standards setting the permissible amount, volume, emission rate or concentration of a specified substance or a mixture of substances, need to be established for such emitters. Measurements of emissions from controlled emitters must also be carried out. This sets up the potential for nation-wide vehicle emission testing on a regular basis.

The Act also makes provision for the declaration of a substance or a mixture of substances as a 'controlled fuel'. Standards may be established for the use, manufacture, sale and composition of the controlled fuel. Alternatively, the manufacture, sale or use of the controlled fuel could be prohibited. As and when these interventions are rolled out at a national level, the province should adopt these measures at a feasible scale.

Recommended management interventions for vehicle emissions at the provincial level include the following:

- Develop and regularly update an electronic database with the latest traffic count data as it becomes available.
- Compile a detailed assessment of the vehicle fleet in the district including information on vehicle numbers, type, age and fuel usage.
- Synchronise traffic lights.
- Construct public transport infrastructure.
- Develop public transport plans and integrate into local municipality IDPs and the province's developmental strategy.

6.2 Residential Fuel Burning

6.2.1 Background to Residential Fuel Burning Emission Sources in KZN

The province of KwaZulu-Natal is characterised by both urban and rural areas and the sources of energy used for household purposes may differ in these areas. In rural areas the backlogs on electricity supply services are still concerning, and some households that still do not have access to electricity rely on alternative sources of energy. Between 2011 and 2016 the total number of households in KwaZulu-Natal has increased from 2 539 336 to 2 875 843 (StatsSA, 2016). Approximately 82% of the households use electricity for cooking and 88% for lighting (Table 12). The eThekwini Metropolitan Municipality has the highest number of households with access to electricity for cooking (94%) and lighting (96%), uMkhanyakude recorded the lowest proportion of households with access to electricity for both cooking (47%) and lighting (53%). Consequently, other forms of fuel are burnt for these functions in the remaining households (Figure 37, Figure 38 and Figure 39).

Table 12: Households in KZN using electricity (StatsSA, 2016).

District Municipality	Number of Households (2016)	Households Using Electricity for Cooking (%)	Households Using Electricity for Heating (%)	Households Using Electricity for Lighting (%)
Amajuba	117 256	86	65	92
eThekwini	1 125 767	94	80	96
Harry Gwala	123 705	59	27	81
iLembe	191 369	77	55	85
King Cetshwayo	225 797	81	66	92
Ugu	175 146	74	50	84
uMgungundlovu	298 463	88	74	93
uMkhanyakude	151 245	47	30	53
uMzinyathi	126 791	57	41	70
uThukela	161 788	73	55	85
Zululand	178 516	75	50	85
Total	**2 875 843**	**82**	**64**	**88**

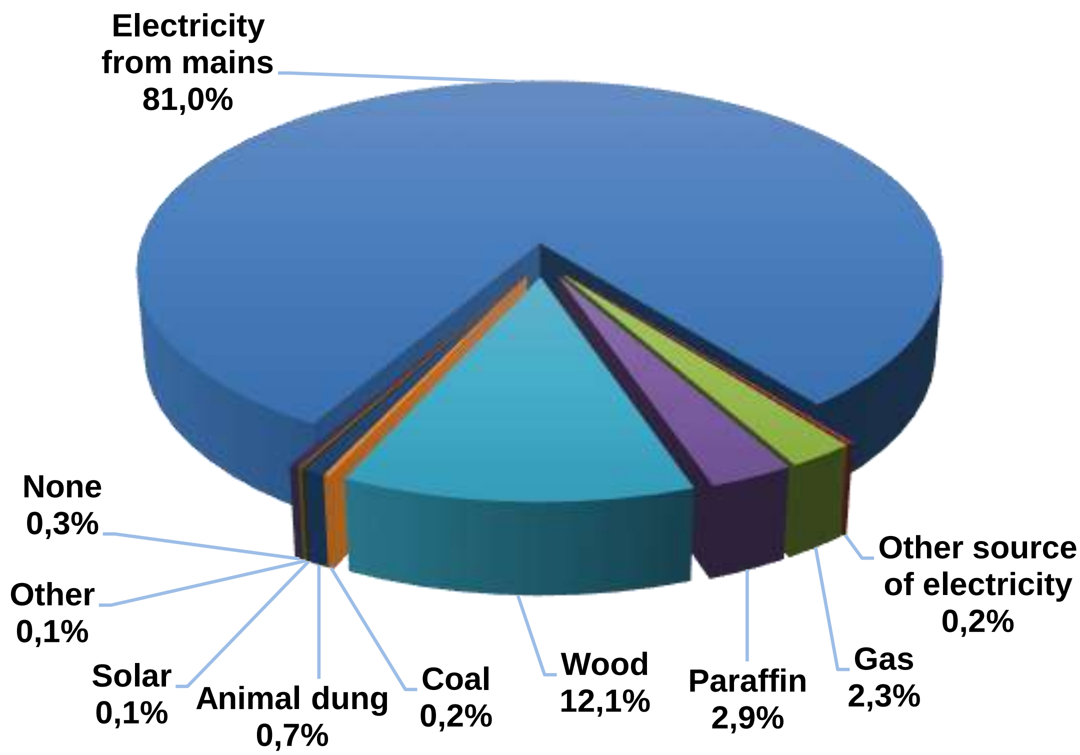


Figure 37: Energy Sources Used for Cooking in KZN.

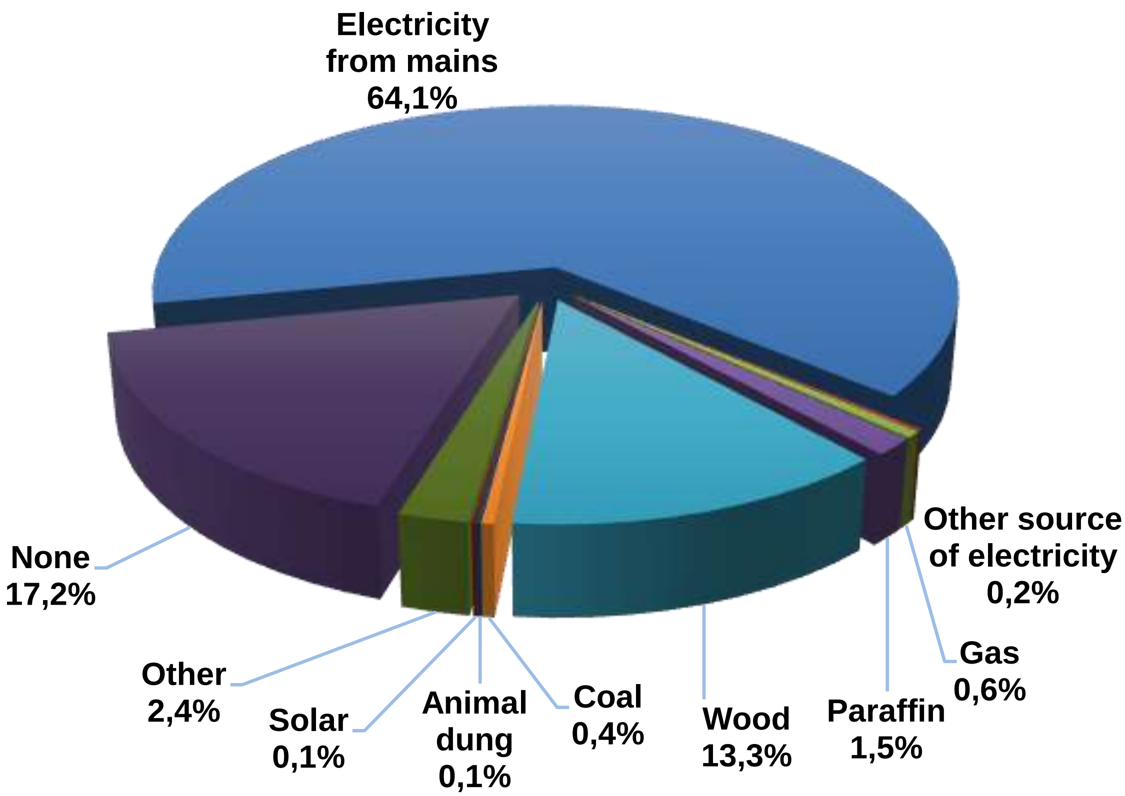


Figure 38: Energy Sources Used for Heating in KZN.

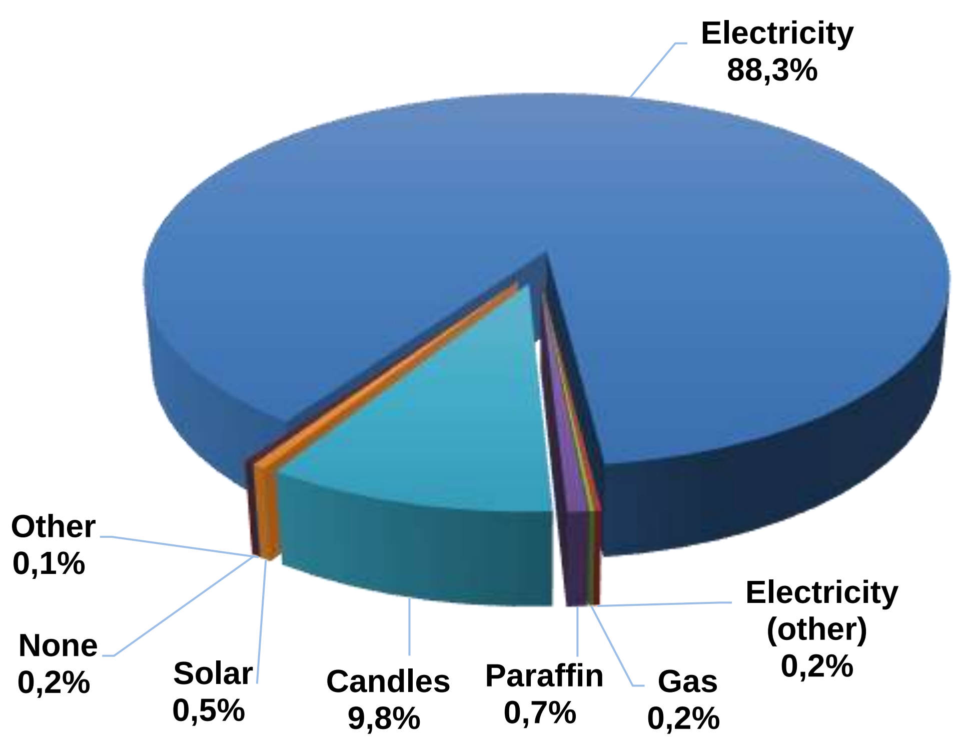


Figure 39: Energy Sources Used for Lighting in KZN.

Residential combustion of fuel is mostly found in densely populated, low-income, and informal settlements. Fuels such as wood, paraffin and, to a lesser extent, coal are used for cooking and heating, especially in the colder months. Air pollutants are emitted within the living space of many households, hence human health impacts related to household coal and wood burning remains the most serious and pressing national air pollution problem (DEA, 2008; Vegter, 2016).

Coal burning emits a large amount of gaseous and particulate matter pollutants including SO_2, PM_{10}, $PM_{2.5}$, heavy metals, inorganic ash, CO, benzo(a)pyrene and polycyclic aromatic hydrocarbons (PAH), which are recognised as carcinogens. Pollutants resulting from the combustion of wood include PM_{10}, $PM_{2.5}$, NO_2, CO, PAH, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning within South Africa have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons (DEA, 2008).

Even though many people living in dense, low-income communities know and acknowledge that the burning of coal or wood may have a negative impact on their health and well-being, they continue to burn these fuels. The reason for this is simply that they cannot afford to use alternative energy sources to satisfy their needs (DEA, 2008).

6.2.2 Methodology for Quantifying Emissions from Residential Fuel Burning

Residential fuel usage for cooking, heating, and lighting comprises a wide range of sources including animal dung, candles, coal, electricity, gas, paraffin, solar power and wood. The two dominant fuels used in KZN, which have quantifiable emissions, are paraffin and wood. Although only small quantities of coal are used in the province, emissions from coal combustion are comparatively high, therefore residential coal burning has been included in this assessment. All other fuels used, are consumed in small quantities or have low emissions, thus making their impact relatively insignificant.

To quantify emissions from paraffin, wood and coal, information regarding the total mass of each fuel burned per annum is required. As this information was not available, the number of households utilizing each source and an average fuel usage per household were used to calculate an approximate total fuel combusted value. The estimated total annual fuel usage for paraffin, wood and coal was then multiplied by an emission factor (Table 13) to establish total criteria pollutant emissions per fuel type per year (Equation 3).

Table 13: Emission Factors from Residential Fuel Burning (Thomas, 2008).

Fuel Type	Residential Fuel Burning Emission Factors (g/kg)		
	SO_2	NO_X	PM_{10}
Paraffin	0.1	1.5	0.2
Wood	0.2	1.3	17.3
Coal	11.6	4	12

Equation 3: Residential Fuel Burning Emissions.

$$Pollutant\left(\frac{kg}{year}\right) = No.Households \times Fuel\ per\ Household \times Pollutant\ Emission\ Factor$$

Population data per District Municipality from the StatsSA Community Survey were used (2016). The survey data provides the number of households that utilize each fuel type for cooking, heating, and lighting. Households can use one type of fuel for more than one purpose. Hence, to avoid overestimation of emissions, it is assumed that the maximum number of households using a specific energy source for either cooking or heating is the actual number of households that use the energy source. A limitation associated with these assumptions is a household that utilises a fuel for a less common use only, will not be counted. The emissions from lighting are regarded as negligible.

Average household quantities of paraffin and wood used as residential fuel were derived from a study conducted by Van Nierop (1995) and average household quantities of coal are derived from Scorgie *et al.* (2005). Both studies were conducted in the Vaal Triangle. Paraffin usage was calculated at 173.33 litres per annum per household and wood at 0.22 tonnes per annum per household (van Nierop, 1995). Coal usage was calculated at 1.19 tonnes per annum per household (Scorgie, Watson, & Fischer, 2005). These values are used as a best estimate for this study to calculate the total amount of fuel used for each fuel type in the KZN Province due to lack of alternative, site-specific data.

6.2.3 Residential Fuel Burning Emission Inventory Results

Emissions from residential burning of paraffin, wood and coal (for cooking, heating and lighting) were calculated, at the district level (Table 14, Table 15 and Table 16).

Table 14: Emissions from residential burning of paraffin.

District Municipalities	Number of Households Using Paraffin	Total Paraffin Usage (kg/year)	Total Emissions from Burning Paraffin (kg/year)		
			SO_2	NO_X	PM_{10}
Amajuba	3 137	435 020	44	653	87
eThekwini	37 021	5 133 421	513	7 700	1 027
Harry Gwala	10 566	1 465 134	147	2 198	293
iLembe	3 460	479 762	48	720	96
King Cetshwayo	1 757	243 611	24	365	49
Ugu	10 463	1 450 847	145	2 176	290
uMgungundlovu	9 045	1 254 222	125	1 881	251
uMkhanyakude	520	72 078	7	108	14
uMzinyathi	5 371	744 731	74	1 117	149
uThukela	6 857	950 782	95	1 426	190
Zululand	2 661	369 052	37	554	74
Total	**90 857**	**12 598 660**	**1 260**	**18 898**	**2 520**

Table 15: Emissions from residential burning of wood.

District Municipalities	Number of Households Using Wood	Total Wood Usage (kg/year)	Total Emissions from Burning Wood (kg/year)		
			SO_2	NO_X	PM_{10}
Amajuba	8 808	1 937 833	388	2 519	33 525
eThekwini	10 403	2 288 669	458	2 975	39 594
Harry Gwala	58 659	12 904 910	2 581	16 776	223 255
iLembe	36 604	8 052 813	1 611	10 469	139 314
King Cetshwayo	34 313	7 548 923	1 510	9 814	130 596
Ugu	29 761	6 547 493	1 309	8 512	113 272
uMgungundlovu	35 280	7 761 552	1 552	10 090	134 275
uMkhanyakude	69 251	15 235 114	3 047	19 806	263 567
uMzinyathi	52 917	11 641 768	2 328	15 134	201 403
uThukela	41 482	9 125 968	1 825	11 864	157 879

Zululand	43 866	9 650 552	1 930	12 546	166 955
Total	**421 344**	**92 695 595**	**18 539**		**1 603 634**

Table 16: Emissions from residential burning of coal.

District Municipalities	Number of Households Using Coal	Total Coal Usage (kg/year)	Total Emissions from Burning Coal (kg/year)		
			SO_2	NO	PM_{10}
Amajuba	6 523	7 761 818	90 037	31 047	93 142
eThekwini	391	465 531	5 400	1 862	5 586
Harry Gwala	181	215 240	2 497	861	2 583
iLembe	181	215 240	2 497	861	2 583
King Cetshwayo	199	236 343	2 742	945	2 836
Ugu	226	268 938	3 120	1 076	3 227
uMgungundlovu	847	1 007 711	11 689	4 031	12 093
uMkhanyakude	595	708 176	8 215	2 833	8 498
uMzinyathi	1 768	2 103 997	24 406	8 416	25 248
uThukela	589	701 470	8 137	2 806	8 418
Zululand	505	600 692	6 968	2 403	7 208
Total	**12 004**	**14 285 156**	**165 708**	**57 141**	**171 422**

Electricity is the preferred domestic energy source for cooking, heating and lighting in all households in KZN. Wood is the second highest energy source for cooking in the uMkhanyakude (46%), Harry Gwala (34%) and uMzinyathi (33%) households. In the other eight district municipalities, more than 60% of households use electricity for cooking.

For the purpose of heating, wood was the second highest energy source in the uMkhanyakude (28%), Harry Gwala (47%), and uMzinyathi (42%) households with more than 50% of the remaining district households using electricity for heating.

After electricity, candles are the main energy source used for lighting in the uMkhanyakude DM, with 53% of households using electricity and 42% of households using candles. In the other ten district municipalities over 70% of households use electricity for lighting.

Wood burning is the biggest polluter by mass in terms of both PM_{10}, and NO_X, while coal accounts for the largest emissions by mass of SO_2 in KZN from residential fuel burning (Figure 40). Coal is the second largest polluter by mass of PM_{10} and NO. Although there are more households using paraffin than coal as a source of energy for residential purposes, the relatively high emissions per kilogram of coal burnt leads to coal burning being the second largest source of air pollution after wood within the province in terms of domestic fuel burning.

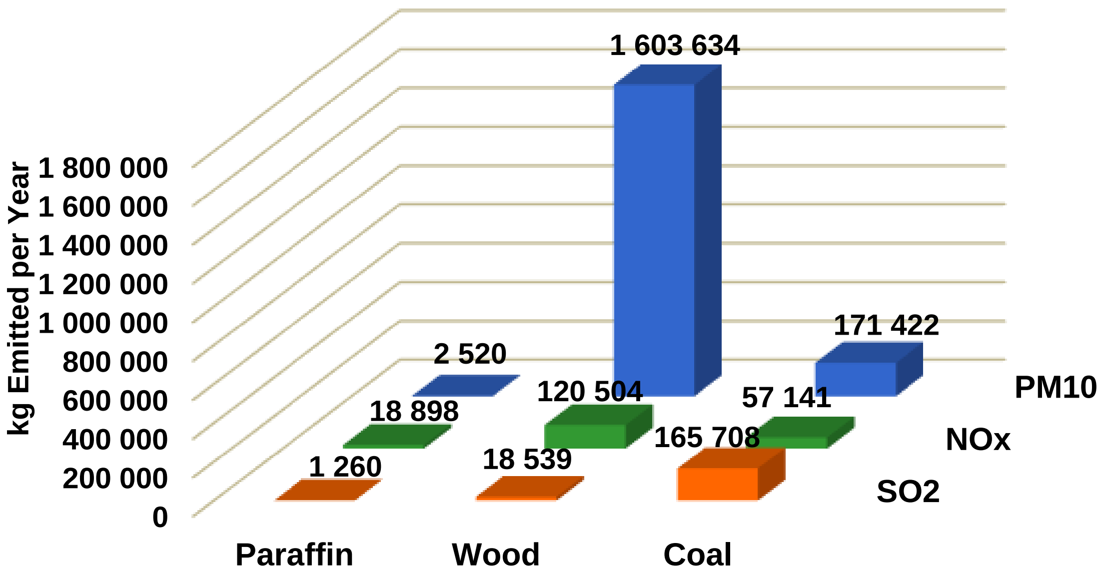


Figure 40: Emissions (kg per year) from residential fuel burning by fuel type in KZN.

6.2.4 Household Fuel Combustion Emission Reduction Goals

- Quantify fuel usage by households; determine local emission factors and assess impact to air quality.
- Reduce emissions from the household sector to the extent that contributions from the sector do not cause exceedance of national ambient air quality standards.
- Undertake health risk assessments in respect of exposure to air pollutants in priority settlements as a result of exposure to household fuel combustion emissions.
- Undertake an assessment of household emission reduction options including but not limited to the rollout of new stoves, retrofit of houses with energy efficiency measures, energy efficient RDP houses, fitment of ceilings, LPG rollout and subsidy.
- Develop a household emission reduction action plan.

6.2.5 Proposed Management Interventions

a) *National Government Interventions*

The DoE published the Draft Post-2015 National Energy Efficiency Strategy in 2016. This strategy aims to make energy affordable to everyone and to minimise the effects of energy usage on human health and the environment. Measures to reduce energy demand include the successive tightening of building standards while the feasibility of energy performance certificates is investigated; the successive tightening of minimum energy performance standards for household appliances; continued energy labelling of appliances and potentially introducing an energy endorsement label for the most efficient appliances in each class; the investigation of a scrappage scheme for older, less efficient appliances; and awareness campaigns around the cost-benefits of energy efficiency within households. The approach is focused on energy efficiency in higher income areas as well as in state-subsidised housing which will incorporate energy efficiency measures (Government Notice No. 948, 2016).

Residential air pollution is usually associated with low-income settlements. In response to this problem, the DEA published the Draft Strategy to Address Air Pollution in Dense Low-Income Settlements. Objectives of this strategy include ensuring air pollution reduction efforts made by different parties (government departments, Provinces, Municipalities, parastatals, community based organisations, private companies and academic and research institutions) are coordinated; facilitating the implementation of emission reduction interventions in low-income settlements; and ensuring continued monitoring, evaluation and reporting on the successes and failures of the proposed interventions and on air quality improvements. In order to achieve these objectives, measures that should be implemented include the establishment of The National Coordinating Committee (NCC) on Residential Air Pollution; the effective prioritization of air pollution interventions in dense, low-income settlements; the provision of affordable or subsidised clean energy alternatives; ensuring that low-income houses are built in line with energy efficiency housing guidelines; influencing development planning initiatives to take into account air quality issues; encouraging social upliftment programs with air quality benefits; the creation of public awareness of air pollution through campaigns and information materials; and annual reports on the implementation of interventions. (Government Notice No. 356, 2016).

The top-down ignition method, called 'Basa Njengo Magogo', which has proven to be successful, is considered a short- to medium-term solution to address domestic fuel burning (Figure 41). This method, meaning 'make fire like grandmother', is a top-down approach to fuel loading in mbawulas and stoves. In the classical bottom-up fire ignition approach, the order of preparing a fire is a few lumps of coal, followed by paper, wood kindling and ignition. The bulk of the coal is then added once the fire is established. In the 'Basa Njengo Magogo' method, the order of preparing a fire is coal, paper, wood followed by ignition and a few pieces of coal at the top (Makonese, Masekameni, Annegarn, & Forbes, 2015). Smoke generated in the latter method is burnt as it rises through the hot zone, resulting in reduced smoke emissions. The Basa Njengo Magogo method reduces PM_{10} and $PM_{2.5}$ emissions by 76% to 80% (Makonese, Masekameni, Annegarn, & Forbes, 2015).

Figure 41: The 'Basa Njengo Magogo' fire-lighting Method (left) and classical fire lighting method (right)

In addition to the method of ignition, ventilation rates affect the emissions from domestic fuel burning. High stove ventilation rates result in 50% lower PM_{10} and $PM_{2.5}$ emissions than low ventilation rates (Makonese, Masekameni, Annegarn, & Forbes, 2015). Ventilation rates can be influenced by the number and size of the holes made in rural stoves (Figure 51).

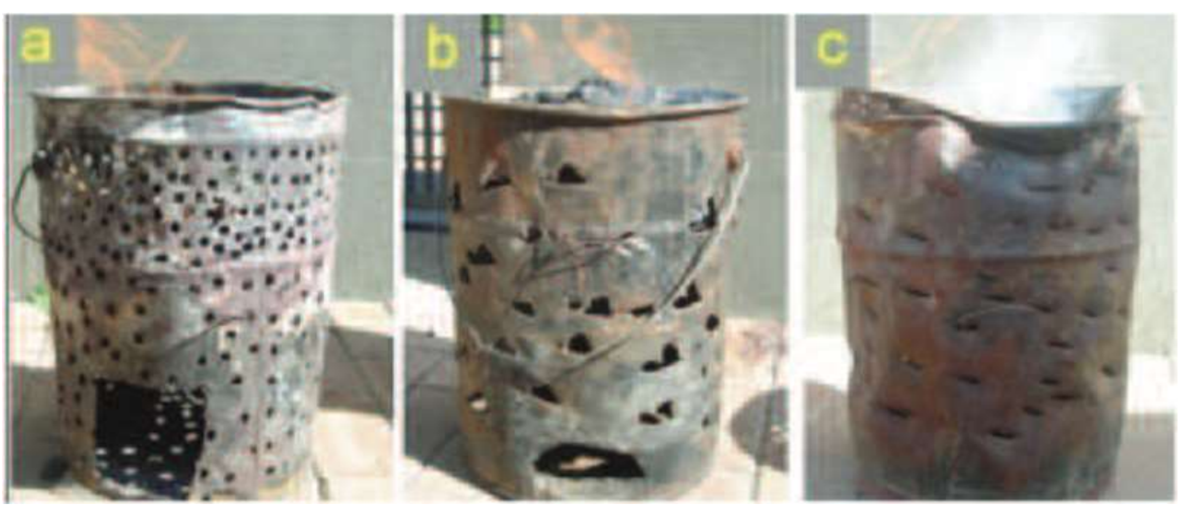


Figure 42: a) high ventilation brazier, b) medium ventilation brazier, and c) low ventilation brazier

b) Proposed Interventions

Emissions from domestic fuel burning need to be accurately determined to ensure that the contribution to the overall ambient air quality in the province is accurately quantified. As part of this Baseline Assessment, a first step in the quantification of domestic fuel burning was undertaken. This initial domestic fuel burning emissions inventory needs to be updated as population statistics become available.

An awareness campaign should be initiated in the province to educate people on the social and financial benefits of using alternative options. This awareness campaign (or strategy) should use all forms of media including television, radio, newspapers and flyers. The use of other forms of domestic energy such as low smoke fuels (e.g., char briquettes), gas (Liquid Petroleum Gas) and paraffin should also be encouraged (where available and accessible).

The introduction of energy efficiency measures into low-cost housing is considered to be a viable option. Such measures include solar water heaters, roof insulation and energy efficient lighting to reduce financial costs and environmental impacts.

Although electrification is often the preferred option, domestic fuels are often still used even after electrification due to factors such as affordability, accessibility and social preferences.

In 2013, Eskom initiated a pre-feasibility study for an offset project, whereby the stack emissions from Eskom's power plants would be offset by household emission reductions. This intervention project can be implemented in areas where air quality is impacted both by Eskom and domestic fuel burning in households. Interventions will include:

- Fully retrofitting subsidy houses with thermal insulation in both the walls and ceilings.
- Installing ceilings and ceiling insulation in houses that do not have ceilings.
- Designing and constructing new subsidy houses which have a high thermal standard (shell insulation, ventilation, orientation, surface to volume ratio and solar heat absorption).
- Replacing old stoves with new smokeless stoves.
- Subsidising electricity and electric heaters.

- Providing subsidised Liquefied Petroleum Gas (LPG) and heating appliances (and possibly also cooking appliances) through a “stove-for-LPG” exchange programme.

The province and district Air Quality Unit should contribute to the improvement of service delivery to low-income residential areas through the following means:

- Communicate the air quality benefits of improvement in the following aspects of service delivery, to the relevant departments: electrification, housing provision, road surfacing, refuse removal, and greening.
- Provide input to provincial developmental strategy and municipal IDPs in respect of service delivery plans for: electrification, housing provision, road surfacing, refuse removal, and greening.
- Participate in development of prioritisation methodology for electricity provision.
- Engage Eskom to electrify areas of poor air quality in hot spots as a priority.

6.3 Waste Burning

6.3.1 Background to Waste Burning Emission Sources

Open waste burning is a widespread practice in South Africa spurred, in part, by a lack of systematic waste collection. The diffuse nature of waste burning occurring at major landfills, small or remote dumpsites, and individual households, makes it a complex problem to address. Domestic waste burning is a major source of pollution in the less formal municipal communities. Due to lack of refuse removal services, residents resort to alternate methods of waste disposal.

According to Stats SA (2016) almost half of KZN households (47.7%) have their waste collected at least weekly by the local government or a private company (

Municipality	Removed once a week	Removed less often than a week	Communal refuse dump	Communal container	Own refuse dump	No rubbish disposal	Other	Total
Amajuba	63 093	2 148	1 739	483	44 937	3 730	1 126	117 256

eThekwini	878 679	56 763	25 503	27 602	107 928	19 549	9 743	1 125 767
Harry Gwala	28 566	2 071	2 257	375	85 228	4 694	513	123 705
iLembe	62 147	3 942	10 915	9 747	92 775	8 934	2 907	191 369
King Cetshwayo	61 617	4 850	9 001	8 763	132 848	8 114	604	225 797
Ugu	34 455	1 533	8 565	5 220	116 354	8 469	551	175 146
uMgungundlovu	123 619	10 867	7 237	964	141 241	10 387	4 148	298 463
uMkhanyakude	6 023	1 420	2 548	1 448	121 863	13 184	4 760	151 245
uMzinyathi	23 730	1 844	5 450	3 802	76 463	10 140	5 362	126 791
uThukela	50 711	4 065	3 252	1 894	86 134	13 872	1 859	161 788
Zululand	39 827	2 741	4 661	501	108 833	16 628	5 324	178 516
Total	***1 372 467***	***92 244***	***81 128***	***60 799***	***1 114 604***	***117 701***	***36 897***	***2 875 843***

Table 17). The second most common form of refuse removal (38,8% of households) is the disposal of waste at residents' own or communal dumps. In urban areas approximately 85% of households receive waste collection services, while only 12% of households dispose of their waste at their own or communal dumps. In the rural areas only 8% of the households have their waste collected by the local authority or private company, while the majority of households (81%) dispose of their waste at their own or communal dumps. Approximately 10% of households reported illegally dumping their waste anywhere or using other disposal options (backyard burning of waste) (Department of Environmental Affairs, 2018).

eThekwini has the greatest proportion of households whose refuse is collected at least once a week by the approved service provider (78.1%), followed by uMgungundlovu District Municipality (41.4%). uMzinyathi District Municipality has a high proportion of households who have their own refuse dump (60.3%). According to Stats SA (2016) Zululand and uMkhanyakude District Municipalities have the highest proportion of households that do not receive waste collection services. These two districts' proportions are also higher than the average of both the province and the country (StatsSA, 2016).

Table 17: Distribution of households by refuse removal (StatsSA, 2016).

Municipality	Removed once a week	Removed less often than a week	Communal refuse dump	Communal container	Own refuse dump	No rubbish disposal	Other	Total
Amajuba	63 093	2 148	1 739	483	44 937	3 730	1 126	117 256
eThekwini	878 679	56 763	25 503	27 602	107 928	19 549	9 743	1 125 767
Harry Gwala	28 566	2 071	2 257	375	85 228	4 694	513	123 705
iLembe	62 147	3 942	10 915	9 747	92 775	8 934	2 907	191 369
King Cetshwayo	61 617	4 850	9 001	8 763	132 848	8 114	604	225 797
Ugu	34 455	1 533	8 565	5 220	116 354	8 469	551	175 146
uMgungundlovu	123 619	10 867	7 237	964	141 241	10 387	4 148	298 463
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uThukela	50 711	4 065	3 252	1 894	86 134	13 872	1 859	161 788
Zululand	39 827	2 741	4 661	501	108 833	16 628	5 324	178 516
Total	***1 372 467***	***92 244***	***81 128***	***60 799***	***1 114 604***	***117 701***	***36 897***	***2 875 843***

Waste burning is a significant source of a variety of toxic pollutants in the air. Open burning of waste is the burning of unwanted waste by households in barrels, open pits, and outdoor furnaces. This open burning of waste is a health and environmental concern due to being associated with the emission of persistent organic pollutants. This includes polycyclic aromatic hydrocarbons, dioxins and furans, all of which are carcinogenic and have been linked to a variety of other diseases (Cogut, 2016). Furthermore, each fire adds CO, NO_X, SO_2, non-methane volatile organic compounds (NMVOCs), PM, ammonia (NH_3) and GHGs to the atmosphere. Emissions of particulate matter from fires are of the order of 20 to 400 times the acceptable level for a controlled combustion source. Where a fire has a poor supply of oxygen, or is smouldering, the particulate emissions are even greater (Persson & Simonson, 1998).

6.3.2 Methodology for Quantifying Emissions from Waste Burning

The Department of Environmental Affairs calculated that, on average each person in South Africa produces 0.7 kg of waste per day (DEA, 2009). Statistics of waste collection and households in KZN were used to estimate the extent of waste burning. Approximately 47% of households in KZN do not recieve any refuse removal services. They either use their own or a communal refuse dump, or are recorded as having no refuse disposal or 'other' in the census data. For the purposes of this emission inventory, emission rate calculations were based on the worst case scenario that all the waste disposed by these households is burnt (Figure 43).

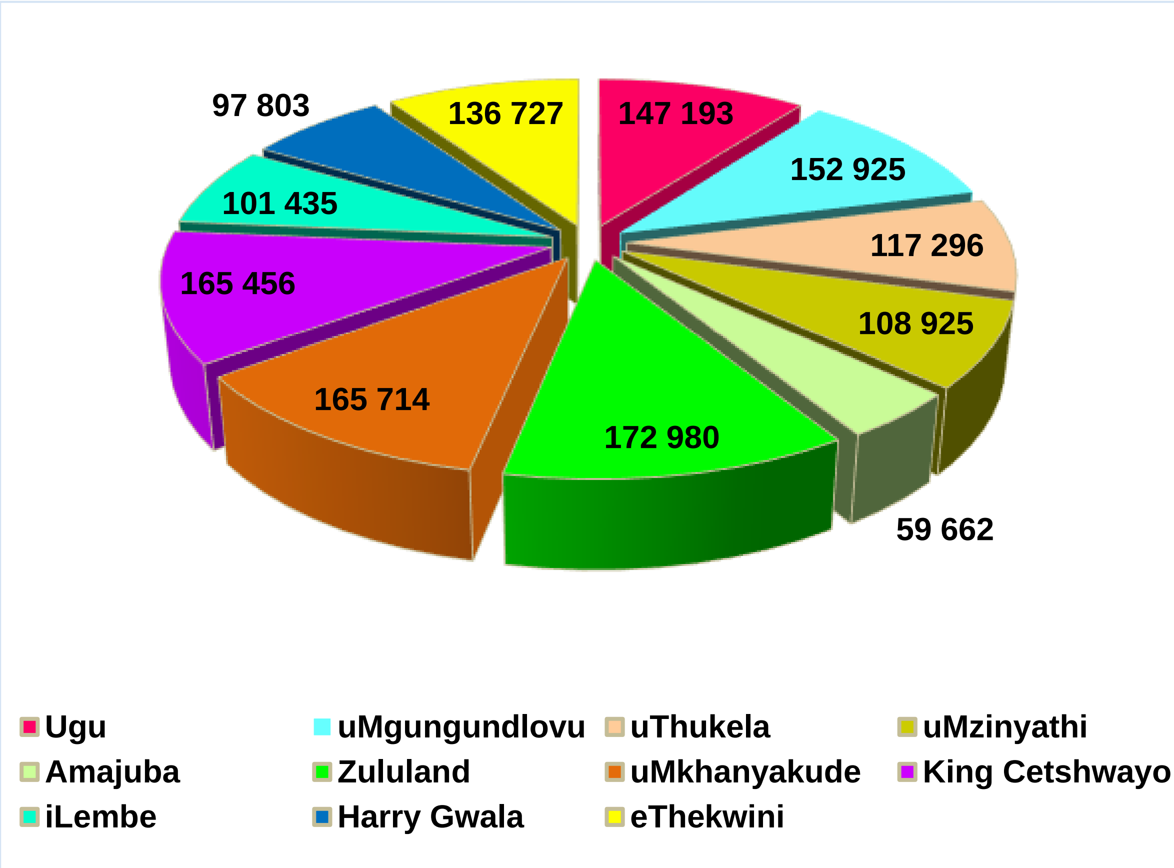


Figure 43: Total waste (tonnes per year) burnt per district municipality.

The emission factors for the open burning of municipal waste were obtained from a report on the domestic burning of waste in South Africa (Kwatala, Naidoo, Naidoo, & Garland, 2019) which adapted the emission rates proposed by Wiedinmyer (2014) (Table 18). A burning fraction of 0.6 was applied indicating that, on average, approximately 60% of the projected waste volume actually burns (Wiedinmyer C., 2014).

Table 18: Emission factors for the open burning of municipal waste (Wiedinmyer C., 2014)

Air pollutant	Emission Factor (kg of pollutant per tonne of waste)
CO	38
Benzene	0.9
PM_{10}	11.9
$PM_{2.5}$	9.8
NO_X	3.74
SO_2	0.5

The general equation used to estimate emissions from household waste is:

Equation 4: Waste burning emissions

$$Pollutant\left(\frac{kg}{year}\right) = Waste\ per\ Household \times 60\% \times Pollutant\ Emission\ Factor$$

6.3.3 Waste Burning Emission Inventory Results

Emissions from waste burning were calculated at the district municipality level (Table 19). The KwaZulu-Natal Province produces approximately 1 426 116 tonnes per annum of household waste that is not collected. The main criteria pollutant emitted from waste burning is CO (Figure 44). Zululand, uMkhanyakude, King Cetshwayo, uMgungundlovu, and Ugu are the municipalities with the highest emissions from waste burning, as they are predominantly characterised by informal settlements not receiving waste collection services. The assumption that waste burning is proportional to waste produced in areas without waste collection service is simplistic, especially since urban areas have more access to alternative methods of waste disposal. However, people in urban areas also have less space to discard their waste if not collected.

Table 19: Total emissions from waste burning in KZN.

District Municipality	Household waste that	Emissions from waste burning (kg per year)

	gets burnt per year (tonnes)	CO	C_6H_6	PM_{10}	$PM_{2.5}$	NO_X	SO_2
Amajuba	59 662	1 360 284	32 217	425 984	350 810	133 881	17 898
eThekwini	136 727	3 117 380	73 833	976 232	803 956	306 816	41 018
Harry Gwala	97 803	2 229 908	52 814	698 313	575 081	219 470	29 341
iLembe	101 435	2 312 717	54 775	724 245	596 437	227 620	30 430
King Cetshwayo	165 456	3 772 393	89 346	1 181 355	972 880	371 283	49 637
Ugu	147 193	3 355 995	79 484	1 050 956	865 493	330 301	44 158
uMgungundlovu	152 925	3 486 700	82 580	1 091 888	899 202	343 165	45 878
uMkhanyakude	165 714	3 778 274	89 485	1 183 196	974 397	371 862	49 714
uMzinyathi	108 925	2 483 498	58 820	777 727	640 481	244 428	32 678
uThukela	117 296	2 674 353	63 340	837 495	689 701	263 213	35 189
Zululand	172 980	3 943 942	93 409	1 235 077	1 017 122	388 167	51 894
Total	**1 426 116**	**32 515 442**	**770 103**	**10 182 467**	**8 385 561**	**3 200 204**	**427 835**

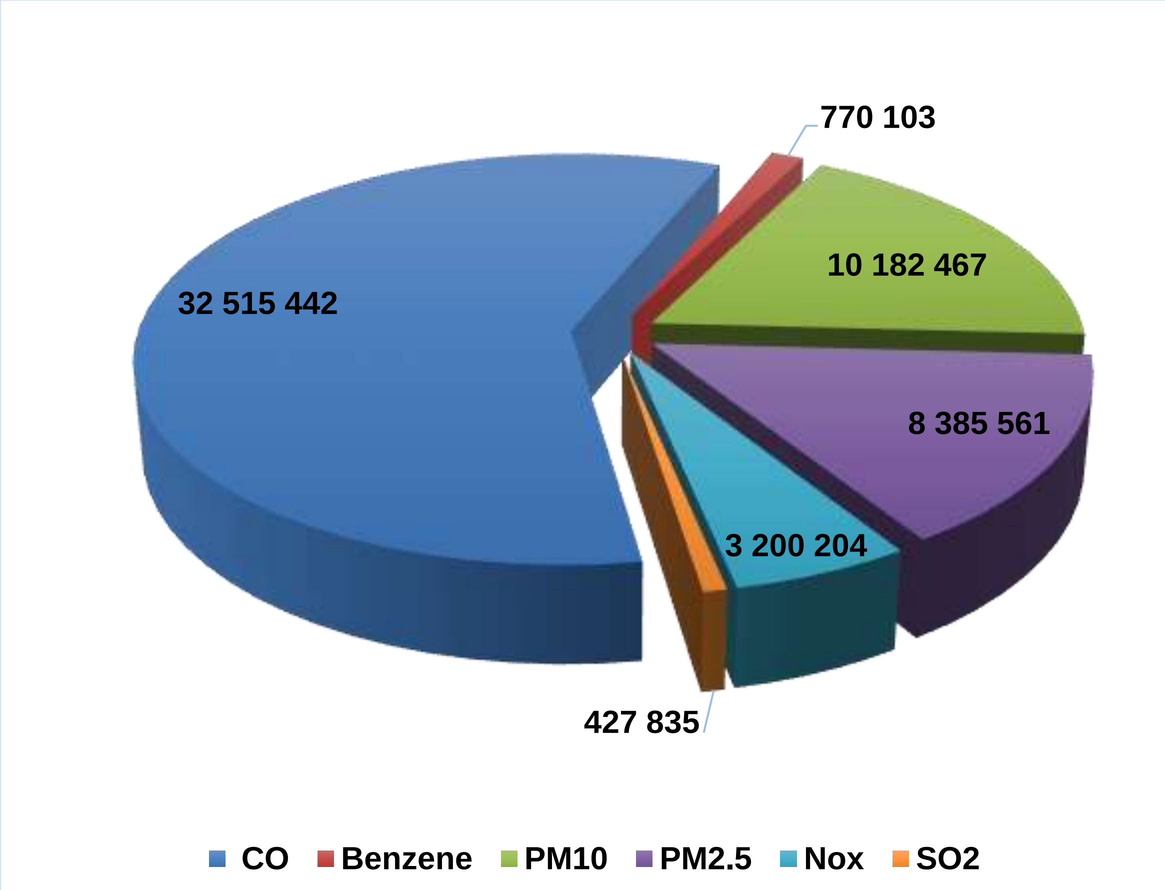


Figure 44: Emissions (kilograms per year) from waste burning

6.3.4 Waste Burning Reduction Goals

- Quantify waste burning emissions spatially and temporally to facilitate assessment of the impact to air quality.
- Undertake health risk assessments of exposure to air pollutants in priority settlements and the cost to the South African economy as a result exposure to waste burning.
- Undertake an evaluation of waste burning emission reduction options.
- Develop a waste burning emission reduction action plan.
- Serve all communities with refuse collection services.

6.3.5 Proposed Management Interventions

Waste management is key to reducing waste burning. Waste minimisation, community-based waste management, environmental education, law enforcement and safe disposal were found to be the best practices in decreasing emissions from waste (Buso, Nakin, Abraham, & Musampa, 2015). Recommended management interventions for waste burning include the following:

- Public awareness should be raised about the dangers associated with uncontrolled waste burning and the implications for air quality and human health. Possible forms of media for this campaign include environmental programmes at schools, community forums and posters.
- Quantify waste burning emissions to enable an assessment of the impact to air quality.
- Conduct health risk assessments to establish impacts of exposure to atmospheric pollutants from waste burning.
- Landfill sites within the district need to be issued with permits to ensure that these landfills are effectively managed and controlled. The responsibility of issuing landfill permits and of ensuring that landfills operate within their permits lies with the province.
- Investigate the feasibility of methane extraction for energy generation. The eThekwini Metropolitan Municipality has shown interest in initiating an Energy-from-Waste Project.
- Up to 57% reduction in methane emissions can be achieved by reducing waste disposal, the separate collection of biodegradable waste, the use of landfill gas for generating power and flaring of landfill gas (Boerboom, Vatamanu, & Zegers, 2010). Since 2016, several Municipalities within South Africa, including the eThekwini Municipality, City of Cape Town and Drakenstein Municipalities, have initiated waste-to-energy programmes.
- Promote the use of best available technology in waste management.

6.4 Biomass Burning

6.4.1 Background to Biomass Burning Emission Sources

The risk of veldfires in the various regions within KZN ranges from small pockets of high risk to extreme risk over most of the province (Forsyth, Kruger, & Le Maitre, 2010). According to the National Veldfire, Risk assessment Study (Forsyth, Kruger, & Le Maitre, 2010) 84.1% of the area of KwaZulu-Natal has the highest level of veld fire risk, with the Amajuba (100%), Harry Gwala (100%), uMgungundlovu (99,4%), uThukela (96,7%), and Zululand (91.1%) district municipalities being the most vulnerable to veld fires. The province is characterized by forest plantations and sour grassland that have dense flora of fire-sensitive woody species which are known to have the highest mean fire incidence (Forsyth, Kruger, & Le Maitre, 2010). The vegetation types (Figure 45) combined with the climatic conditions, result in the potential for a high number of veld fires to occur in some regions and fewer in others

(Figure 46). Grassland covers the largest area in KZN. Grasslands are particularly prone to fires because all the elements for fire ignition and spread are provided every year: fine, dry leaves and culms for fuel, dry warm conditions in late winter, and sources of ignition. In addition to these natural types, Forsyth et al (2010) recognized two managed land-cover types as being particularly sensitive to fires: Plantation Forests and Cultivated Lands.

Other than the natural vegetation and forest plantations, sugarcane fields are among the major sources of biomass burning emissions in the province. Sugarcane farming produces a significant amount of pollutants due to pre-harvesting and post-harvesting burning. Approximately 162 500 hectares of sugarcane are planted in the KwaZulu-Natal Province (StatsSA, 2017). Approximately 90% of the sugarcane crop is subjected to pre-harvesting burning (Wilkinson, 2013; Shikwambana, Ncipha, Sangeetha, Sivakumar, & Mhangara, 2021).

The following proposed By-Law was presented at the Sugarcane burning project – Lekgotla in 2011 (Puckree & Mtembu, 2011):

Any person who burns sugarcane shall comply, in addition to the burning requirements provisions of the National Veld and Forest Act, 1998 (Act No. 101 of 1998), with the following control measures:

- Obtain the prior written authorisation of the Council, which authorisation may be granted by the Council with conditions.
- Notify, in writing, the owners and occupiers of all adjacent properties (including surrounding communities within 150 metres) of:
    - The details of the propose area to be burned.
    - The reason for the sugarcane burning.
    - The date and approximate time of the sugarcane burning.
- Provide an alternative date or dates on which the sugarcane burning may occur in the event of inclement weather conditions.
- Inform owners and occupiers of all adjacent properties (including surrounding communities within 150 metres) of their right to lodge written objections to the proposed sugarcane burning with the municipality within 7 days of being notified.
- Pay an administrative fee to the municipality.

Currently, two Acts of Parliament regulate the burning of sugarcane or any other combustible material on a farm. The National Veld and Forest Fire Act, No. 101 of 1998 and the Conservation of Agricultural Resources Act, No. 43 of 1983 apply to any owner, lessee, lawful occupier or other person in control of land where a veld, forest or mountain fire can start on a land, burn on a land or spread on that land. (Wilkinson, 2013)

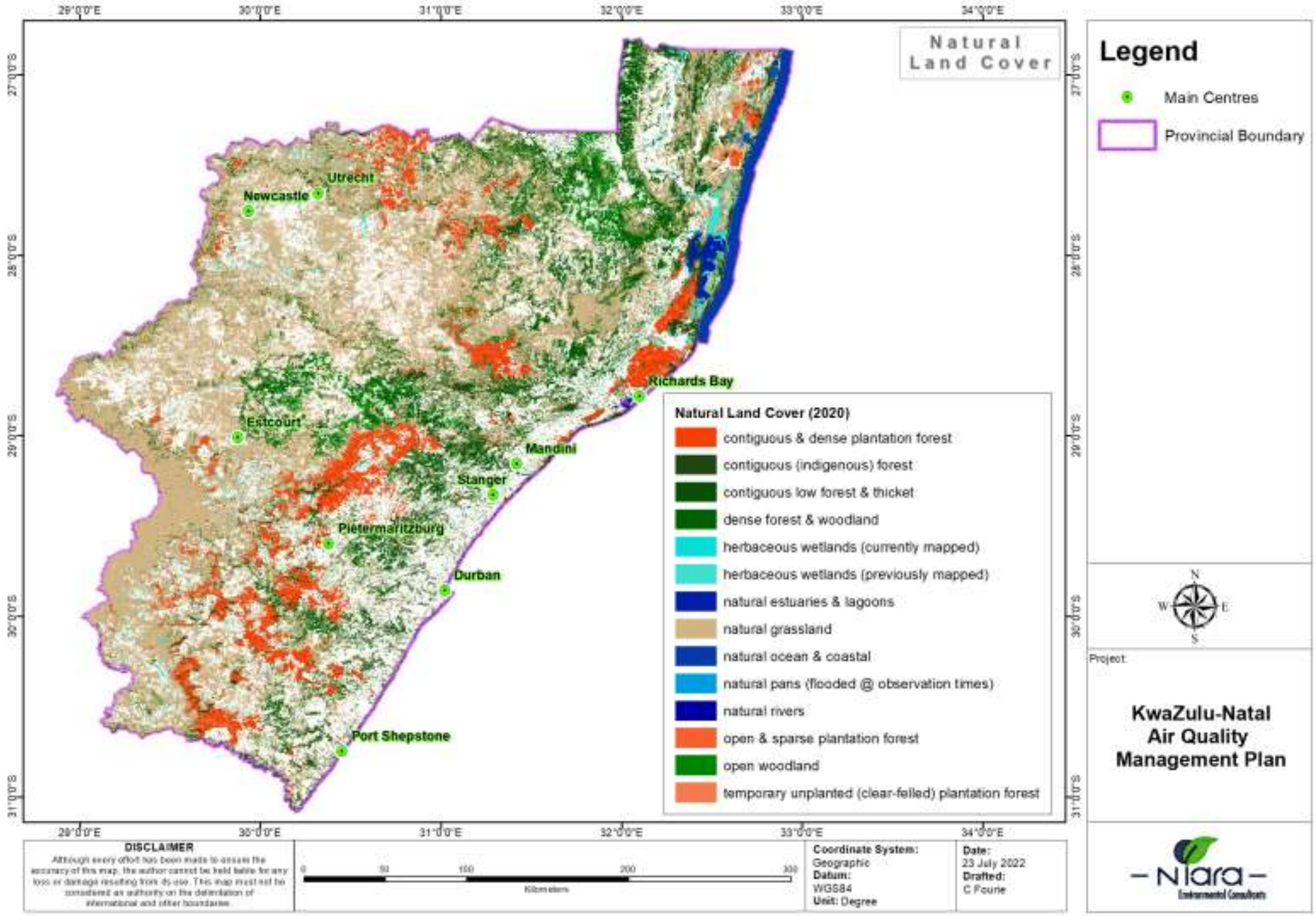


Figure 45: Distribution of natural land cover in KZN.

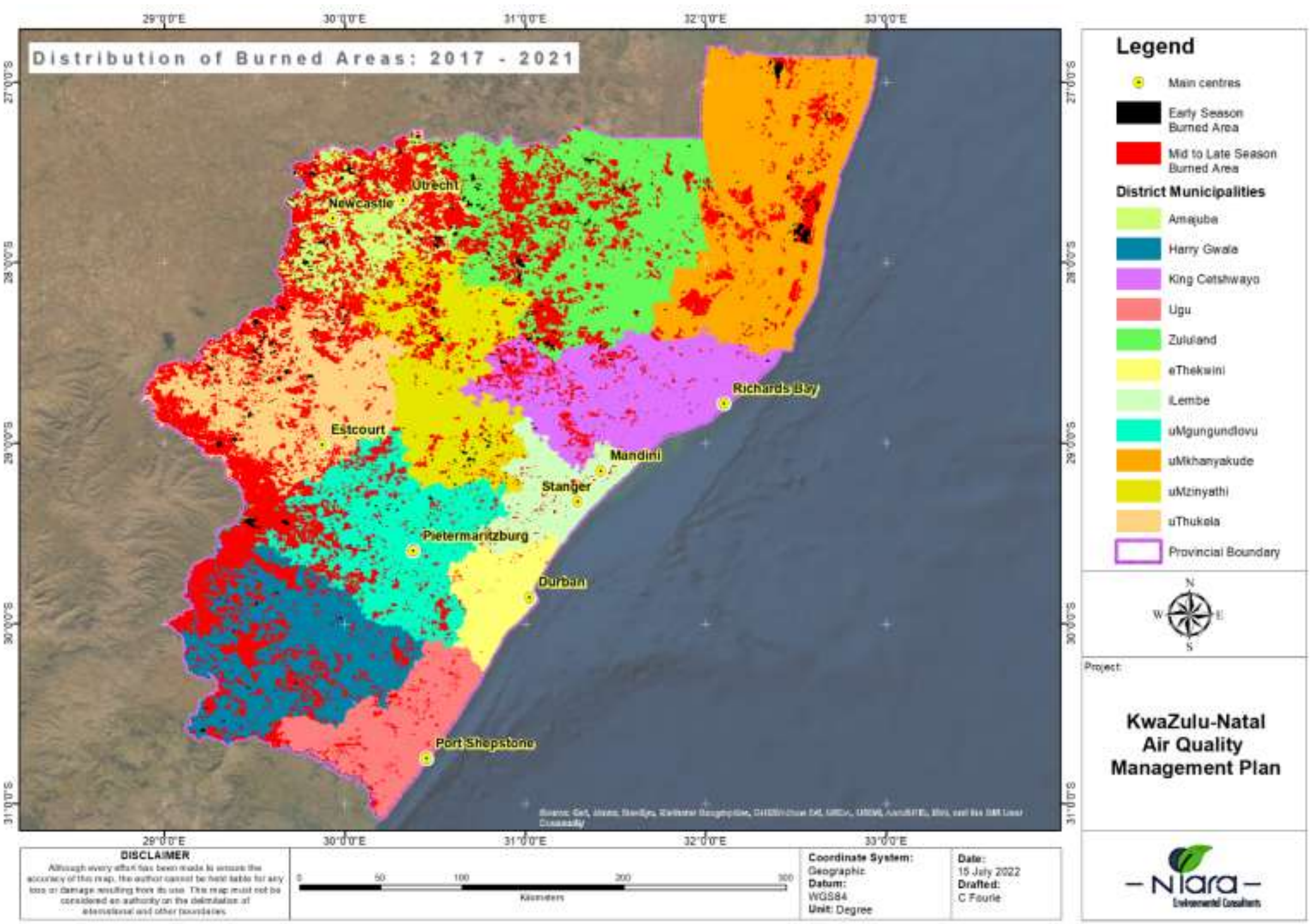


Figure 46: Distribution of burnt areas in KZN.

6.4.2 Methodology for Quantifying Emissions from Biomass Burning

Open veld fires are typically dynamic fires, in which a moving fire front passes through a fuel bed. The emission factors of the various smoke constituents are determined by the composition of the fuel and by the physical and chemical processes during combustion (Andreae & Merlet, 2001). Furthermore, a study on emissions from pre-harvest burning of sugarcane residues found that emissions of $PM_{2.5}$ were five times lower in the flaming phase than in the smouldering phase (Kanokkanjana & Garivait, 2012).

This makes it difficult to predict the type and extent of pollution emissions from veld fires and sugarcane burning. Furthermore, the timing, location and movement of the fire front are unpredictable. Since the information needed to take these factors into account is not available, the calculations of the emissions undertaken in this report are taken as a Tier 1 approximation. Emission factors for the burning of savannah and grasslands (Table 20) were used for burning of natural vegetation.

Emission factors for sugarcane burning vary considerably (Table 21). This may be the result of differences in burning chambers or stoves used for the research, burning conditions, sampling of fuels and analytical methods. Kanokkanjana and Garivait (2012) showed the difference in $PM_{2.5}$ emissions depending on the intensity of burning. The higher average emissions of CO in this study are also indicative of the inclusion of incomplete combustion in the smouldering phase. De Azeredo Franca et al. (2012) also found that a smouldering phase may precede and follow the flaming phase in cases where there is more moisture in the plant matter. Increased moisture also decreases the efficiency of combustion, thus increasing the emission of CO. The emission factors used for the emissions calculations for this emissions inventory are 124.0, 20.0, 1.5 and 0.5 grams of pollutant per kilogram of dry burned biomass for CO, $PM_{2.5}$, NO_X and SO_2 respectively.

Table 20: Emission factors of the criteria pollutants from field burning in savannah and grassland (Andreae & Merlet, 2001).

Air pollutant	Emission Factor (g of pollutant/kg of dry weight)
CO	65
NO_x as NO	3.9
SO_2	0.35
$PM_{2.5}$	5.4

Table 21: Emission factors of criteria pollutants from sugarcane burning.

Air pollutant	Emission Factor [g/kg] of dry burned sugarcane biomass				
	(Kanokkanjana & Garivait, 2012)	(Mugica-Álvarez, et al., 2018)	(De Azeredo França, et al., 2012)	(US EPA, 1975)	(EMEP/EEA, 2019)
CO	124.0 (±45)	25.7 (±2.04)	65 (±14)	35	66.7
NO_x			1.5 (±0.4)		2.3
SO_2					0.5
PM		2.1		4	5.8
PM_{10}		1.1			5.7
$PM_{2.5}$	20.0 (±15)	0.7	2.6 (±1.6)		5.4

The general equation used to estimate emissions from biomass burning is:

Equation 5: Biomass burning emissions

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

Where:

- L_{fire}: emissions from biomass fires (for each pollutant, tonnes x year^{-1}).
- A: area burnt (ha).
- M_B: mass of fuel available for combustion (tonnes x ha^{-1}). This includes biomass, underground litter and dead wood.
- C_f: combustion factor (dimensionless).
- G_{ef}: emission factor (g x kg^{-1} dry matter burnt).

For the mass of fuel combusted, the default biomass density for temperate grasslands of 450 g/m^2 dry weight (EMEP/EEA, 2013) was used for late season burns, when the amount of fine, dry leaves, grass culms, underground litter and dead wood is expected to be at a maximum. This value is more or less in keeping with 4.1 tonnes of dry matter per hectare given for mid or late dry season burns in savannah grasslands (IPCC, 2006). For early dry season burns, the value of to 210 g/m^2 dry weight, given for early dry season burns in all savannah grasslands, was used (IPCC, 2006). Fires occurring from November to April were considered to be 'early dry season' burns, and fires occurring from May to October were considered to be 'mid and late dry season' burns.

For the mass of fuel combusted in sugarcane burning, the average biomass load in a sugarcane field calculated by Kanokkanjana and Garivait (2012) of 1 007 g/m^2 dry weight with a residue to product ratio of 0.28 was used, resulting in a mass of 2.82 tons/ha available for combustion.

The combustion factor (C_f) gives the proportion of pre-fire fuel biomass consumed. The mean value of 0.74 (IPCC, 2006) was used for general biomass fires. The mean value of 0.64 calculated by Sornpoon et al. (2014)
was used for sugarcane.

The MODIS burned area dataset for the period from 2017 to 2021 (Giglio, Justice, Boschetti, & Roy, 2015) was used to calculate the average area of biomass burning in the province. The MODIS Burned Area Product User's Guide (Giglio, et al., 2022) indicates that there is a large negative bias in global area burned, primarily due to the systematic underestimation of smaller burned areas in the MCD64A1 product. Therefore, it should be noted that the emissions may be considerably understated. Emissions were allocated to the district municipalities in proportion to the burned area established from the MODIS dataset.

For sugarcane, it was found that the MODIS data did not reflect the expected result of 90% of the sugarcane crop being subjected to pre-harvesting burning (
Figure 47). This finding is corroborated by the MODIS Burned Area Product User's Guide (Giglio, et al., 2022) which identifies cropland burning as a 'Known Problem' that should generally be treated as low confidence. They refer to a study undertaken by Hall et al. (2016) in assessing the capabilities of global burned area products. Their analysis showed that all three burned area products tested, were unable to map approximately 95% of burn validation samples. This demonstrates that satellites with a resolution of ≥500 m are not adequate for accurately mapping burned area associated with the small spatial scale of agricultural fires. Furthermore, crop burn scars are more transient in nature than grassland or forest fires as they are rapidly lost to weathering and/or plowing within a short period of time. Therefore, satellites with a resolution of 10-50 m, which would be able to pick up the small spatial scale of crop burning, are limited because of the repeat cycle being 8-16 days instead of the daily overpasses of the coarser resolution satellites.

Consequently, a Tier 1 estimation of emissions was used to calculate the emissions from sugarcane burning. It was assumed that 90% of the 162 539 hectares of sugarcane crop is subjected to pre-harvesting burning with emissions calculated using Equation 5 above. The emissions were allocated to the District Municipalities in proportion to the area of sugarcane cropland per district.

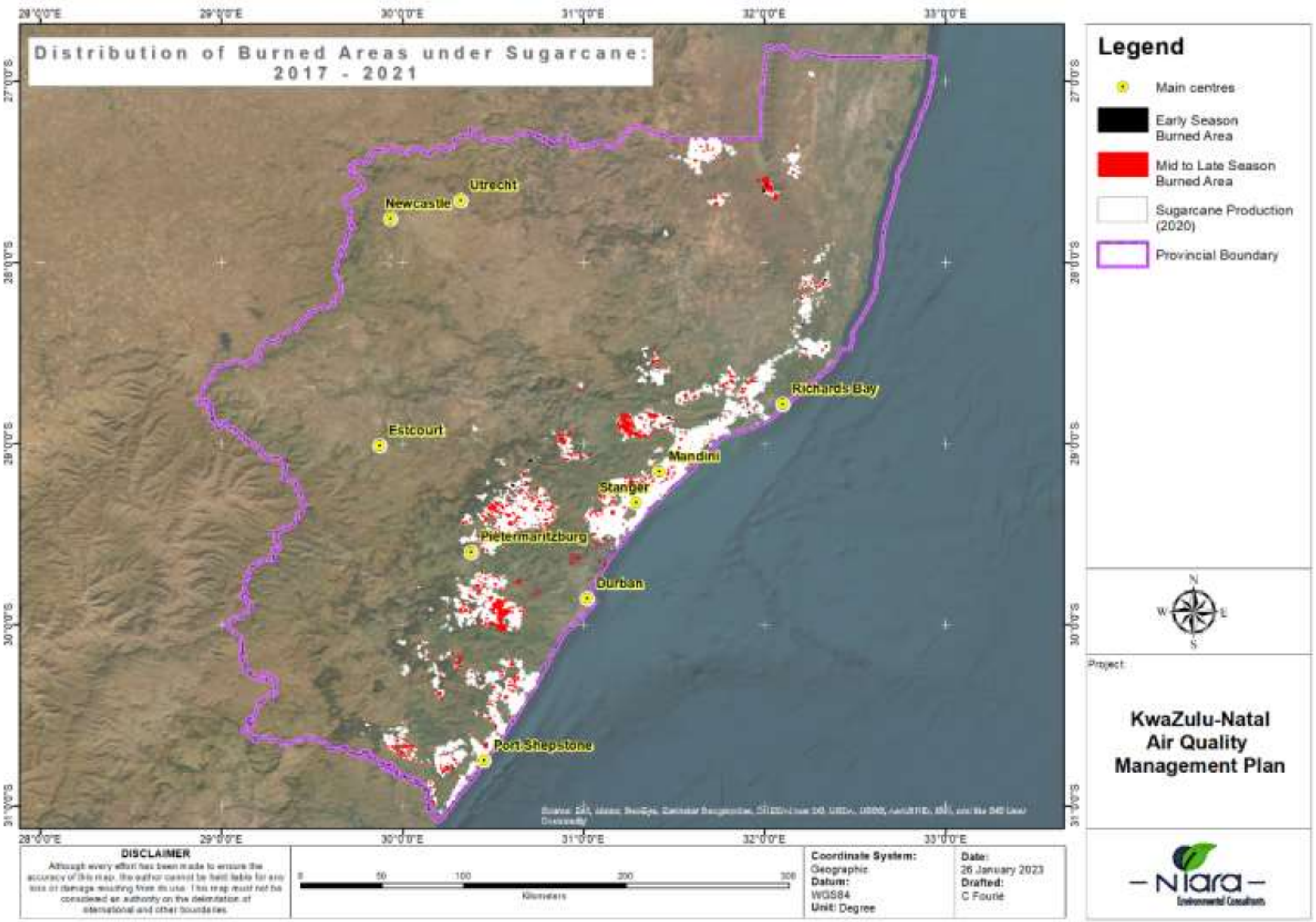


Figure 47: Distribution sugarcane burned areas using the MODIS burned area dataset for the period from 2017 to 2021 (Giglio, Justice, Boschetti, & Roy, 2015).

6.4.3 Biomass Burning Emission Inventory Results

The total area burned in KZN between 2017 and 2021 (excluding burns in the sugarcane croplands) was 2 176 845 ha (Table 22). CO represents the highest criteria pollutant emission from biomass burning by mass, followed by particulate matter (Figure 48).

Table 22: Total emissions from biomass burning in KZN (2017 - 2021).

District Municipalities	Total Burnt Area [ha] (2017-2021)	CO [kg]	NO_x as NO [kg]	SO_2 [kg]	$PM_{2.5}$ [kg]
Amajuba	361 962	75 920 335	4 555 220	408 802	6 307 228
eThekwini	2 665	572 018	34 321	3 080	47 522
iLembe	8 962	1 939 795	116 388	10 445	161 152
Harry Gwala	332 623	71 646 366	4 298 782	385 788	5 952 160
Ugu	33 038	7 150 999	429 060	38 505	594 083
uMgungundlovu	231 248	49 353 065	2 961 184	265 747	4 100 101
uMkhanyakude	195 538	40 406 362	2 424 382	217 573	3 356 836
uMzinyathi	133 495	28 059 836	1 683 590	151 091	2 331 125
uThukela	393 289	82 925 055	4 975 503	446 520	6 889 158
King Cetshwayo	90 201	19 149 718	1 148 983	103 114	1 590 900
Zululand	377 212	79 391 052	4 763 463	427 490	6 595 564
Total	**2 176 845**	**458 192 646**	**27 491 559**	**2 467 191**	**38 065 235**

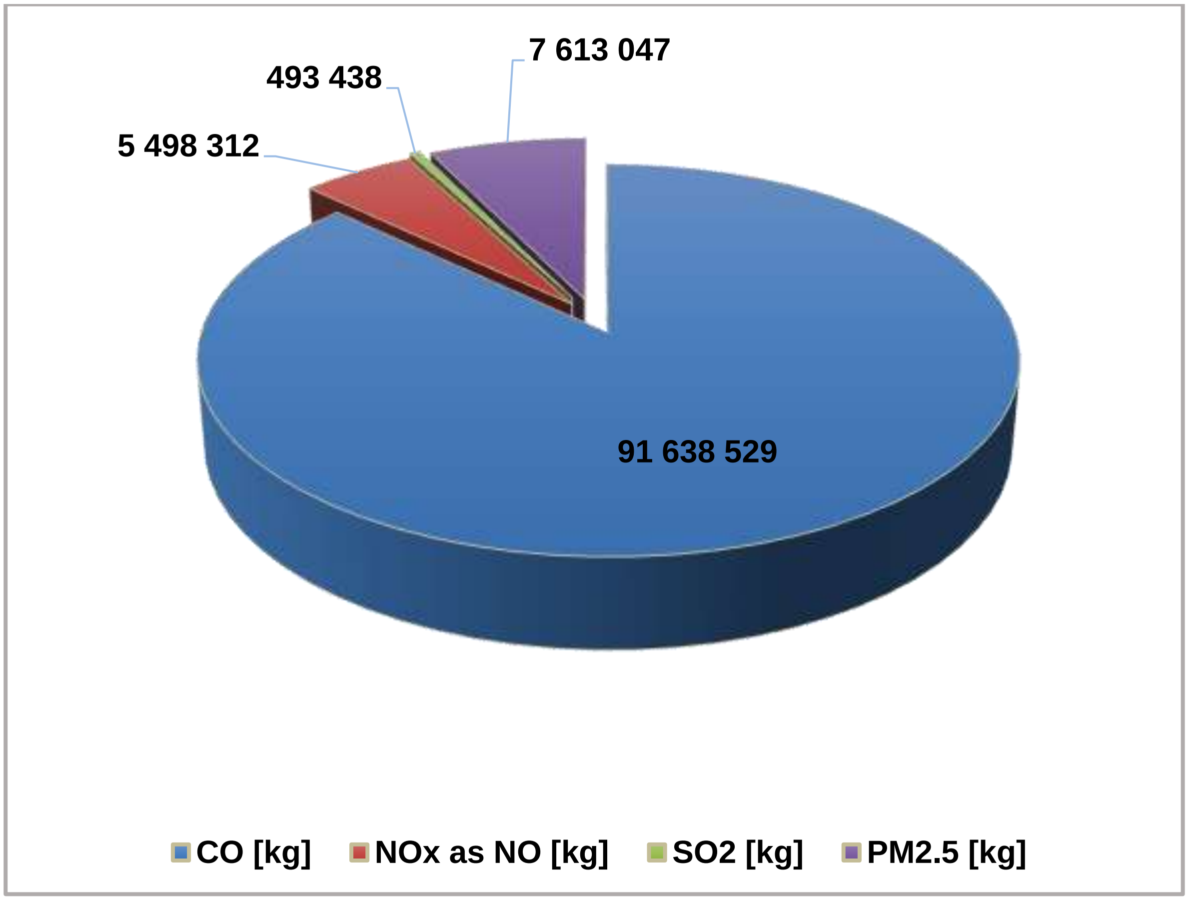


Figure 48: Annual emissions (kilograms per year) from biomass burning in KZN.

Biomass burning is a seasonal emission; thus, the total burned area between 2017 and 2021 was classified into early and mid-late dry seasons. Approximately 95% of all fires occurred during the mid-late dry season (Table 23).

Table 23: Seasonal emissions from biomass burning in KZN.

Air pollutant / GHG	Total Emissions [kg] (2017-2021)		Annual Average Emissions [kg]	
	Mid-Late Dry Season	Early Dry Season	Mid-Late Dry Season	Early Dry Season
CO	446 830 369	11 362 277	89 366 074	2 272 455
NO_x as NO	26 809 822	681 737	5 361 964	136 347
SO_2	2 406 010	61 181	481 202	12 236
$PM_{2.5}$	37 121 292	943 943	7 424 258	188 789

The total area of sugarcane cropland burned in KZN annually is approximately 94 311 ha of the total 104 790 ha planted (Table 24). CO represents the highest criteria pollutant emission from sugarcane burning by mass, followed by particulate matter (Figure 49).

Table 24: Total emissions from sugarcane burning in KZN.

District Municipalities	Sugarcane area [ha]	Sugarcane area burnt [ha]	CO [kg]	NO_x as NO [kg]	SO_2 [kg]	$PM_{2.5}$ [kg]
Amajuba	835	752	168 158	2 034	678	27 122
eThekwini	25 775	23 198	5 190 753	62 791	20 930	837 218
iLembe	29 609	26 648	5 962 871	72 132	24 044	961 753
Harry Gwala	1 530	1 377	308 122	3 727	1 242	49 697
Ugu	21 911	19 720	4 412 593	53 378	17 793	711 709
uMgungundlovu	39 847	35 862	8 024 672	97 073	32 358	1 294 302
uMkhanyakude	4 918	4 426	990 422	11 981	3 994	159 745
uMzinyathi	3 332	2 999	671 022	8 117	2 706	108 229
uThukela	0	0	0	0	0	0
King Cetshwayo	26 179	23 561	5 272 113	63 776	21 259	850 341
Zululand	8 603	7 743	1 732 533	20 958	6 986	279 441
Total	**104 790**	**94 311**	**21 103 355**	**255 283**	**85 094**	**3 403 767**

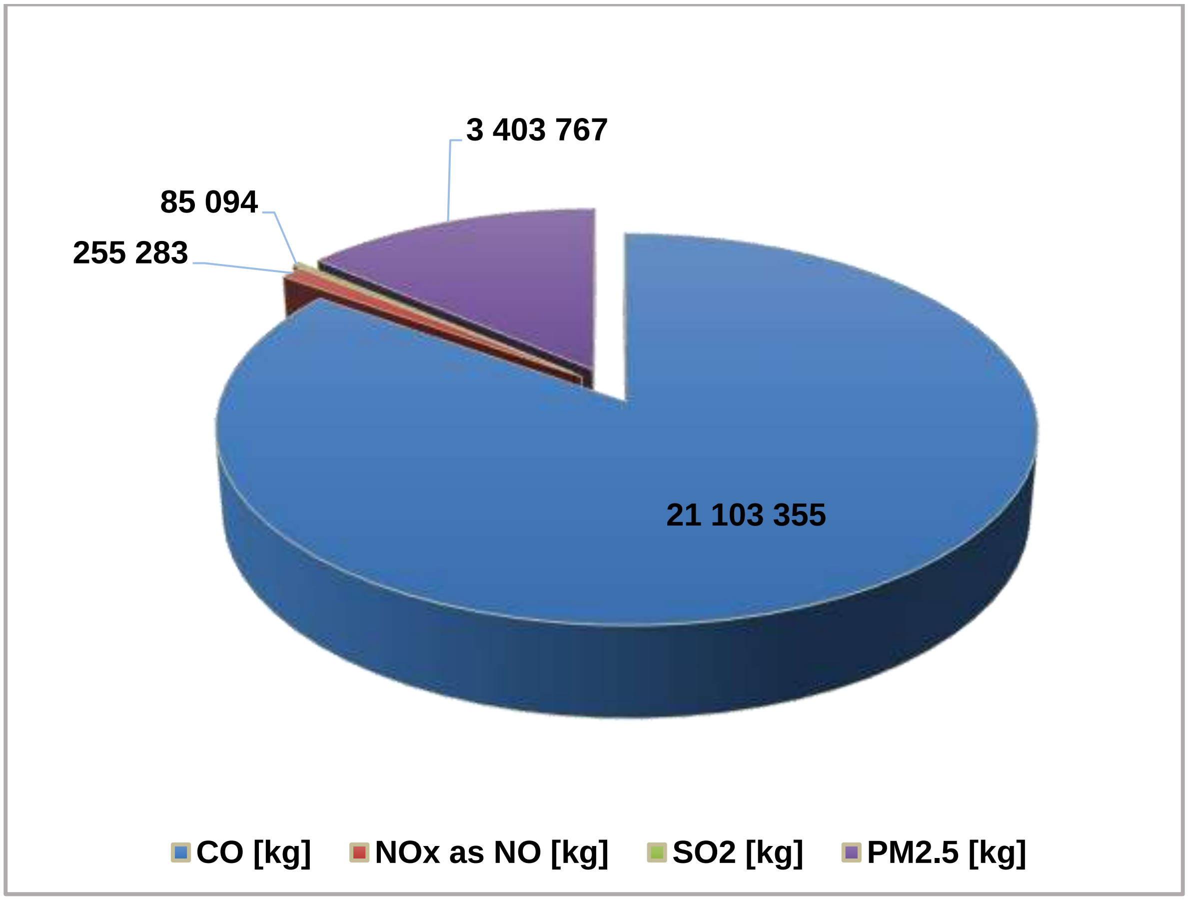


Figure 49: Annual emissions (kg per year) from sugarcane burning in KZN.

6.4.4 Proposed Management Interventions

- Public awareness should be raised about the dangers associated with uncontrolled fires and the implications for air quality and human health.
- Plan and develop fire early warning systems.
- Plan and provide for a buffer zone between residential and vegetation areas.
- Plan and provide access roads for fire trucks in informal settlements.
- Ensure compliance with fire regulations and by-laws.
- Promote grass cutting and baling in agricultural, protected and road reserve areas, to be used as a resource e.g., fodder, compost, smokeless fuel.
- Identify the role of fire services to assist in air pollution control.
- Each local Fire Department should maintain and update a database of the locations of veld fires and the extent of the areas burnt.

- Establish a biomass burning advisory line which will help people to burn firebreaks on days that are not hazardous to air quality and when weather conditions are not likely to cause runaway fires.
- Plan and provide fire breaks in high-risk vegetation areas.
- A complaints line should be set up for reports regarding negligent fire starters.
- Obtain information on burning as an agricultural practice in the province using the Advanced Fire Information System (AFIS) and other resources. The province could establish relationships with systems operators (e.g., the CSIR, ARC, etc.) to help identify, manage, and quantify the emissions from biomass burning.
- Model and determine the contribution of biomass burning to the ambient pollutant load.
- Undertake a health risk assessment related to exposure to biomass burning atmospheric pollutants.
- Motivate for research on veld management practices/strategies for alternatives to burning and on the relationship between fire and environmental factors.
- Optimise the use of existing regulatory tools to prevent agricultural burning in poor conditions.
- Motivate for specific conditions for creating fire breaks in Veld and Forest Fires Act.
- Motivate for regulation of burning in sensitive ecosystems and surrounding areas.

6.5 Agricultural Activities

6.5.1 Background to Agricultural Emission Sources

In 2018 the KZN agricultural sector contributed 4.4% of the provincial economic production which is approximately 30% of South Africa's agricultural output (Column, 2019). KZN produces a variety of agricultural products, mainly sugarcane, maize, grain sorghum, oats, grass for fodder, dry beans, soya beans, wheat, lucerne, potatoes, oranges, lemons and other citrus and subtropical fruits.

According to the Bureau for Food and Agricultural Policy (BFAP), KZN produces about 30% of the dairy herd for South Africa, and a 12% share of chicken eggs and pigs (Sihlobo, 2022). The province has a good climate for agriculture and has fertile soils. KZN has 1.8 million hectares of land utilised for agriculture which accounts for 19.5% of the total area of the province. Agricultural activities can be sub-divided into two groups – crop farming and livestock farming. Commercial agricultural land is comprised of arable land (0.9 million hectares) for crops and grazing land (0.5 million hectares) for livestock and game (StatsSA, 2020).

Crop Farming

There are four main sources of emissions from crop farming and agricultural soils (pollutants emitted denoted in brackets):

- Fertiliser application (NH_3).
- Soil microbial processes (NO).
- Crop processes (NH_3 and NMVOCs).
- Soil cultivation and crop harvesting (PM).

NH_3 emissions can cause acidification and eutrophication of natural ecosystems (EMEP/EEA, 2013). NH_3 may also form secondary PM. NO and NMVOCs play a role in the formation of O_3 which, near the surface of the Earth, can have an adverse effect on human health and plant growth. PM emissions also have an adverse impact on human health (EMEP/EEA, 2013).

Emissions of gaseous NH_3 and NO from crop farming and agricultural soils are generally closely related to the amount of nitrogen fertiliser applied. A portion of N contained in the fertilizers is emitted into the atmosphere as NH_3 and NO. The emissions of NH_3 are influenced by the types and amounts of fertilizers, methods and timing of fertilizer application, types of soils to which fertilizers are applied, and climate factors. In the absence of detailed information related to these influencing factors, the emissions of NO can be calculated as a fraction of the total amount of N fertilizers applied (SCMEIEA, 2011).

Standing crops emit NMVOC during the growing season (EMEP/EEA, 2019).

Windblown dust emissions from agricultural land can be influenced by non-climatic factors (Mansell, et al., 2003) as follows:

- Long-term effects of irrigation (i.e., soil “clodiness”).
- Short-term effects of irrigation (i.e., surface soil wetness).
- Crop canopy cover.
- Post-harvest vegetative cover (i.e., residue).
- Post-harvest replanting (i.e., multi-cropping).

- Bare soil (i.e., barren areas within an agricultural field that do not develop crop canopy for various reasons).
- Field borders (i.e., bare areas surrounding and adjacent to agricultural fields).

This level of information, however, is not available for agricultural activities in KZN. Furthermore, PM emissions from soil cultivation and crop harvesting together account for > 80% of total PM_{10} emissions from tillage land.

Livestock Farming

There are four main sources of emissions from livestock farming (pollutant emitted denoted in brackets):

- Livestock housing (PM).
- Livestock manure management (NH_3, methane (CH_4) and nitrous oxide (N_2O)).
- Land spreading of manure (nitrogen oxides (NO_X) and NH_3).
- Land spreading of urea (NH_3 and CO_2).

Information on manure and urea management was not available for KZN, therefore, only PM emissions were calculated.

6.5.2 Methodology for Quantifying Emissions from Agricultural Activities

Crop Farming and Agricultural Soil Emissions

The source strength of soil cultivation and crop harvesting depends on the crop, soil type, cultivation method and weather conditions before and during working. Because of the absence of information on crop, soil type and cultivation method, Tier 1 emission factors, based on cultivated area were used in this study.

NO_X and NH_3 emissions from unfertilised crops, with the exception of legumes, are usually considered to be negligible and all fertilized crops are treated the same. The Tier 1 approach for NH_3 and NO emissions from crop farming and agricultural soils use the general equation.

Equation 6: NH3 and NO emissions from agricultural practices

$$E_{pollutant} = AR_{fertiliser\_applied} \times EF_{pollutant}$$

Where:

- $E_{pollutant}$: amount of pollutant emitted (kg x $year^{-1}$).
- $AR_{fertiliser\_applied}$: amount of N applied (kg x $year^{-1}$).
- $EF_{pollutant}$: Emission factor of pollutant (kg x kg^{-1}).

Fertilizer use was calculated using nitrogen fertilizer use rates per crop type (Table 25). Crops such as grain sorghum and other summer cereals, barley and other winter cereals, teff and other fodder crops and seeds were categorised as 'other pastures'. The emission factors used were derived from the EMEP/EEA (Table 26).

Table 25: Proportions of crops fertilized, and average rates of nitrogen fertilizer use in South Africa (FAO, 2005; FSSA, 2004).

Description	Percent fertilized (%)	N Fertilizer Use Rate (kg/ha of the fertilized area)
Wheat	100	30
Sunflowers (Oil seeds)	85	15
Soybeans	40	7
Sugarcane	95	92
Lucerne	90	15
Other Pastures	30	50
Subtropical fruits/nuts	100	180
Groundnuts		Groundnuts are leguminous therefore fix N and don't need N fertilizer
Citrus	100	80
Deciduous Fruit	100	110
Vegetables	100	170
Potatoes	100	170

Table 26: Pollutant Emission Factors from Fertilizer Application (EMEP/EEA, 2016).

Air pollutant	NO	NH_3	PM_{10}	$PM_{2.5}$
Units	kg/kg fertilizer-N applied		kg/ha	
Emission Factor	0.04	0.05	1.56	0.06

The Tier 1 approach for PM emissions from crop farming and agricultural soils uses the general equation:

Equation 7: PM Emissions from Agricultural Practices

$$E_{pollutant} = AR_{area} \times EF_{pollutant}$$

Where:

- $E_{pollutant}$: amount of pollutant emitted (kg x year^{-1}).
- AR_{area}: area covered by crop (ha).
- $EF_{pollutant}$: EF of pollutant (kg x ha^{-1} x year^{-1}).

It was decided to use emission factors for Greece and Great Britain (Table 27) for the crops grown in the KZN as country-specific emission factors are not available for South Africa. Where possible, emission factors for Greece were preferred over those for Great Britain as the annual rainfall in Greece is closer to that of South Africa. No current crop data was available for KZN. Therefore, Agricultural Census data for commercial areas within KZN was used (StatsSA, 2017).

It should be noted that PM_{10} emissions from soil cultivation and harvesting originate at the sites where the tractors and other machinery operate and are thought to consist of a mixture of organic fragments from the crop, soil, minerals and organic matter. Total dust emissions contain only small proportions of PM_{10} and $PM_{2.5}$ (EMEP/EEA, 2016). It is important to note that the PM emissions calculated here are, therefore, intended to reflect the amounts found immediately adjacent to the field operations. A substantial proportion of this emission will normally be deposited within a short distance of the location at which it is generated.

Table 27: Emission Factors for PM for Greece and Great Britain (IIASA, 2000).

Crop types	Greece				Great Britain	
	PM_{10} (kg/ha/year)			$PM_{2.5}$ (kg/ha/year)	PM_{10} (kg/ha/year)	$PM_{2.5}$ (kg/ha/year)
	Land Preparation	Harvest	Total	Total	Total	Total
Barley	4.15	1.95	6.1	1.35	6.945	1.136
Fruit	-	-	-	-	0	0
Maize	5.25	1.88	7.13	1.58	-	-
Oil seeds	-	-	-	-	6.945	1.136
Other Cereals	4.15	1.23	5.38	1.19	6.945	1.136
Pastures	0	0	0	0	0	0
Potatoes	25.56	1.91	27.46	6.1	2.87	0.231
Pulses	-	-	-	-	6.945	1.136

Rye	4.15	1.23	5.38	1.19	-	-
Soya	8.63	1.88	10.51	2.33	-	-
Stone fruits	0.08	0.09	0.17	0.04	-	-
Sugar beets	25.56	1.88	27.44	6.09	2.82	0.22
Vegetables	-	-	-	-	2.82	0.22
Vineyards	1.68	0.19	1.87	0.42	-	-
Wheat	4.15	2.25	6.4	1.42	9.48	1.698

Livestock Farming

Emissions from livestock were calculated as follows:

Equation 8: Emissions from livestock

$$E_{pollutant\_animal} = AAP_{animal} \times EF_{pollutant\_animal}$$

Where:

- $E_{pollutant\_animal}$: amount of pollutant emitted (kg year^{-1}).
- AAP_{animal}: annual average animal population.
- $EF_{pollutant\_animal}$: EF of pollutant (kg year^{-1}).

The numbers of commercial cattle, chickens, ostriches, pigs, goats, sheep, and game in the different district municipality areas within KZN were sourced from the Census of commercial agriculture, 2017 for KZN (StatsSA, 2020). PM_{10} and $PM_{2.5}$ emission factors for cattle, chicken, pigs, goats and sheep (Table 28) were taken from the European Environmental Agency (EEA) emission factor database (EMEP/EEA, 2016).

Table 28: Livestock emission factors (EMEP/EEA, 2016).

Animal types	PM_{10} (kg/head)	$PM_{2.5}$ (kg/head)
Cattle	0.45	0.295
Pigs	0.155	0.008
Sheep/Goats	0.06	0.02

6.5.3 Agricultural Activities Emission Inventory Results

Crop Farming and Agricultural Soil Emissions

NO and NH_3 emissions from crop farming were calculated in terms of fertilizer application. A total of ~29 million kilograms of nitrogen fertilizer is applied for agricultural activities per annum. The application of fertilizer results in approximately 1.5 million kilograms of NH_3 emissions and 1.2 million kilograms of NO emissions (Table 29).

Table 29: NO and NH3 Emissions from Fertilizer Application.

Municipality	Fertilizer Applied (kg)	Area Fertilized (ha)	Emissions from Fertilizer Application (kg)	
			NO	NH_3
Amajuba	1 566 337	47 011	62 653	78 317
eThekwini	3 053 806	31 138	122 152	152 690
Harry Gwala	1 610 915	48 840	64 437	80 546
iLembe	2 923 753	32 229	116 950	146 188
King Cetshwayo	2 934 735	30 143	117 389	146 737
Ugu	2 299 715	30 293	91 989	114 986
uMgungundlovu	4 519 331	61 597	180 773	225 967
uMkhanyakude	615 763	5 951	24 631	30 788
uMzinyathi	2 169 315	53 840	86 773	108 466
uThukela	5 255 375	147 312	210 215	262 769
Zululand	2 058 723	48 362	82 349	102 936
Total	**29 007 766**	**536 716**	**1 160 311**	**1 450 388**

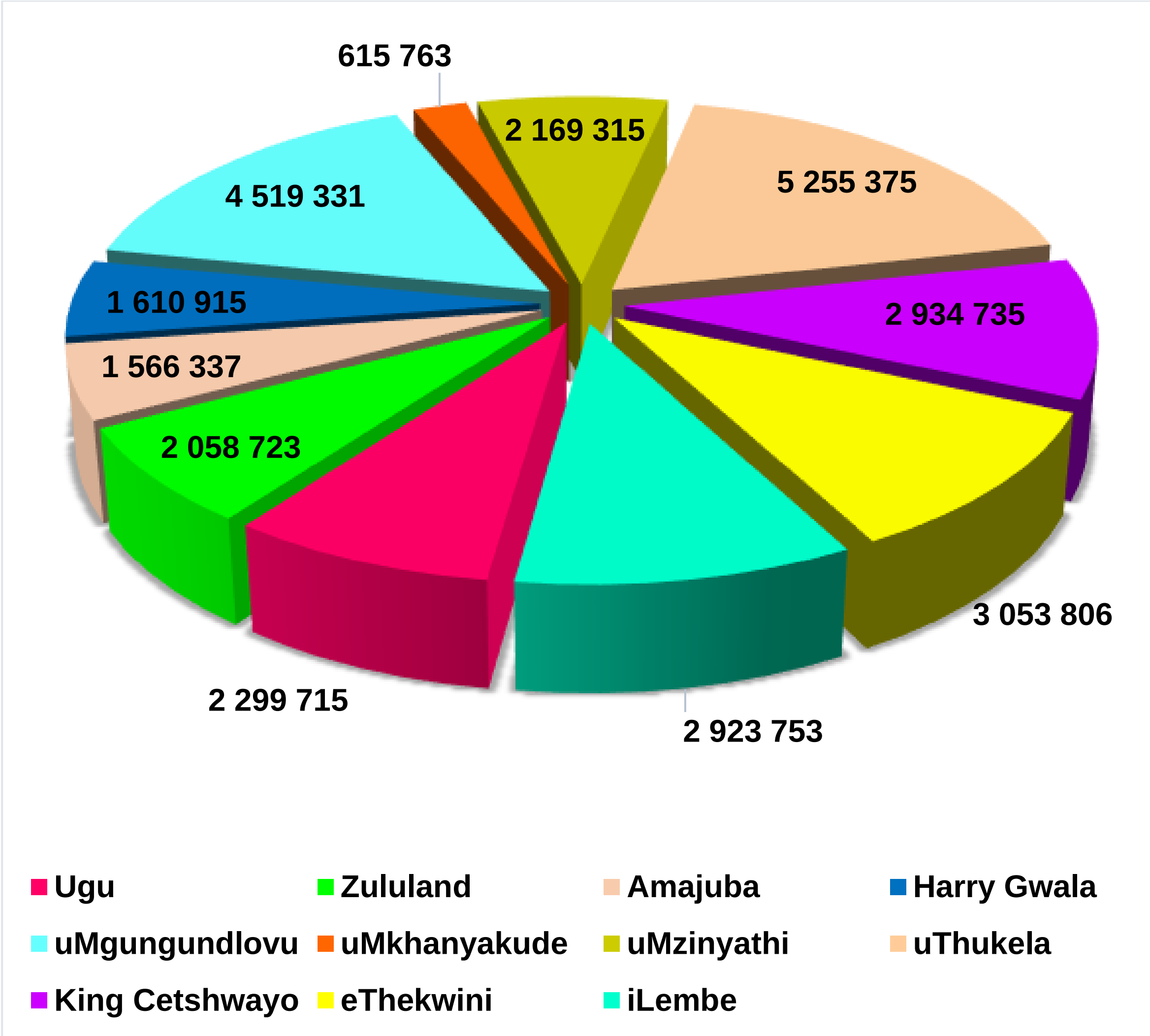


Figure 50: Proportions of fertilizer application per District Municipality within KZN.

Crops identified in KZN include grain/cereals, oil seeds, legumes, maize, fodder, wheat, oats, lucerne, sugarcane, potatoes, vegetables, subtropical fruits, other citrus fruits and deciuous fruits. PM emissions were calculated from the application of fertilizers as well as from the land preparation and harvesting of these crops by crop type and by District Municipality (Table 30 and Table 31). Crop farming in KZN accounts for over 4 million kilograms of PM_{10} emissions and ~8 hundred-thousand kilograms of $PM_{2.5}$ emissions. uThukela has the largest area of land used for crop farming (Figure 51) and hence the highest emissions (Table 31). Sugarcane has the highest proportion of cultivated land in KZN accounting for 30% of total crop production area, followed by grain/cereal crops (25%) and maize (21%), these three crops contribute significantly to the total crop farming emissions in the province. (Table 30 and Figure 52).

Table 30: Particulate matter emissions from agricultural crops.

Emissions by Crop type (kg)		
Crop	PM_{10}	$PM_{2.5}$
Grain/cereals	937 490	168 856
Oil seeds	205 294	28 869
Legumes	17 724	2 492
Maize	964 043	181 937
Fodder	292 792	52 736
Soya beans	258 938	51 273
Wheat	121 724	22 632
Oats	8 710	1 569
Lucerne	451	63
Sugarcane	1 412 464	266 564
Potatoes	38 132	8 094
Vegetables	57 470	3 674
Subtropical fruits	7 812	300
Other citrus fruits	3 496	134
Decidious fruit	11	0.4
	4 326 550	**789 195**

Table 31: Total particulate matter emissions from District Municipalities.

Emissions by District Municipality (kg)		
District Municipality	PM_{10}	$PM_{2.5}$
Amajuba	332 199	57 744
eThekwini	240 494	43 310
Harry Gwala	362 290	66 036
iLembe	270 620	50 017
King Cetshwayo	320 099	58 376
Ugu	245 350	45 346
uMgungundlovu	499 524	92 379
uMkhanyakude	44 352	8 128
uMzinyathi	396 854	70 177
uThukela	1 097 073	197 240
Zululand	277 384	48 028

Emissions by District Municipality (kg)		
District Municipality	PM_{10}	$PM_{2.5}$
Total	4 086 238	736 782

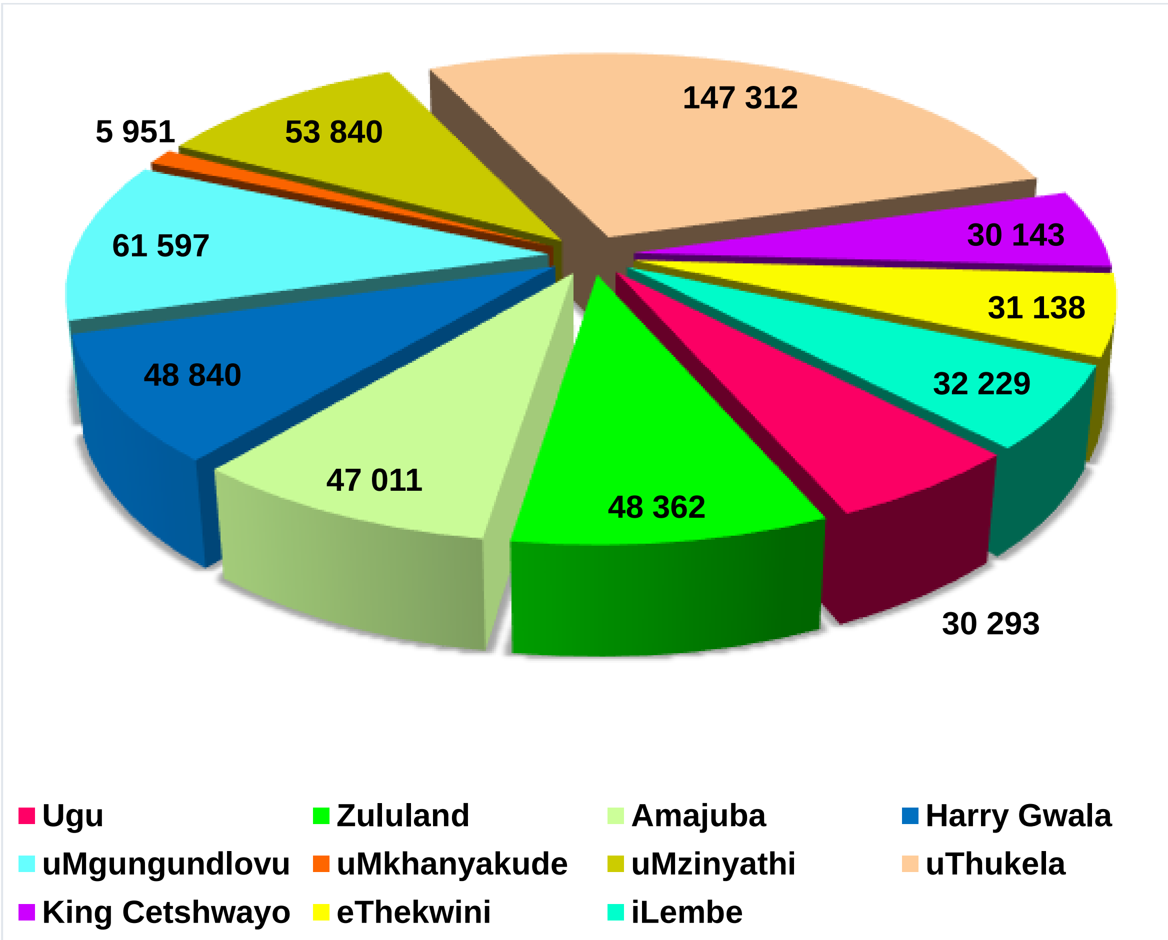


Figure 51: Proportions of Crop Land per District Municipality within KZN.

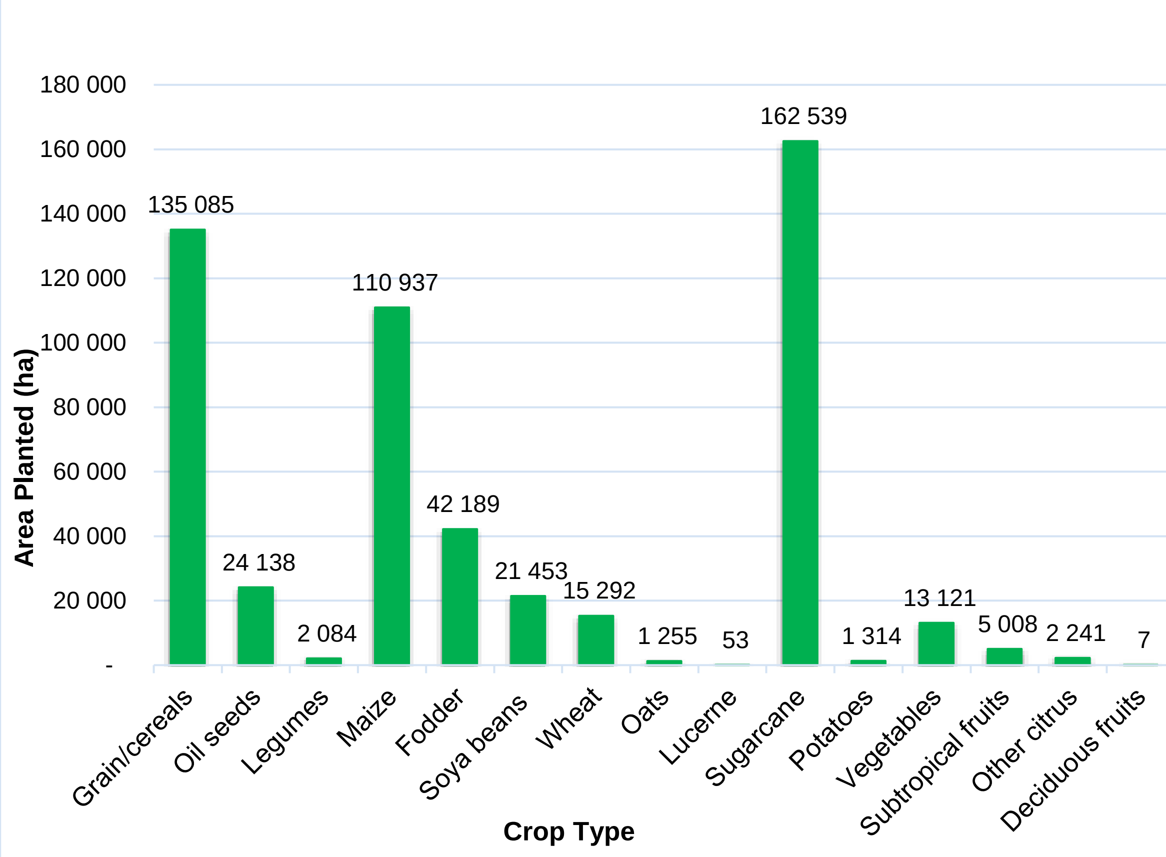
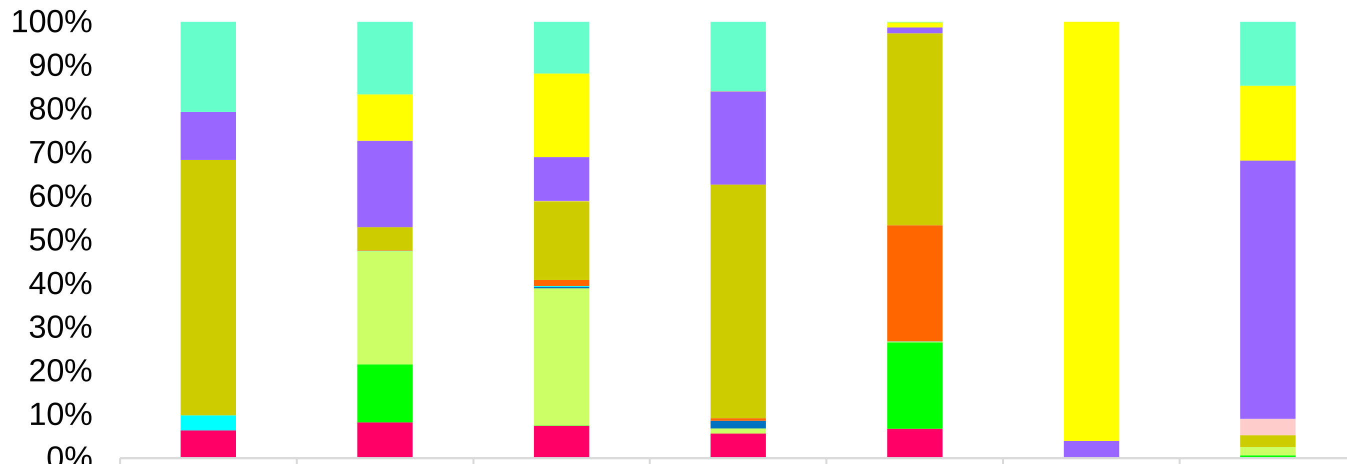


Figure 52: Proportions of the area planted per crop in KZN.

Livestock Farming

The uMgungundlovu DM has the highest number of livestock on farms as of 2018, followed by the Ugu DM and eThekwini DM. Emissions from livestock farming were calculated at district level (Figure 53 and Table 32).



	Goats	Sheep	Cattle	Pigs	Chickens	Ostriches	Game
Zululand	400	12 951	82 774	38 827	7 235		1 928
uThukela		8 277	133 673	89	72 058	294	2 247
uMzinyathi	213	15 407	70 405	52 081	86 358	12	7 774
uMkhanyakude			463		83		491
uMgungundlovu	1 134	4 111	125 998	130 476	2 758 699		360
Ugu		93	9 603	1 422	1 669 966		
King Cetshwayo	67	30	1 636		2 876		
iLembe			1 870	4 405			
Harry Gwala		20 243	219 915	2 729	10 490		250
eThekwini		10 288	331		1 240 736		80
Amajuba	123	6 397	51 844	13 803	424 224		4

Figure 53: Number of livestock in the District Municipalities within KZN

Table 32: Total emissions from livestock.

District Municipality	Number of Heads						Estimated Emissions (kg/year)	
	Goats	Sheep	Cattle	Pig	Chickens	Ostriches	PM_{10}	$PM_{2.5}$
Amajuba	123	6397	51 844	13 803	424 224		45 799	35 473
eThekwini		10 288	331		1240 736		59 081	58 618
Harry Gwala		20 243	21 9915	2729	10 490		101 092	65 795
iLembe			1870	4 405	0		1524	587
King Cetshwayo	67	30	1636		2 876		877	620
Ugu		93	9 603	1 422	1 669 966		83 036	81 335
uMgungundlovu	1 134	4 111	125 998	130 476	2 758 699		206 896	167 977
uMkhanyakude			463		83		212	140
uMzinyathi	213	15 407	70 405	52 081	86 358	12	44 751	25 558
uThukela		8 277	133 673	89	72 058	294	64 064	43 000
Zululand	400	12 951	82 774	38 827	7 235		44 408	25 336
Total	**1 937**	**77 797**	**698 512**	**243 832**	**627 2725**	**306**	**651 741**	**504 439**

6.5.4 Proposed Management Interventions

- Public awareness should be raised about the dangers associated with uncontrolled fires and the implications for air quality and human health.
- Plan and develop fire early warning systems.
- Plan and provide for a buffer zone between residential and vegetation areas.
- Plan and provide access roads for fire trucks in informal settlements.
- Ensure compliance with fire regulations and by-laws.
- Promote grass cutting and baling in agricultural, protected and road reserve areas, to be used as a resource e.g., fodder, compost, smokeless fuel.
- Identify the role of fire services to assist in air pollution control.
- Each local Fire Department should maintain and update a database of the locations of veld fires and the extent of the areas burnt.

- Establish a biomass burning advisory line which will help people to burn firebreaks on days that are not hazardous to air quality and when weather conditions are not likely to cause runaway fires.
- Plan and provide fire breaks in high-risk vegetation areas.
- A complaints line should be set up for reports regarding negligent fire starters.
- Obtain information on burning as an agricultural practice in KZN using the Advanced Fire Information System (AFIS) and other resources. The province could establish relationships with systems operators (e.g., the CSIR, ARC, etc.) to help identify, manage, and quantify the emissions from biomass burning.
- Model and determine the contribution of biomass burning to the ambient pollutant load.
- Undertake a health risk assessment related to exposure to biomass burning atmospheric pollutants.
- Motivate for research on veld management practices/strategies for alternatives to burning and on the relationship between fire and environmental factors.
- Optimise the use of existing regulatory tools to prevent agricultural burning in poor conditions.
- Motivate for specific conditions for creating fire breaks in Veld and Forest Fires Act.
- Motivate for regulation of burning in sensitive ecosystems and surrounding areas.

6.6 Denuded Land

6.6.1 Background to Denuded Land Emission Sources

A source of PM pollution is windblown dust from denuded land. Windblown dust emissions from denuded land are fraught with complexities – from the definition of denuded land to the quantification of the emission (Maricopa, 2011):

> *"there are many factors that control the production of windblown dust beyond wind speed velocities and disturbance levels that cannot be directly accounted for in this dust scheme (e.g., soil texture, soil moisture, topography, land use, etc.). Data for these factors can be limited, non-existent or unreliable. It is also unknown what degree of importance each of these factors have when they combine in the processes that contribute to the production of windblown dust."*

For the purposes of this report, both the 'erosion dongas' and the 'bare non-vegetated' land-cover categories from the National Land-Cover Data Set (DFFE, 2020) were included in the area defined as denuded land. Based on this classification, denuded land comprises approximately 2 124.31 km^2 of the total area of the KZN (Figure 54).

6.6.2 Methodology for Quantifying Emissions from Denuded Land

Denuded land was extracted from the base dataset, converted to shapefiles and the area (km^2) calculated. The uMkhanyakude DM has the largest area of denuded land, followed by the Zululand DM and uMzinyathi DM (Figure 55).

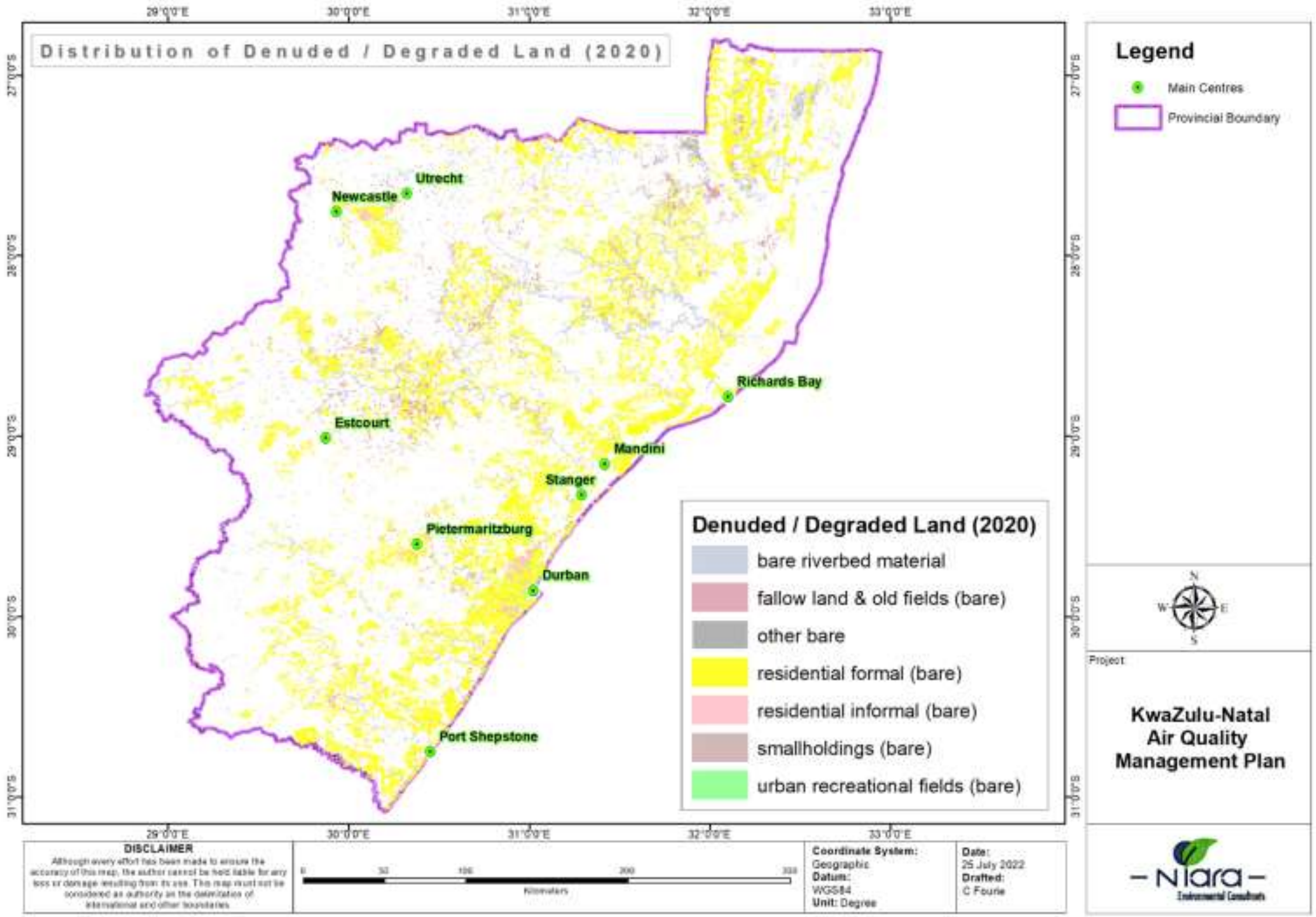


Figure **54: Distribution of denuded/degraded land in KZN.**

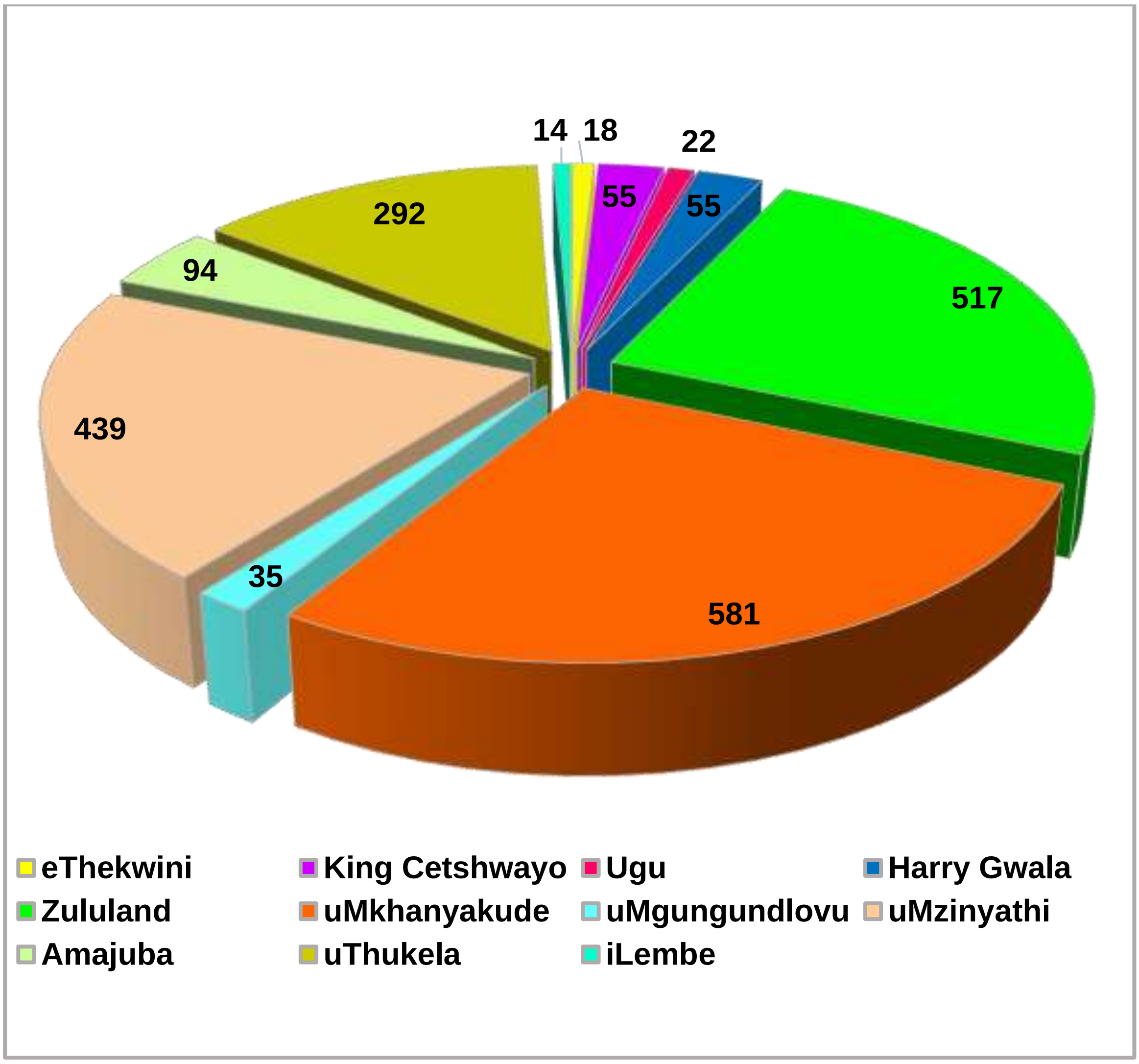


Figure 55: Area of denuded land (km2) per district municipality in KZN.

Given the lack of detailed information required to perform a complex estimation of emissions from denuded land, the approach taken in this study is to estimate the PM_{10} and $PM_{2.5}$ emissions of denuded land using a worked example from the literature (Maricopa, 2011). The emission factor for denuded land is thus calculated as follows:

Equation 9: Denuded Land Emission Factor

$$EF_{Pollutant} = ER_{Pollutant}/A$$

Where:

- $EF_{Pollutant}$: The estimated emission factor for Denuded Land (tonnes x km^{-2} x $year^{-1}$).
- $ER_{Pollutant}$: Average emission rate Vacant Land for the 2008 Maricopa County study (tonnes x $year^{-1}$) (Maricopa, 2011).
- A: The total area of vacant land identified in the Maricopa County study (km^2).

Table 33: Emission factors denuded land (Maricopa, 2011).

Pollutant	tonnes/km²/year
$PM_{2.5}$	0.054
PM_{10}	0.360

6.6.3 Denuded Land Emission Inventory Results

Denuded land in KZN contributes approximately 765 tonnes of PM_{10} emissions and 115 tonnes of $PM_{2.5}$ emissions (Table 34).

Table 34: Denuded land particulate emissions in KZN.

District Municipalities	Area of Denuded Land (km²)	Estimated Emissions (tonnes/year)	
		PM_{10}	$PM_{2.5}$
Amajuba	94	33.96	5.09
eThekwini	18	6.62	0.99
Harry Gwala	55	19.79	2.97
iLembe	14	5.18	0.78
King Cetshwayo	55	19.96	2.99
Ugu	22	8.00	1.20
uMgungundlovu	35	12.62	1.89
uMkhanyakude	581	209.29	31.39
uMzinyathi	439	158.17	23.73
uThukela	292	105.01	15.75
Zululand	517	186.13	27.92
TOTAL	**2 124.31**	**764.75**	**114.71**

6.7 Mines and Quarries

6.7.1 Background to Mining Emission Sources

The mining industry in KZN consists mainly of sand and coal mining. Approximately 60% of the total surface mining area is related to sand mining, and the remaining 40% is related to coal mining. The coal mines are situated in Zululand, uMkhanyakude, uMzinyathi and Amajuba (Figure 56**).** PM is the main pollutant emitted by both sand and coal mines with sources of PM including the use of vehicles on unpaved and paved roads for transporting ore, personnel, waste rock, etc.; blasting; overburden stripping; ore and overburden handling; crushing and screening of ore; and wind entrainment from stockpiles (US EPA, 1995 c11s9). The total area of mined land was extracted from the National Land-Cover Data Set (DFFE, 2020). Although this would include other types of mineral mining and quarries, distinguishing between the different types of mines was not possible.

Spontaneous combustion of coal incidents are common in the South African coal mining industry in both underground and surface coal mining. These events are expected to increase in the future due to factors such as increased mining rates, mining on previously worked seams and the need for higher ventilation pressures (Genc, B. and Cook, A., 2015). Following extraction, the sizes of the coal particles are inevitably reduced, increasing the surface area exposed to oxidation and therefore increasing the risk of spontaneous combustion (Phillips, Uludag, & Chabedi, 2011). The spontaneous combustion of coal results in many of the same types of emissions that arise from coal combustion in power plants but, since there are no control technologies in place, the emission factors are generally higher for spontaneous combustion (Sloss, 2013). Nevertheless, because coal fires are very dynamic and irregular by nature, and because of variations in the chemical composition of different coal seams and variability in the composition of discard dumps, it is virtually impossible to quantify emissions from spontaneous combustion. If the composition of a discard dump were known, unrealistic assumptions such as complete and uniform combustion over a set period of time would have to be made to predict emissions. Furthermore, there are no known national or international methods prescribed for quantifying emissions from spontaneous combustion.

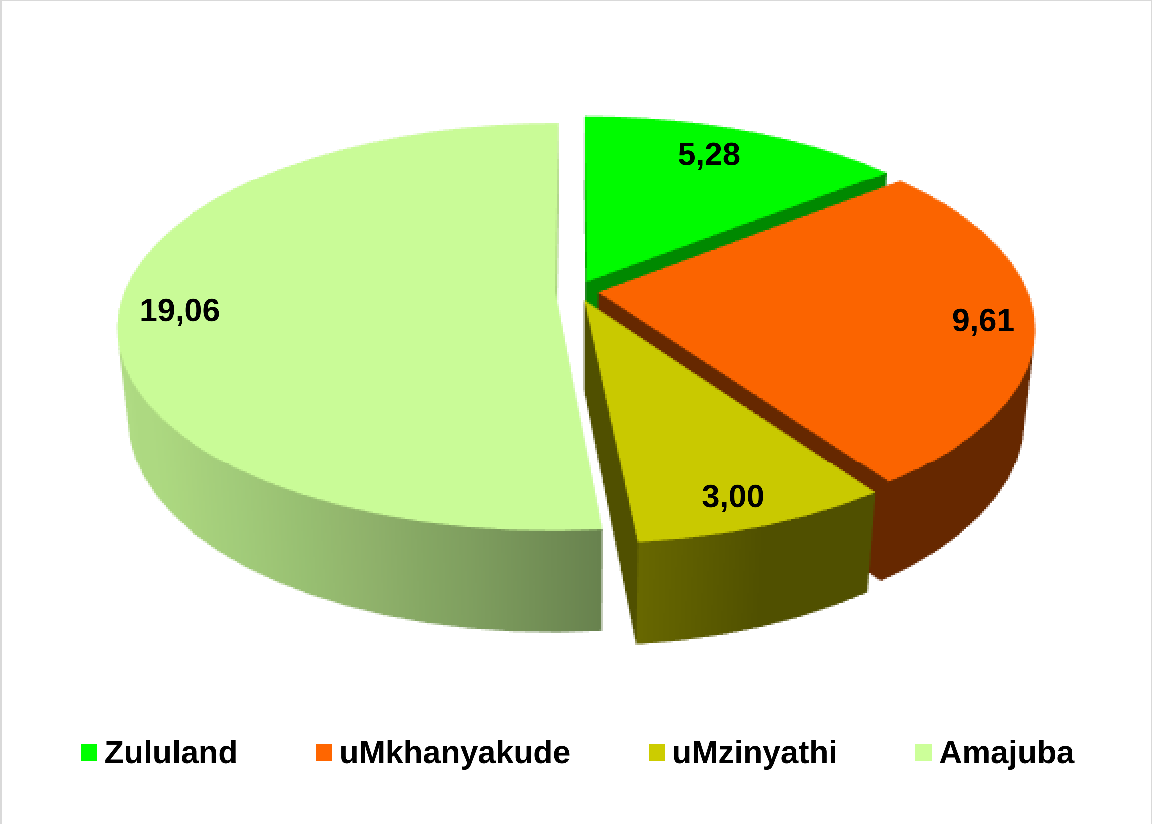


Figure 56: Area (km2) of coal mining within the District Municipalities in KZN.

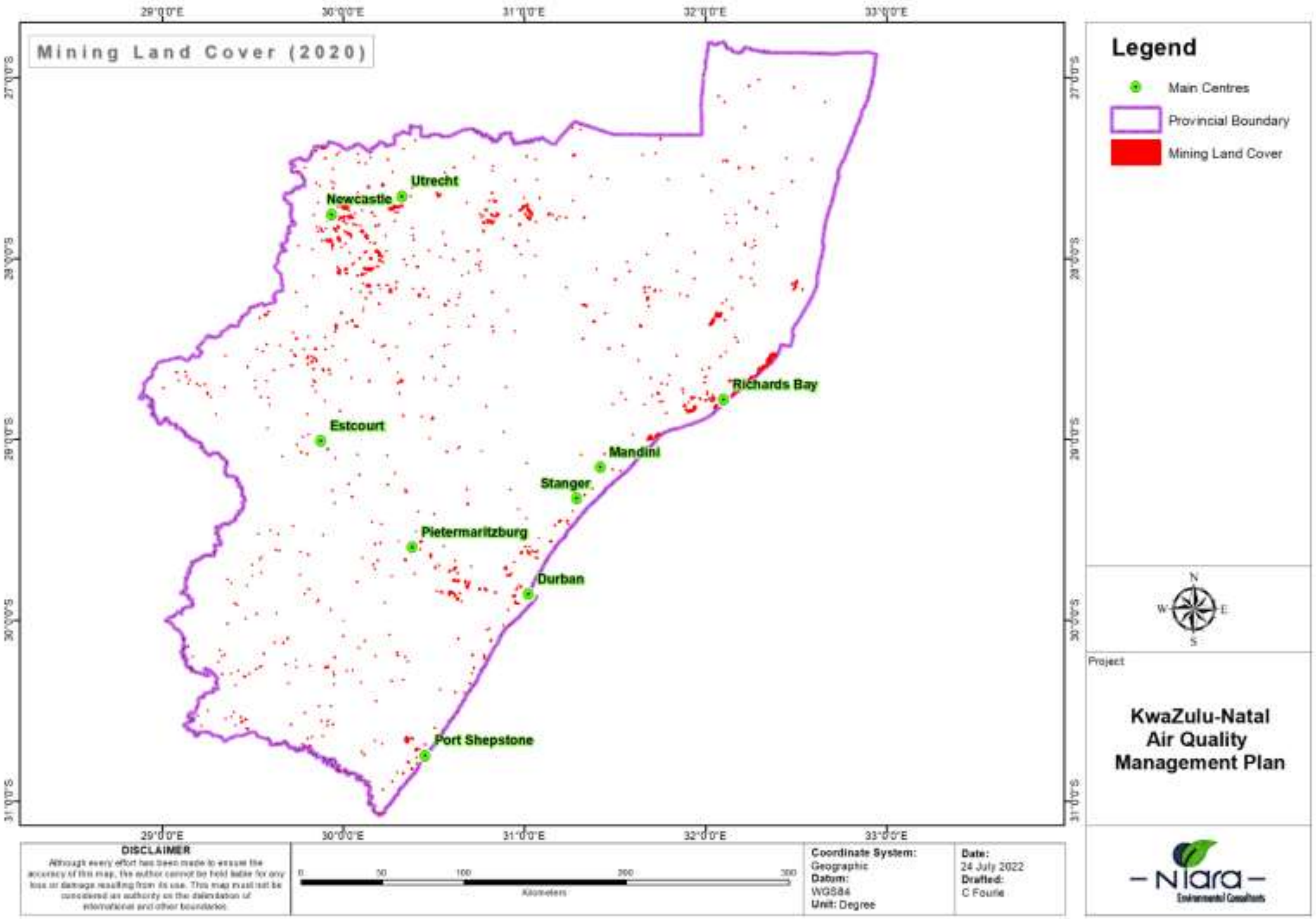


Figure 57: Distribution of mines and quarries in KZN.

6.7.2 Methodology for Quantifying Emissions from Mining

Mines are required to submit their emissions to the NAEIS system. The information provided by the NAEIS showed that not all mines have yet reported their PM_{10} emissions to the system. A total of 22 350.61 tonnes per year of PM_{10} was reported by 30 mines on the NAEIS. As such, using only the NAEIS mining inventory would be underrepresenting the emissions from mining activities in KZN.

For the purposes of this report, it was assumed that the total area of mining land cover, as extracted from the National Land Cover Data Set (DFFE, 2020), is categorized as sand and coal mining land. Mining activities account for 92 km^2 of the total provincial area. This data was used to calculate the particulate matter emission rate from mining for the province.

Huertas (2012) found that open pit coal mines in northern Columbia are emitting 0.726 and 0.180 kg of TSP and PM_{10}, respectively, per Mg of coal produced. It was also found that these mines are using on average 1.148 m^2 of land per Mg of coal produced per year. From these statistics, an emission factor of 0.157 kg/m^2/year was derived for PM_{10} emissions from coal mines.

Emission factors for sand mining were determined using an Air Quality Impact Assessment for a proposed quarry in South Africa (Table 35). Both the $PM_{2.5}$ and PM_{10} emission rate were determined by multiplying the area by the emissions factor to get an emission rate in tonnes per year.

Table 35: Emission factors for sand mining (Van Basten & Van Nierop, 2018).

Pollutant	Emission Factor (kg/m^2/year)
PM_{10}	0.653
$PM_{2.5}$	0.161

6.7.3 Mining Emission Inventory Results

A surface area of approximately 92 km^2 is affected by mining and quarries in KZN. Sand mining activities account for approximately 35 976 tonnes of PM_{10} emissions and 14 808 tonnes of $PM_{2.5}$ emissions per annum. Emissions from coal mining activities are estimated as 5 7945 tonnes of PM_{10} and 869 tonnes of $PM_{2.5}$ per annum (Table 36). A substantial area of the land mined within the province lies within the King Cetshwayo DM (46%) followed by the Amajuba DM (14%) (Figure 58).

Table 36: Particulate emissions from sand and coal mining in KZN.

District	Mining Area (km^2)	Sand Mining Emissions (metric tonnes/year)		Coal Mining Emissions (tonnes/year)	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Amajuba	26.67	4 964.60	4 288.97	2 988.82	448.32
eThekwini	5.16	3 370.84	830.50		
Harry Gwala	2.39	1 561.53	384.72		
iLembe	1.51	987.12	243		
King Cetshwayo	25.21	16 455.59	4 054.28		
Ugu	3.07	2 004.86	493.95		
uMgungundlovu	2.91	1 901.95	468.60		
uMkhanyakude	9.91	197.46	1 594.26	1 506.79	226.02
uMzinyathi	4.01	661.64	645.51	470.38	70.56
uThukela	3.99	2 603.32	641.40		
Zululand	7.23	1 267.20	1 162.20	828.64	124.30
Total	**92.07**	**35 976.11**	**14 807.59**	**5 794.64**	**869.20**

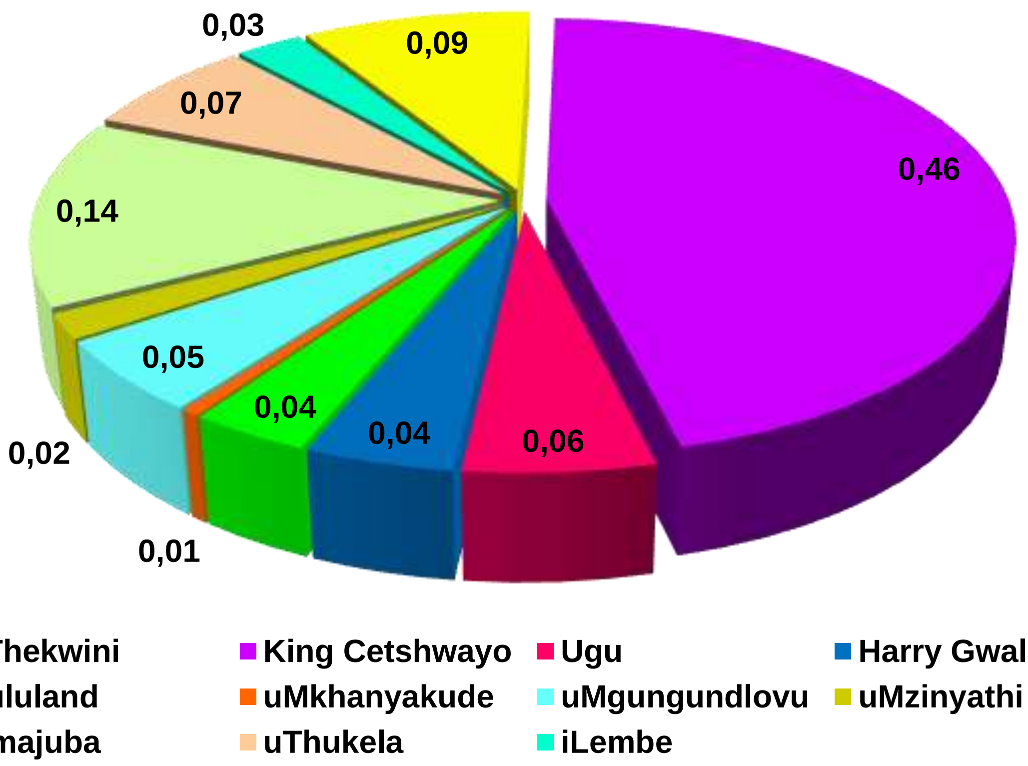


Figure 58: Percentage of mining land within the District Municipalities in KZN.

6.7.4 Proposed Management Interventions:

Possible emission reduction interventions that can be employed by mining companies include, but are not limited to:

- Wet suppression or chemical surface treatment of unpaved haul roads as well as sweeping, vacuum sweeping, or watering of paved haul roads to reduce dust emissions significantly (Olsen, 2015).
- Replacement of haul trucks, as far as possible, with conveyor belts to further reduce dust emissions from transportation of products especially in conjunction with wetting of the product during transport and at transfer points as well as belt cleaning (Colinet, Rider, Listak, Organiscak, & Wolfe, 2010).
- Dust emissions from screening of coal can be controlled by wet suppression (US EPA, 1995).
- Cyclones can be used to control dust emissions from secondary and tertiary crushing of coal (US EPA, 2003).
- Either topical spray consisting of magnesium chloride, other salt solutions, vinyl copolymer or hay crimping can be used to reduce fugitive dust emissions from tailing dam walls (Degner, Horn, Galligan, Bernard, & Jameson, 2017).
- Recovering methane from coal mines simultaneously during the mining of coal, from ventilation air or after an underground mine has been abandoned for utilization as an energy source can reduce methane emissions (Singh & Kumar, 2016).
- Extraction fans with air filters to reduce dust and emissions at beneficiation plants.,
- Planned vehicle maintenance programmes to reduce COx emissions (Dietz, Gardner, Gilligan, Stern, & Van den Bergh, 2009).
- Promote the need for compliance monitoring of abandoned mines.
- Communicate the need for identification and prevention of spontaneous combustion at operating mines.
- Develop a list of active mines and mining operations in the province, with associated emissions inventories. There are currently 129 operating mines in the province which are currently not reporting on the NAEIS. These mines should be approached to comply with reporting regulations.

6.8 Landfills

6.8.1 Background to Landfill Emission Sources

According to the South African Waste Information Centre (SAWIC), the total waste generated in KwaZulu-Natal was 1 809 929.80 tonnes in 2021 with the waste stream comprised of 84.6% of general waste and 15.4% of hazardous waste (SAWIC, 2022). According to South Africa's State of Waste report (2018), KZN is the second largest province with a high contribution of municipal waste in the country, accounting for 17.9% of the total municipal solid waste. There are 107 licensed facilities for the disposal of waste in the province (Figure 59) (Department of Environmental Affairs, 2018).

The disposal of waste at landfill sites has a potentially negative impact on the environment in a number of ways, including emissions to the atmosphere. These emissions can be a nuisance in terms of odour and can cause health impacts. While gas generated from the anaerobic decomposition of landfilled waste is primarily methane (50 to 60%), the primary criteria pollutants emitted are CO and C_6H_6. Significant health effects occur within 500 m of a well-managed landfill (DEA, 2007). The impact of odour can occur between 200 m and 5 km from the landfill depending on the management of the facility (DEA, 2007).

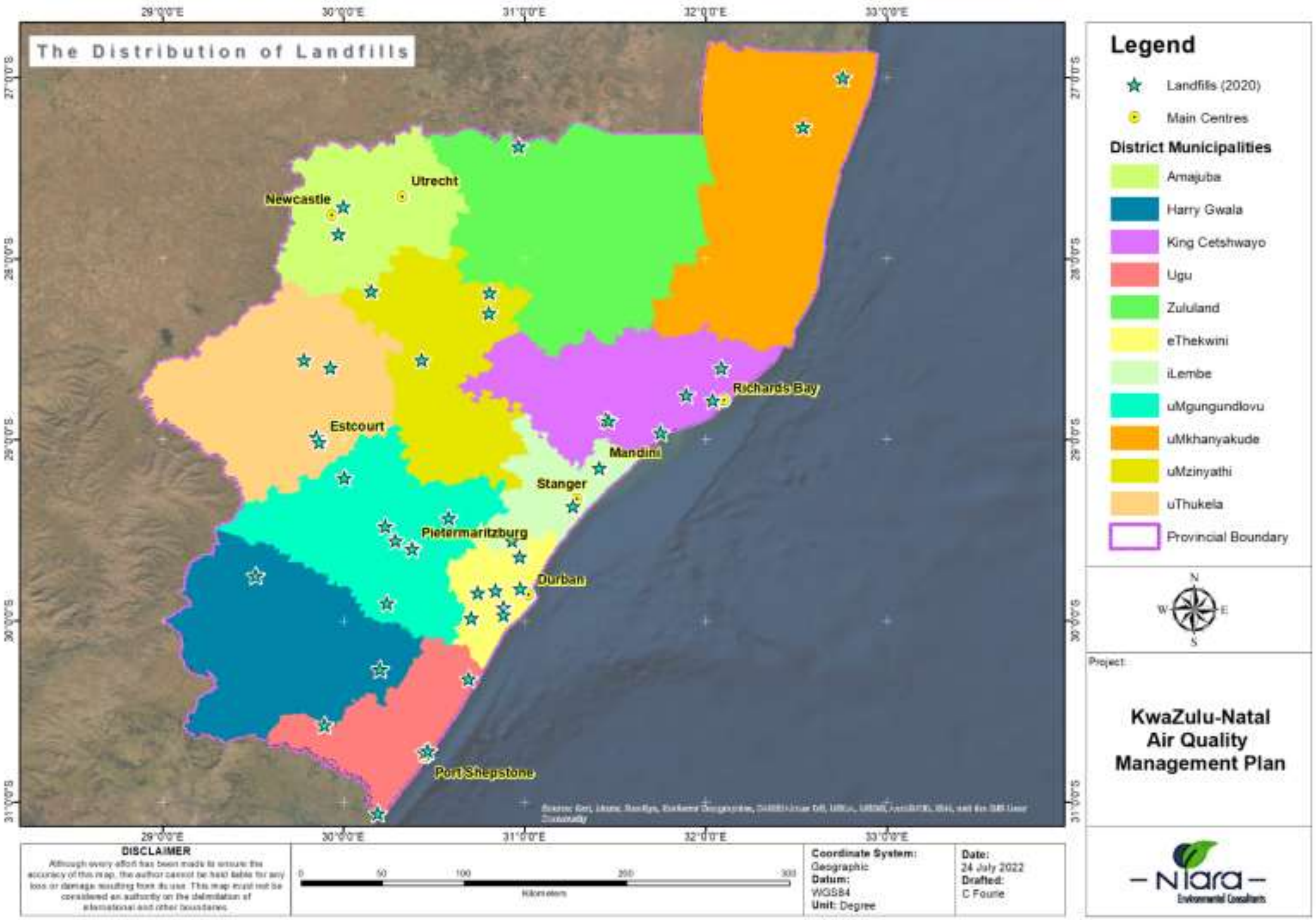


Figure 59: Location of landfills and WWTW in the KZN.

6.8.2 Methodology for Quantifying Emissions from Landfills

Emissions from landfills are a function of the type and volume of waste in the landfill, and the length of time the waste has been in the landfill. Estimates of emission rates from landfills in KZN were calculated using the US EPA Landfill Gas Emissions Model (LandGem); a software package designed to model emissions from anaerobic decomposition of landfilled waste (EPA, 2005). Total tonnes of waste received in the district municipalities' landfills were estimated using the Maximum Rate of Deposition (MRD) method to calculate waste inputs in tonnes per day using the landfill size classification information found in all the landfills with licenses registered with SAWIC. The average tonnes from both the SAWIC and the MRD were used as the annual waste input for each landfill. The LandGem model uses the first order decomposition rate equation to estimate landfill gas emissions over a period of time.

The First- Order Decomposition Rate Equation:

Equation 10: Decomposition equation (EPA, 2005)

$$Q_{CH_4} = \sum_{r=1}^{n} \sum_{j=0.1}^{1} KL_O \left(\frac{M_1}{10}\right) e^{-kt_{i\,j}}$$

Where:

- Q_{CH4} = annual methane generation in the year of the calculation (m^3/year).
- i = 1 year time increment.
- n = (year of the calculation) - (initial year of waste acceptance).
- j = 0.1 year time increment.
- k = methane generation rate ($year^{-1}$).
- L_o = potential methane generation capacity (m^3/Mg).
- M_i = mass of waste accepted in the i^{th} year (Mg).
- t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (decimal years, e.g.,3.2 years).

6.8.3 Landfill Emission Inventory Results

Landfills are known to emit substantial amounts of pollutants which can be harmful to human health and the environment. The estimated carbon monoxide emissions are 76 070 kg/year, NMVOC 96 715 kg/year and Benzene emissions are 2 879 kg/year (Figure 60). eThekwini landfills contribute 47% of the total emissions in the province accounting for the highest total emissions released from landfills (Table 37). Although some burning of waste to reduce waste volumes at landfills has been noted (EDTEA, 2017), these emissions are not accounted for in this section. This may, however, be a significant source of air pollution which should be prevented.

Table 37: Emissions from KZN landfills.

District Municipality	Number of Landfills registered with SAWIC	Estimated Emissions (kg/year)		
		Benzene	CO	NMVOC
Amajuba	3	315	8 312	10 568
eThekwini	9	1 361	35 949	45 705
Harry Gwala	1	11	303	385
iLembe	4	296	7 823	9 946
King Cetshwayo	10	606	16 021	20 369
Ugu	7	44	1 155	1 468
uMgungundlovu	6	122	3 226	4 101
uMkhanyakude	3	85	2 242	2 850
uMzanyathi	6	16	421	535
uThukela	4	16	420	534
Zululand	2	8	199	253
KZN TOTAL		**2 879**	**76 070**	**96 715**

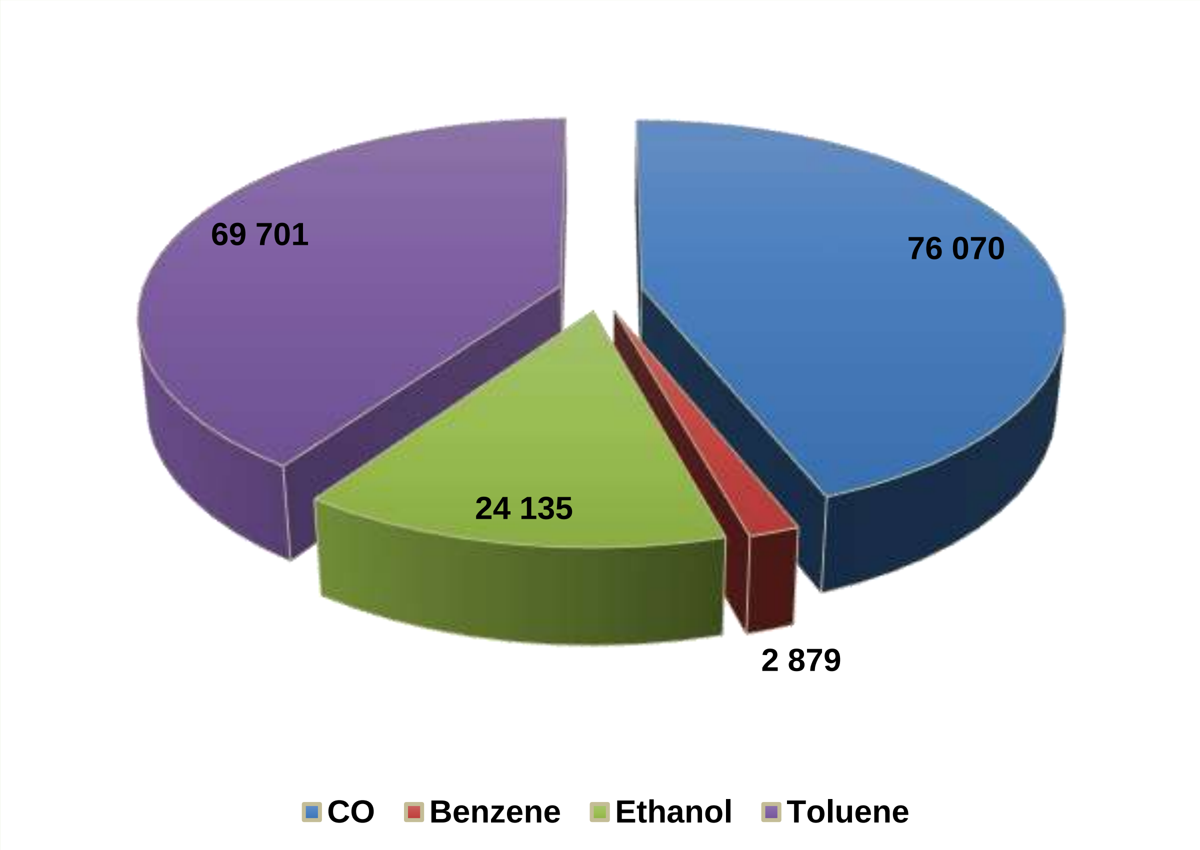


Figure 60: Emissions (kilograms per year) from landfills.

6.8.4 Proposed Management Interventions

Recommended management interventions for landfills include the following:

- Maintain a current database of landfill sites. Landfill sites within KZN needed to be issued with permits to ensure that these landfills are effectively managed and controlled. The responsibility of issuing landfill permits and of ensuring that landfills operate within their permits lies with the province.
- Undertake landfill gas monitoring and management schemes. Up to 57% reduction in methane emissions can be achieved by reducing waste disposal, the separate collection of biodegradable waste, the use of landfill gas for generating power and flaring of landfill gas (Boerboom, Vatamanu, & Zegers, 2010).
- Awareness campaigns around the environmental benefits of waste minimisation and recycling should be promoted. These campaigns should focus on schools with recycling bins and depots installed at each school in the region.
- Proper refuse collection in all areas within the province will also minimise illegal waste dumping and residential waste burning in informal settlements.

6.9 Wastewater Treatment Works

6.9.1 Background to Wastewater Treatment Works Emission Sources

According to the province's 2021 Green Drop report, KZN has 147 wastewater treatment works (WWTW) (Department of Water and Sanitation, 2022) with approximately 44% of households using a flush toilet connected to the public sewerage system (Table 38). The flush toilets are mostly found in urban areas. Of the remaining households, 13% use a pit latrine/toilet without ventilation pipe and 19% use a pit latrine/toilet with ventilation pipe. Only 2.5% of households reported that they do not have any form of toilet facility. According to (Provincial Survery Kwazulu-Natal In Community Survey 2016) eThekwini has the highest proportion of households (71%) using a flush toilet connected to the public sewerage system, followed by the uMgungundlovu District Municipality households (43%) which is also KZN's district municipality with the highest number of households (7.6%) using a flush toilet connected to a septic tank, which is above the 5% average of households using this type of sanitation in other districts (StatsSA, 2016).

The province's Green Drop status is exceptionally low, with only three systems awarded a Green Drop Certificate in 2021 compared to 19 awards in 2013. Overall, uMgungundlovu is the only DM that achieved a municipal green drop score of 86% and the other 10 district municipalities performing below average (<80%). Between 2013 and 2021 the Green Drop scores decreased significantly, from having 34 wastewater systems in the 'excellent and good state' (>80%) to only 17 remaining at that level. Systems in a 'poor state' increased from 15 to 50 systems, while systems in a 'critical state' decreased from 32 to 20 systems. The majority of the 'critical state' systems are managed by the uMkhanyakude, uMzinyathi and Zululand DMs (Department of Water and Sanitation, 2022).

Table 38: Type of sanitation access by household in KZN.

District Municipality	Flush sewerage system	Flush septic tank	Chemical Toilet	Pit with ventilation pipe	Pit without ventilation pipe	Ecological toilet (VIP toilets)	Bucket System	None
Amajuba	60 950	2 834	9 835	20 993	16 972	351	1 092	2 324
eThekwini	780 043	47 365	118 166	42 408	78 494	3 560	24 422	9 510
Harry Gwala	22 719	2 778	25 006	35 358	29 040	240	2 535	2 470
iLembe	39 064	7 429	45 798	39 868	46 059	891	2 654	5 201
King Cetshwayo	61 784	8 806	58 474	58 331	24 604	1 411	1 874	5 486

Ugu	36 356	6 044	14 590	63 201	28 637	3 853	5 760	7 565
uMgungundlovu	120 937	21 432	33 267	55 861	41 170	2 740	1 859	3 867
uMkhanyakude	11 414	3 164	31 236	56 540	26 032	1 054	1 449	15 460
uMzinyathi	25 800	1 178	15 108	55 191	15 508	3 726	3 170	2 937
uThukela	46 888	1 819	27 092	47 204	24 277	1 699	2 833	3 708
Zululand	33 422	3 122	42 465	50 593	20 628	774	3 007	13 901
Total	**1 239 377**	**105 971**	**421 037**	**525 548**	**351 421**	**20 299**	**50 655**	**72 429**

6.9.2 Methodology for Quantifying Emissions from Wastewater Treatment Works

Volatile Organic Compound (VOCs) are the primary pollutants emitted from WWTW. Emissions from WWTW depend on the type of wastewater entering the facility. However, this information was not available in the Green Drop Report (2022) for the WWTW in KZN. Therefore, the emission factor for VOCs (Table 39) from WWTW determined by the Australian NPI (2011) was used in the WWTW emission calculations in this report.

Table 39: Emission Factor for Wastewater Treatment Works (NPI, 2011).

Pollutant	Emission Factor (g/m^3)
VOCs	1.07

6.9.3 Wastewater Treatment Works Emission Inventory Results

Based on a volume of approximately 407 947 031.50 m^3/year of wastewater treated in the KwaZulu-Natal WWTW, VOC emissions are estimated to be 436 503 kg per year. The WWTW in the eThekwini Municipality emit most of the VOC emissions per year (Table 40).

Table 40: VOC emissions from wastewater treatment works in the KZN.

District Municipality	WWTW	Volume Treated (m^3/year)	Estimated VOC Emissions (kg/year)
Amajuba	Utrecht	365 000	390.55
	Charlestown	182 500	195.28
	Madadeni	4 380 000	4 686.60
	New Castle	9 125 000	9 763.75
	Osizweni	5 365 500	5 741.09
	Kilbarchan	365 000	390.55
	Tweediedale	730 000	781.10

District Municipality	WWTW	Volume Treated (m^3/year)	Estimated VOC Emissions (kg/year)
	Durnacol	730 000	781.10
eThekwini	Verulam	4 745 000	5 077.15
	Tongaat Central	3 650 000	3 905.50
	Genazzano	657 000	702.99
	Umdloti	1 095 000	1 171.65
	Phoenix	18 250 000	19 527.50
	KwaMashu	23 725 000	25 385.75
	Hammarsdale	4 745 000	5 077.15
	Umhlanga	2 482 000	2 655.74
	Mpumalanga	2 336 000	2 499.52
	Fredville	730 000	781.10
	KwaNdengezi	876 000	937.32
	Hillcrest	438 000	468.66
	Dassenhoek	1 825 000	1 952.75
	Glenwood Road	36 500	39.06
	Cato Ridge	346 750	371.02
	Umbilo	8 468 000	9 060.76
	Northen works	25 550 000	27 338.50
	Umhlathuze	5 402 000	5 780.14
	New German	2 555 000	2 733.85
	Isiphingo	6 862 000	7 342.34
	Central -Marine Outfall	49 275 000	52 724.25
	Southern Works	83 950 000	89 826.50
	Amazimtoti	9 855 000	10 544.85
	Craigeburn	368 650	394.46
	Kingsburgh	2 555 000	2 733.85
	Umkomaas	365 000	390.55
	Magabeni	292 000	312.44
Harry Gwala	Bulwer	47 450	50.77
	Polela	10 950	11.72
	St Apolinaris	255 500	273.39
	Underberg Old	87 600	93.73
	Underberg New	65 700	70.30
	Himeville	54 750	58.58
	Kokstad	2 920 000	3 124.40
	Franklin	72 818	77.91
	uMzimkhulu	730 000	781.10
	Ibisi	292 000	312.44
	Riverside	219 000	234.33
	Ixopo	511 000	546.77
iLembe	Darnall	120 450	128.88
	Frasers	4 380 000	4 686.60

District Municipality	WWTW	Volume Treated (m^3/year)	Estimated VOC Emissions (kg/year)
	Gledhow	255 500	273.39
	Mandeni	474 500	507.72
	Maphumulo Hospital	73 000	78.11
	Montebello Hospital	91 250	97.64
	Ntunjambili Hospital	73 000	78.11
	Shakaskraal	584 000	624.88
	Stanger-KwaDukuza	3 650 000	3 905.50
	Sundumbili	4 562 500	4 881.88
	Tugela	273 750	292.91
	Vukile	340 180	363.99
King Cetshwayo	Catherine Booth Hospital	73 000	78.11
	Ekhombe Hospital	73 000	78.11
	Ekuphumuleni Hospital	36 500	39.06
	Gingindlovu	182 500	195.28
	King Dinizulu	328 500	351.50
	KwaBadala	36 500	39.06
	Mbongolwane Hospital	73 000	78.11
	Melmoth Ponds	146 000	156.22
	Empangeni	5 475 000	5 858.25
	Esikhawini	4 562 500	4 881.88
	Esikhaleni	4 562 500	4,881.88
	Ngwelezane	2 117 000	2 265.19
	Nseleni	1 022 000	1 093.54
	Vulindlela	1 022 000	1 022 00
	Oweni Sithole	547 500	585.83
	Mtunzini	547 500	585.83
	Nkandla	292 000	312.44
	Oceanview	219 000	234.33
	Mpushini Ponds	547 500	585.83
Ugu	Eden Wilds	91 250	97.64
	Gamalakhe	1 095 000	1 171.65
	Harding	584 000	624.88
	KwaMbonwa	36 500	39.06
	Malangeni	164 250	175.75
	Margate	2 920 000	3 124.40
	uMbango	4 380 000	4 686.60
	Melville	255 500	273.39
	Munster	65 700	70.30
	Murchison Hospital	91 250	97.64
	Palm Beach/Empanjathi	255 500	273.39
	Pennington	730 000	781.10
	Ramsgate	547 500	585.83

District Municipality	WWTW	Volume Treated (m^3/year)	Estimated VOC Emissions (kg/year)
	Red Desert	219 000	234.33
	Scottburgh	821 250	878.74
	Shelly Beach	273 750	292.91
	Southbroom	36 500	39.06
	Umzinto	912 500	976.38
	Uvongo	876 000	937.32
uMgungundlovu	Appelbosch Hospital	182 500	195.28
	Howick	2 482 000	2 655.74
	Mpofana (Mooi River)	1 277 500	1 366.93
	Richmond	365 000	390.55
	Darvill	27 375 000	29 291.25
	Lynnfield Park	182 500	195.28
uMkhanyakude	Coolair	365 000	390.55
	Camperdown	182 500	195.28
	Bethesda Ubombo Hospital	109 500	117.17
	Hlabisa	262 800	281.20
	Hluhluwe	91 250	97.64
	Ingwavuma-Mosvolt Hospital	365 000	390.55
	Jozini	182 500	195.28
	Kwa-Msane	365 000	390.55
	Manguzi	182 500	195.28
	Mkuze	438 000	468.66
	Mtubatuba	730 000	781.10
uMzinyathi	St Lucia Ponds	365 000	390.55
	Umseleni	365 000	390.55
	Dundee	3 650 000	3 905.50
	Greytown	1 646 880	1 762.16
	Nquthu	365 000	390.55
uThukela	Pomeroy	182 500	195.28
	Tugela Ferry	182 500	195.28
	Bergville	146 000	156.22
	Colenso	803 000	859.21
	Ekuvukeni	1 460 000	1 562.20
	Ezakheni	8 030 000	8 592.10
	Ladysmith	6 570 000	7 029.90
	Weenen Ponds	36 500	39.06
	Wenzeni	456 250	488.19
Zululand	Winterton	438 000	468.66
	Escourt	4 380 000	4 686.60
	Ceza Hospital	51 100	54.68
	Cliffdale -Vrede	365 000	390.55
	Coronation	365 000	390.55

District Municipality	WWTW	Volume Treated (m^3/year)	Estimated VOC Emissions (kg/year)
	eDumbe	182 500	195.28
	eMondlo	1 460 000	1 562.20
	Enyathi	*	*
	Hlobane	1 095 000	1 171.65
	James Nxumalo	54 604	58.43
	Klipfontein	4 197 500	4 491.33
	Mlokothwa	*	*
	Nkongolwane	*	*
	Nkonjeni Hospital	29 200	31.24
	Nongoma	1 095 000	1 171.65
	Pongolo	1 314 000	1 405.98
	St Francis Hospital	43 800	46.87
	Thulasizwe Hospital	21 900	23.43
Total		**414 484 182**	**443 498.32**
Note: Cells with an asterisk indicate no data reported in the KZN Green Drop Report 2022			

6.9.4 Proposed Management Interventions

Recommended management interventions for WWTW include the following:

- Wastewater treatment facilities need to be carefully maintained as emissions increase significantly when equipment deteriorates. Wastewater treatment works emit greenhouse gases such as carbon dioxide, methane and nitrous oxide.
- According to the Global Methane Initiative (2013), any methane gas produced should be collected and used to generate electricity to power the WWTW or purified to pipe-line quality and sold. This reduces CH_4 emissions from WWTW while reducing the municipality's reliance on fossil fuels for electricity.
- Operating biological wastewater treatment plants at high solid retention times can reduce N_2O emissions by maintaining low ammonia and nitrate concentrations (Campos, et al., 2016).
- Capturing and treating greenhouse gas emissions from WWTW will reduce the amount of emissions released, however capital costs to introduce the technology required will be high (Campos, et al., 2016).

6.10 Other Emission Sources

Sources of emissions to the atmosphere are widely varied and it is not possible to cover them all in this project. Some examples of sources that have not been quantified include:

- Aircraft
- Brickmaking
- Tyre burning
- Emissions from unpaved roads by vehicle entrainment
- Harbour activities
    - There is a Port in Richards Bay with industrial activities (coal mines terminal, aluminium smelters and fertilizer plant) situated in the King Cetshwayo District Municipality. The Transnet National Ports Authority is currently compiling a Strategic Environmental Assessment for the port of Richards Bay in relation to the Port Master Plan (PMP) developments.
    - The eThekwini Metropolitan Municipality conducted an emissions inventory study on the port of Durban (C40 Cities, 2021). The emissions inventory focused on the following emission sources within the port boundary:
        - Industrial activity.
        - Port related on-road transportation.
        - Port-related diesel rail activity.
        - Shipping emissions.
        - Cargo handling equipment (CHE, diesel).
        - Electricity usage.

7 Summary of Emissions in KZN

A summary of the emissions from the quantified sources in KZN is presented (Table 41). By mass, CO is the largest pollutant emitted within KZN followed by PM_{10}. Industries (Listed activities and controlled emitters) emit 33.4% of the total emissions within the province followed by vehicles (15.9%). Listed activities emit 42% and 97% of the CO and SO_2 emissions respectively (Figure 61 and Figure 65). Biomass (26%) is the second highest source that contribute to CO emissions. Vehicle emissions contributed 58% of NOx emissions (Figure 63). The mining sector contribute the most PM_{10} emissions followed by residential waste burning (Figure 62). Vehicles emit the most NMVOC emissions closely followed by the industrial contribution (Figure 64).

Table 41: Summary of criteria pollutant emissions from all sources in KZN.

Sector	Pollutant (tonnes/year)							
	PM_{10}	SO_2	NO_X	$PM_{2.5}$	NMVOC	Lead	CO	Benzene
Listed activities	7 203	20 528	13 818	7 203	2 126	3	70 121	7
Controlled emitters	217	156	477	217	-	117	485	-
Vehicles	1 360	-	27 740	958	3 739	-	20 508	-
Residential fuel	1 761	186	197	1 761	-	-	-	-
Biomass burning	7 613	493	5 498	7 613	-	-	91 639	-
Sugarcane burning	3 404	85	255	3 404	-	-	21 103	-
Livestock	652	-	-	504	-	-	-	-
Crops	4 086	-	-	737	-	-	-	-
Denuded Land	0.8	-	-	0.1	-	-	-	-
Mining	41 771	-	-	15 677	-	-	-	-
Landfills	-	-	-	-	97	-	76	3
Waste burning	10 182	428	3 200	8 386	-	-	32 515	770
WWTW	-	-	-	-	437	-	-	-
TOTAL	**78 249**	**21 876**	**51 186**	**46 459**	**6 398**	**120**	**236 447**	**780**

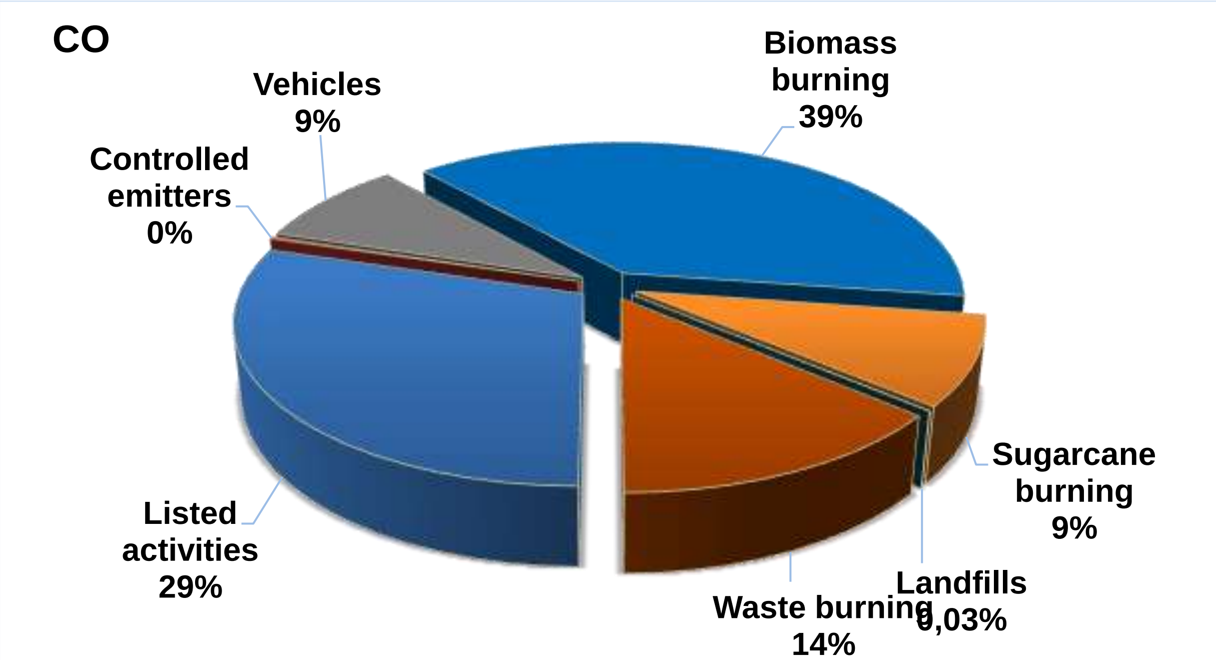


Figure 61: Contribution of sectors to total CO emissions in KZN

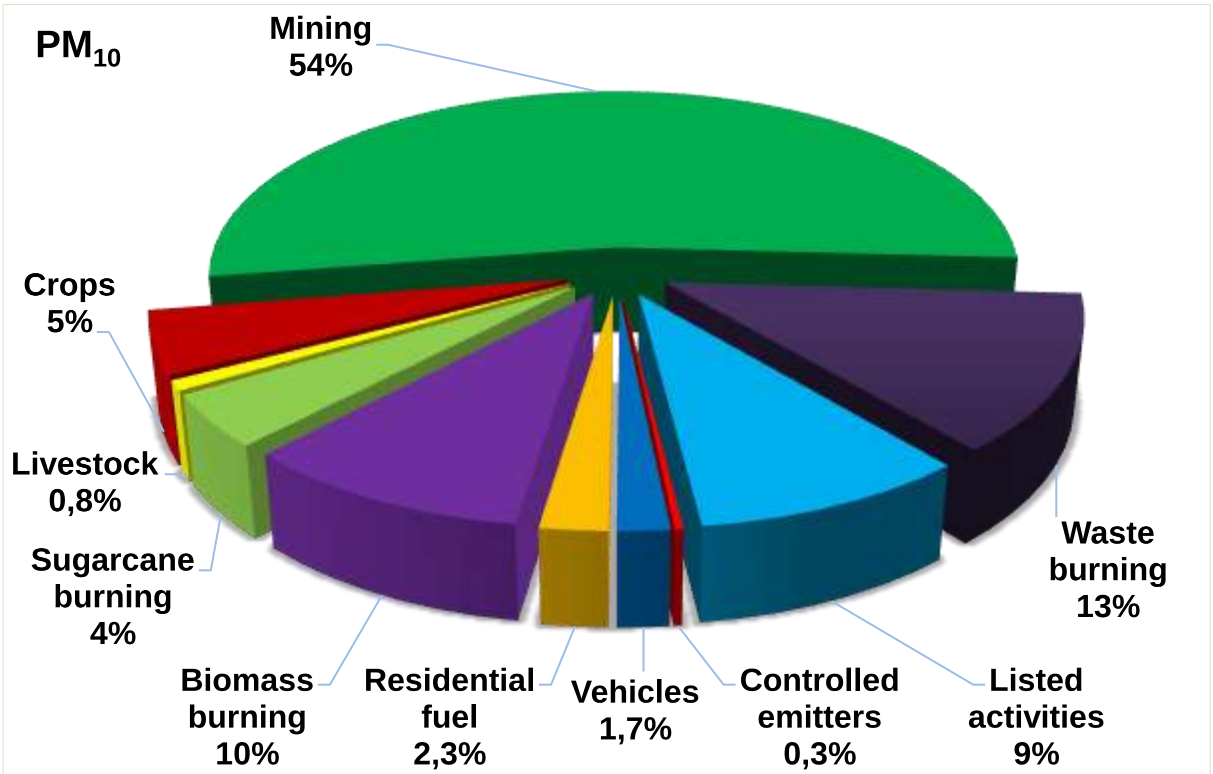


Figure 62: Contribution of sectors to PM10 emissions in KZN

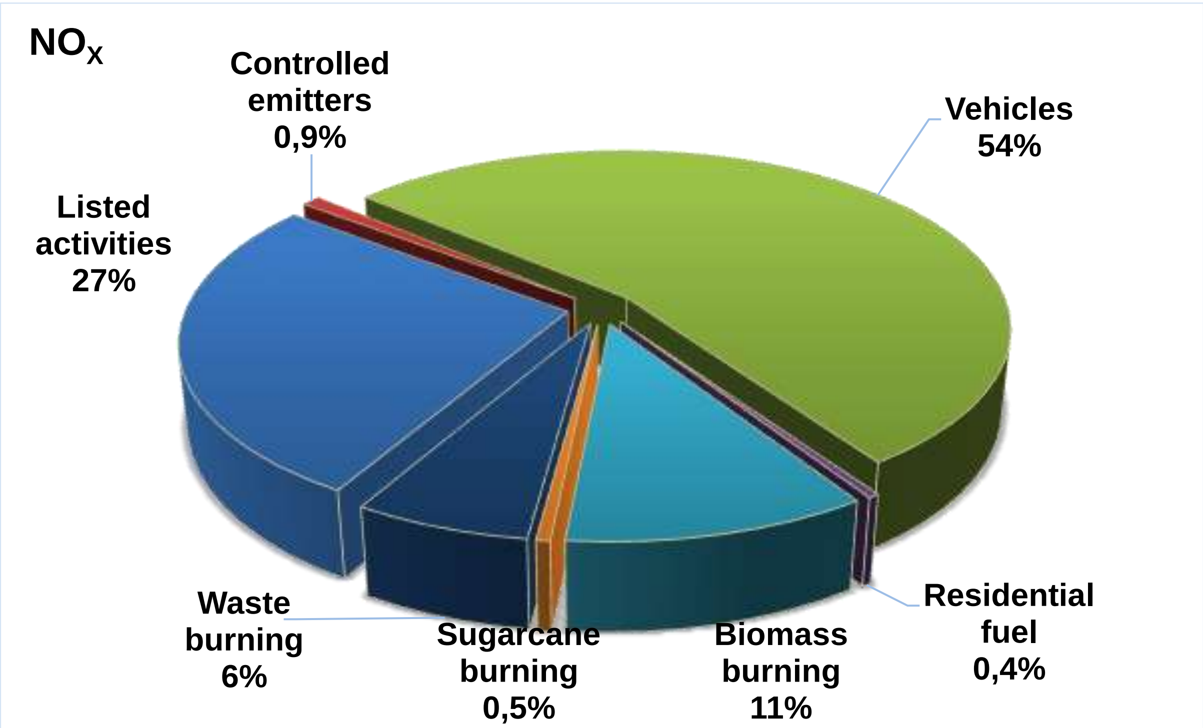


Figure 63: Contribution of sectors to total NOX emissions in KZN

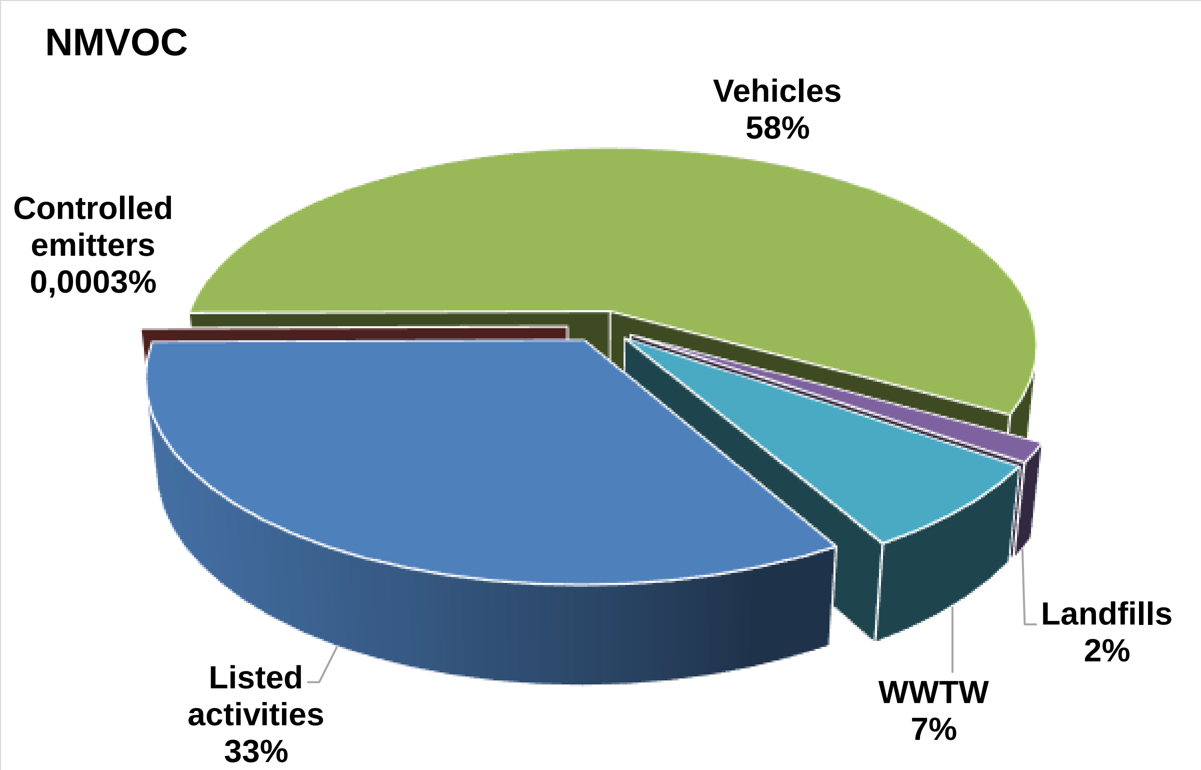


Figure 64:Contribution of sectors to total NMVOC emissions in KZN

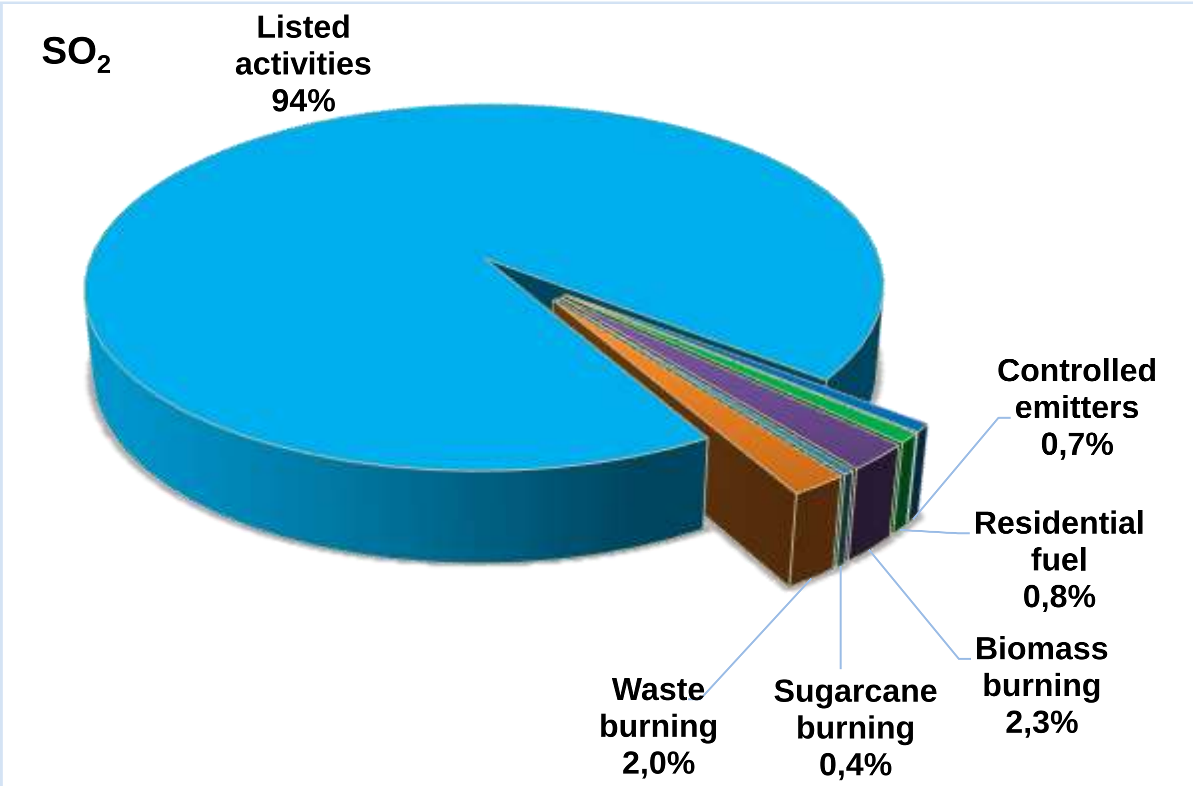


Figure 65: Contribution of sectors to total SO2 emissions in KZN

7.1 Emissions Inventory Results Discussion

Industry and biomass burning dominate the quantified emissions by total mass of pollutants emitted. They are followed by mines, waste burning, and vehicles as the biggest polluters (Figure 66). Waste burning and residential fuel burning raise concerns in terms of potential health impacts because of their proximity to sensitive receptors. This emissions inventory was compiled using the latest available provincial statistics with the census statistics for 2022 currently being updated. Furthermore, there were some limitations in terms of data availability and subsequently also their usability.

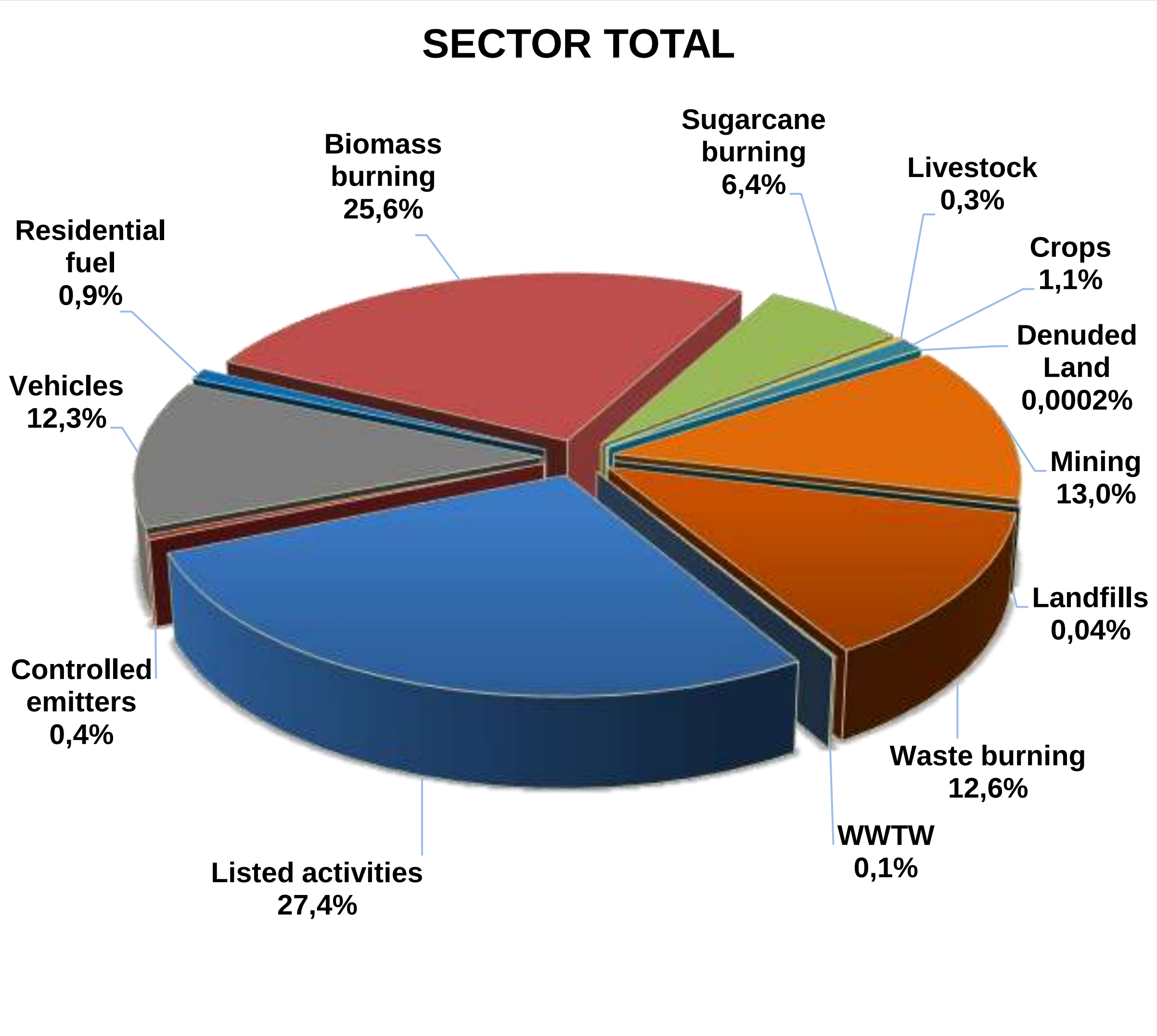


Figure 66: Sector proportions by total mass of emissions.

a) Listed Activities

Emissions data for industries were received from the NAEIS (NAEIS, 2019). There are many concerns about the data received and these have been outlined in the modelling section below. Nevertheless, it is clear that industries represent a large source of criteria pollutant emissions in the province. Current work on validating data submitted to the NAEIS should be continued and expanded in order to ensure that the national inventory of industrial sources is the valuable tool for air quality management that it was designed to be.

b) Biomass burning

Biomass burning emissions are extrapolated from data that might have considerable variation. These emissions are also associated with emission factors with large uncertainties. Although satellite-based products providing the spatial distribution of fires are readily available, uncertainties in the land cover as well as the variability of the associated atmospheric emissions makes biomass burning very difficult to assess. Biomass burning is also seasonal in character, and once burned, a year will typically elapse before the vegetation has regenerated.

c) Emissions from agriculture

The emissions from agriculture are generally low. However, if pre-harvest and/or post-harvest burning of sugarcane is included, it becomes a significant source of emissions in the province.

d) Vehicle emissions

Emission estimates for vehicles were shown to be an important source in KZN. Traffic emissions along the district corridors have a potential to have local impacts especially within 300 m from the roads. While the use of Fuel Sales Volume as a method of quantifying vehicle emissions is generally acceptable as a first order estimate of emissions, having more detailed information on the local fleet, vehicle type, vehicle age, average speed, annual distance travelled, fuel usage, fuel specifications, traffic volumes and environmental conditions will make quantifying the emissions more accurate through an up to date, provincial bottom-up emissions inventory.

e) Residential fuel burning

Residential solid fuel burning is one of the emissions with the greatest impact due to its proximity to sensitive receptors. Even though the total emissions are much lower than from other sources, particulate matter associated with residential fuel burning is emitted close to ground level in areas with the highest population density (Piketh, Burger and Paauw 2014). Even a small number of residential fuel-burning households can have a detrimental impact on the ambient air quality of the whole suburb. Data used in quantifying emissions from domestic fuel burning was obtained from the Stats SA 2016 Community Survey. Such data may not be fully representative of the actual habits of the community regarding use of domestic fuels and may result in the overestimation of emissions due to the manner in which questions are designed. Regular data collection by the district municipalities in the province with specially designed questionnaires could ensure that more accurate data is obtained.

f) Waste Burning

Waste burning is potentially as big a source of emissions as biomass burning, with a continuous supply of combustion material in residential areas. In addition, the contents of waste burning are potentially highly toxic, and therefore, potentially a much greater health risk. Actual data on volumes of waste burnt are not available for landfills nor for residential waste burning. Statistics of waste collection and households in KZN were used to estimate the extent of waste burning in the province. Emission rate calculations were based on the worst-case scenario that all the waste disposed of by households that do not receive refuse removal services is burnt and thus may result in the overestimation of emissions.

g) Mines and Quarries

The majority of mines within KZN were identified to be sand quarries and coal mines. These mining areas pose a low risk to health if located far enough from populated areas. Special attention in permitting applications should be given to the location of proposed mines and quarries in relation to populated areas.

h) Landfills

Landfill emission calculating models, such as LandGem, require data on waste design capacity and annual waste volumes to accurately quantify emissions from the decomposition of landfilled waste in municipal solid waste. Thus, it is recommended that landfills with no weighbridges be equipped with weighbridges and waste volumes received and transferred be recorded on a database for emissions calculation purposes.

8 Dispersion Modelling

Dispersion modelling is used to identify areas where the ambient concentrations of particular compounds exceed the national ambient air quality standards. This typically assists in health and environmental risk assessments. It also provides information for the positioning of ambient air quality monitoring networks and helps to assess source contributions to ambient air quality concentrations. The KZN EDTEA and the eThekwini Metropolitan Municipality are reported to have in-house dispersion modelling capabilities. The complexities involved in dispersion modelling has given rise to the Regulations regarding air dispersion modelling (Government Notice No. R533, 2014) which ensures standardisation of dispersion modelling practices throughout South Africa.

Although huge progress has been made towards better inventories of emissions to air in South Africa, we are a long way from having all the necessary information from all the important sources. Emissions estimates for fugitive sources are based on emission factors, which have a large uncertainty. Including fugitive emissions in the modelling across the province would require a vast amount of information on their spatial distribution, the shape and extent of each source etc. With the number of assumptions that would have to be made, the results of modelling these fugitive emissions would be highly questionable, and hence not very useful. Sources that have sufficient information available, such as the reporting information required from Listed Activities, can be modelled using a dispersion model such as AERMOD or CALPUFF. The emissions reported by industries to the NAEIS were modelled using CALPUFF. There were several issues with regards to the quality of the data received from the NAEIS for industrial emissions.

One of the concerns is that there appears to be a lack of consistency in terms of the units used. Temperature is the clearest example. The NAEIS requires temperatures to be reported in Kelvin. However, the reported stack exit temperatures from some industries would be below 0°C if they were actually reporting their temperature in Kelvin. This is clearly not realistic. It was, therefore, assumed that all reported temperatures were in degrees Celsius. This is a serious limitation to the certainty of the modelling results since the temperature and hence the buoyancy of emissions affects dispersion.

Another concern is that some of the parameters that are required to be reported from point sources are not understood. Stack height should be reported as height above ground level. In many cases, it appears that the length of the stack has been reported without including the height of the building on which the stack is built. Additionally, if a stack is situated on a building, the height of the roof of the building above ground level should be reported so that building downwash effects can be included in the modelling. Once again, this affects the certainty of the modelling results, since the height of emission affects dispersion.

Furthermore, the data for each stack should be specific to the stack, not generic or average data. In many cases there are several stacks at one industry, all reported with the same coordinates and the same emissions, even when other stack parameters are different. This makes it impossible to separate the stacks and know whether the emissions reported are actually the stack's emissions, the average of all the emissions at the facility, or possibly even the sum of all emissions.

There are many concerns about the validity of the reported particulate matter emissions. $PM_{2.5}$ is a subset of PM_{10}, which is a subset of TSP. Therefore, reported TSP should be greater than PM_{10}, and PM_{10} should be greater than $PM_{2.5}$. This was often not the case in the data received from the NAEIS for many of the industries.

Stack emissions can include both filterable and condensable particulate emissions. Material captured when an exhaust train passes through a stack monitoring filter is called 'filterable particulate matter'. Condensable emissions, on the other hand, are typically present as a gas in stacks operating at elevated temperatures. These emissions cannot be caught by a filter. They exit the stack in gaseous form and condense into liquid or solid particles smaller than 1 micron in diameter when cooled to near ambient conditions at the stack's exit. Condensable and filterable PM should add up together to make total primary PM emissions per particle size.

Primary PM is the sum of filterable and condensable material emitted by a facility. Secondary or indirect PM is $PM_{2.5}$ which is formed by chemical reactions in the atmosphere some distance downwind from the point of release. Secondary $PM_{2.5}$ is difficult to quantify and there are currently no stack test methods to calculate the probability of it forming from the stack emissions. For some industries the reported filterable PM_{10} and $PM_{2.5}$ was an order of magnitude higher than the reported primary PM, possibly indicating that they reported what was collected in their abatement equipment filters instead of what was emitted from the stacks.

Another data anolmaly found, was that stack emissions are expected to be largely in the size-range smaller than PM_{10}. However, some industries reported emissions of thousands of kg of TSP per annum, but there was no split into PM_{10} or $PM_{2.5}$.

Consequently, the following assumptions were made for the dispersion modelling, based on the regulatory principle of presenting the 'worst-case scenario':

- Only PM_{10} was used due to the lack of a full set of $PM_{2.5}$ data.
- In cases where reported $PM_{2.5}$ was higher than PM_{10}, the $PM_{2.5}$ value was used.
- In cases where the filterable PM_{10} was higher than primary PM_{10}, the filterable value was used.
- If only TSP was reported as a stack emission, the TSP value was used as PM_{10}.

Dispersion simulations were undertaken using CALPUFF to determine ambient concentrations of CO, NO_2, Pb, PM_{10} and SO_2 resulting from industrial activities in the province. The WRF domain spanned a width of 400 km and length of 480 km centred on 28.948º S latitude and 30.922º E longitude, with a 5 km grid resolution. Four subdomains were used for modelling industrial emissions. The isopleths of the modelling results are presented in Figure 67 to Figure 71 below. Concentrations of NO_2, Pb, PM_{10} and SO_2 are presented in µg/m³. Concentrations of CO are presented in mg/m³.

The modelled CO 8-hour average concentrations were low (< 0.4 mg/m³) compared to the standard of 10 mg/m³. All other modelled pollutants indicated areas where the ambient concentrations may exceed the relevant National Standards. These hotspots or nodes of high risk of health effects from exposure to industrial pollution include: Durban South (NO_2), Pietermaritzburg (NO_2 and Pb), an area approximately 17 km south-east of Pietermaritzburg (NO_2), the area approximately 12 km west of Port Shepstone (NO_2), Newcastle (NO_2), the area just east of Newcastle (SO_2), and the area to the west of Ixopo (NO_2, PM_{10}). The modelling highlights that the emissions from industries in these areas should be investigated. First, the reporting from industries in these areas should be checked for validity. If these checks indicate that reported emissions are valid, monitoring and management of the emissions should become a priority for the province and relevant municipalities.

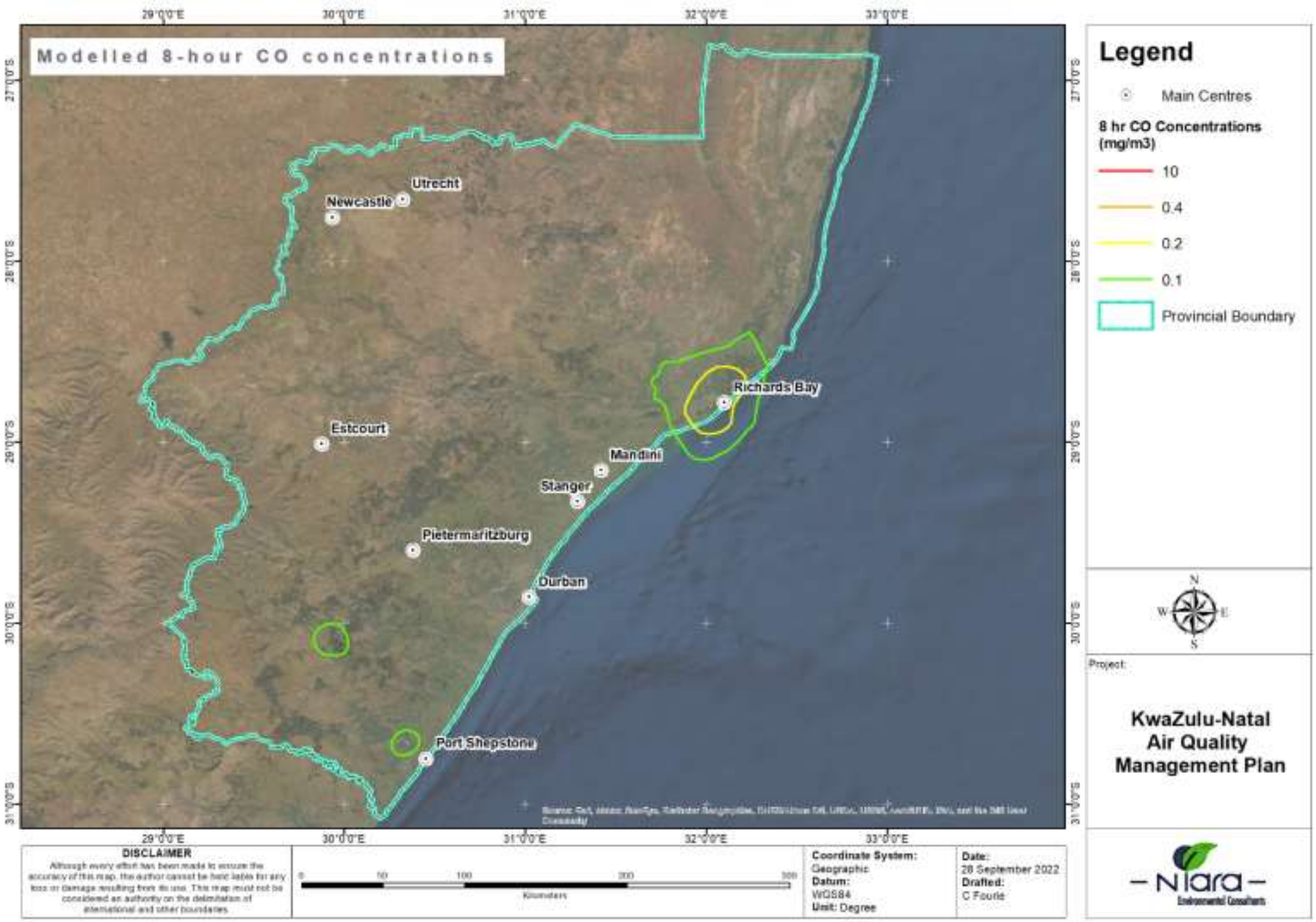


Figure 67: Modelled 8-hour CO Concentrations in KZN.

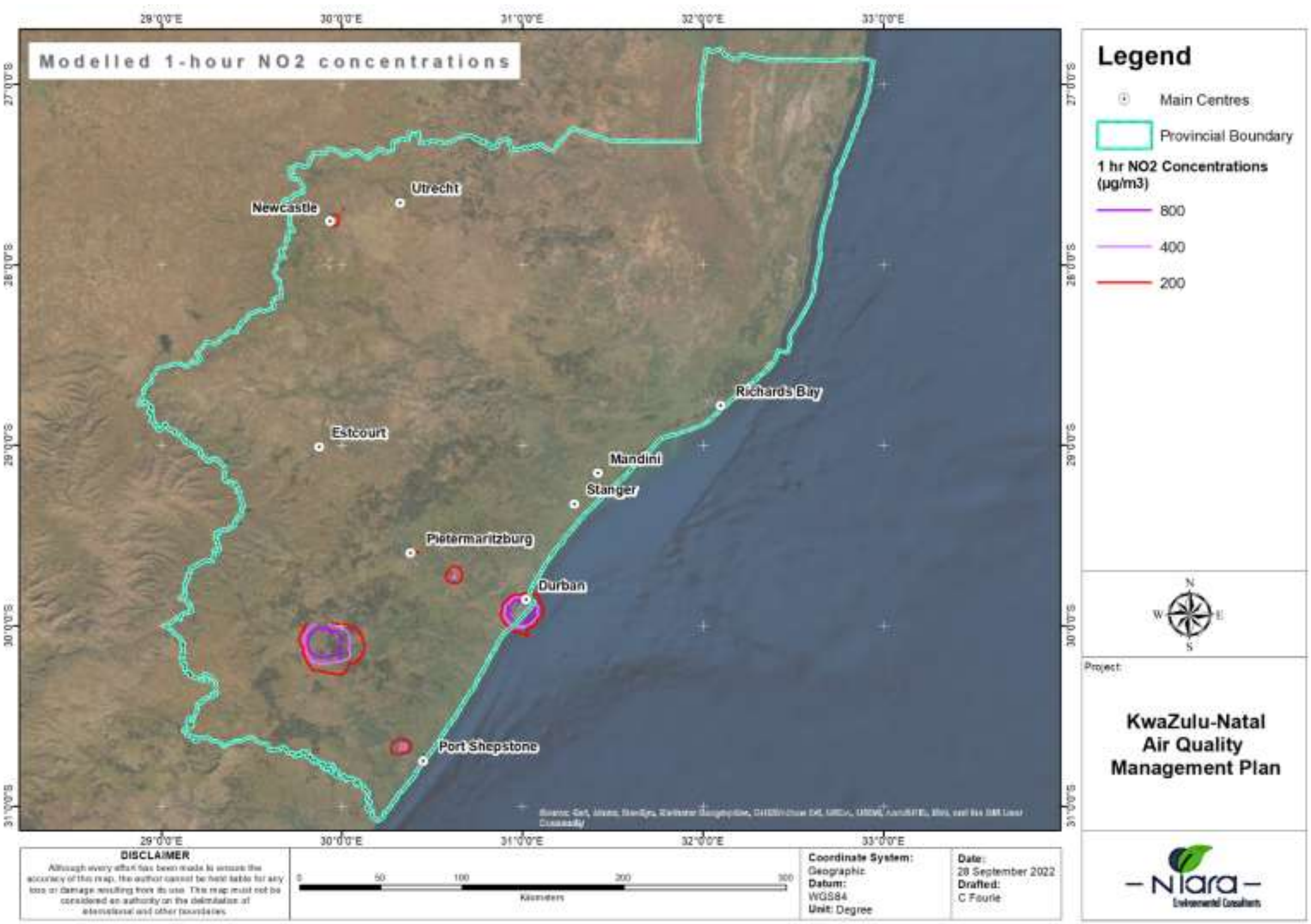


Figure 68: Modelled 1-hour NO2 Concentrations in KZN.

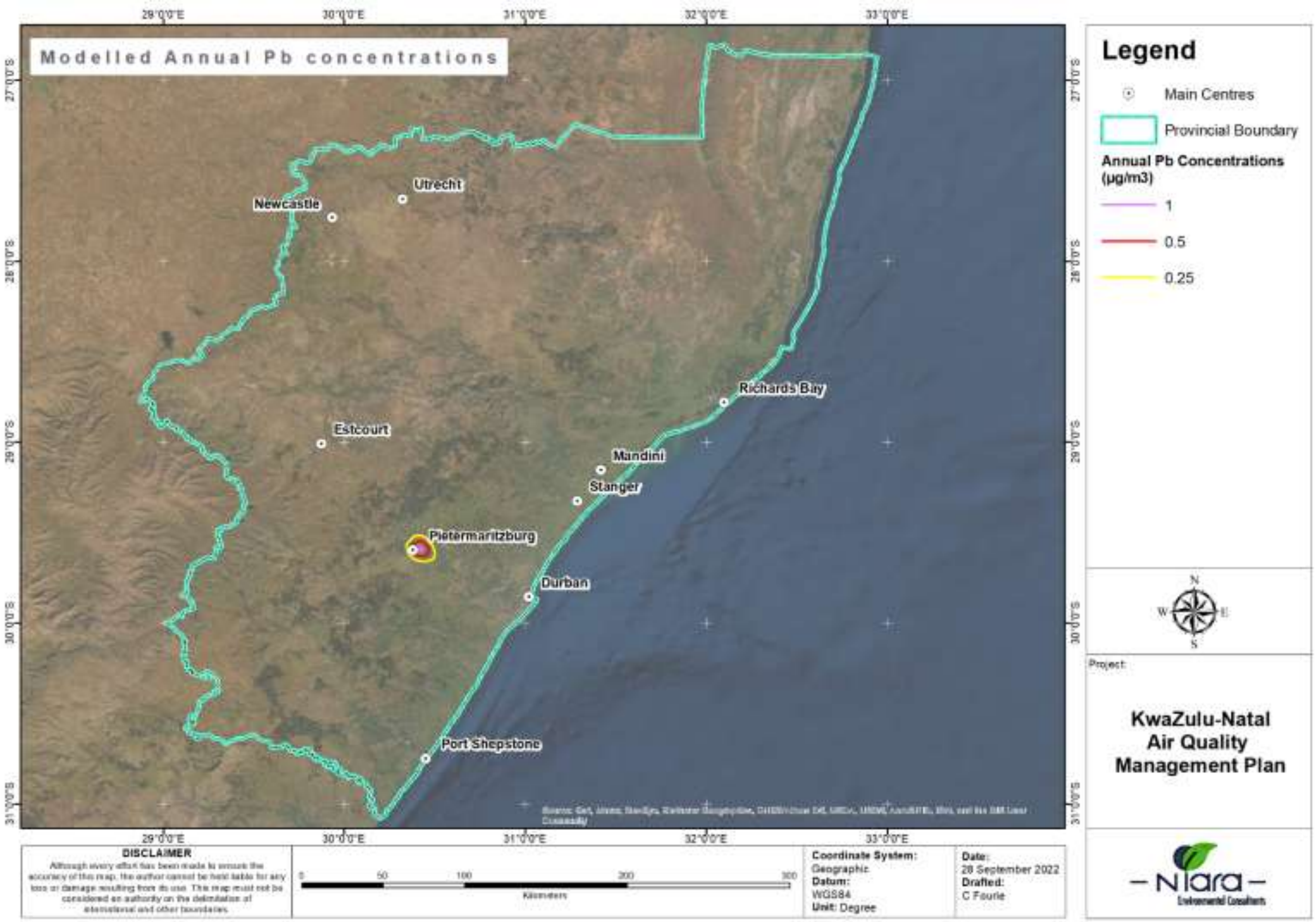


Figure 69: Modelled annual Pb Concentrations in KZN.

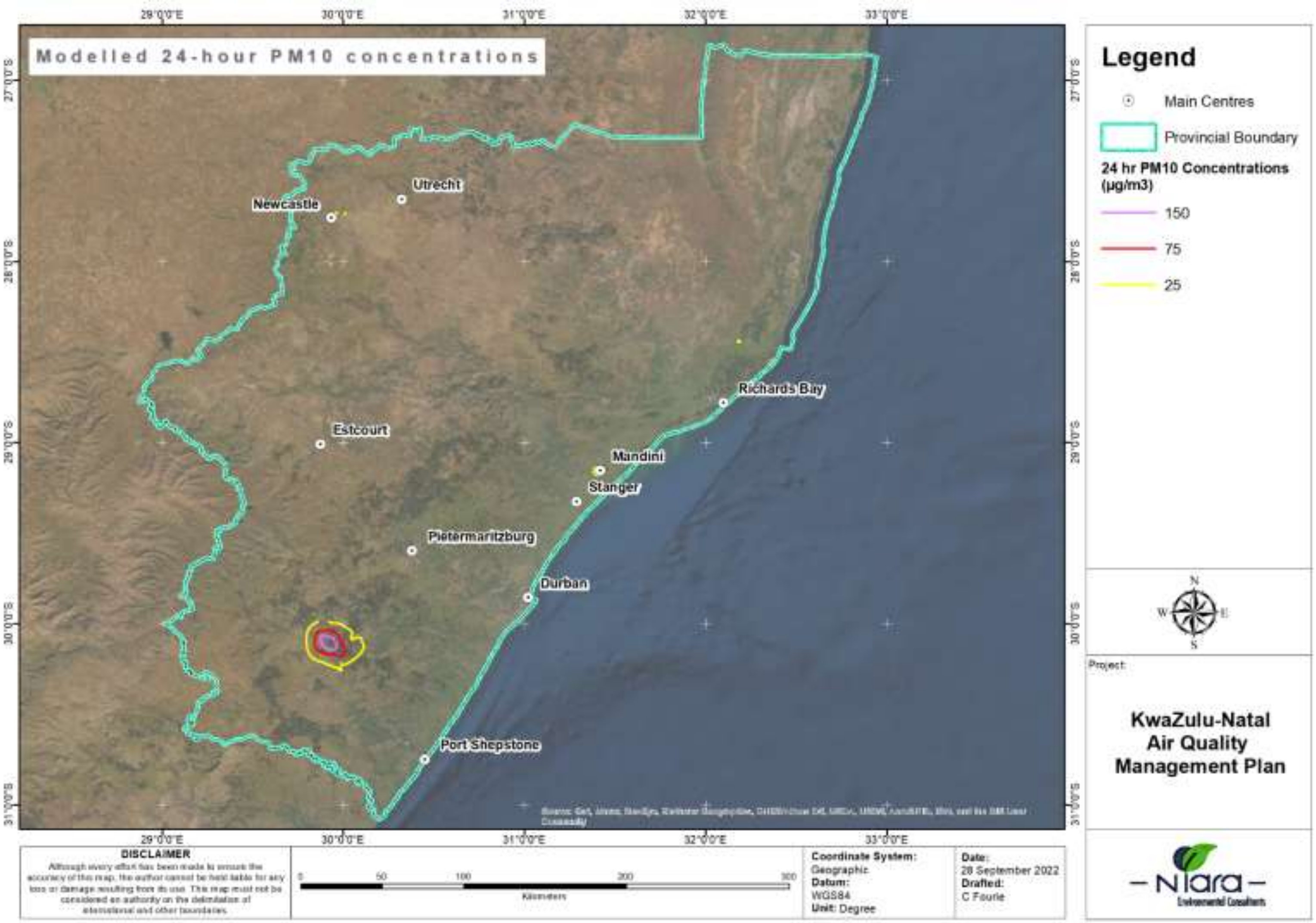


Figure 70: Modelled 24-hour PM10 Concentrations in KZN.

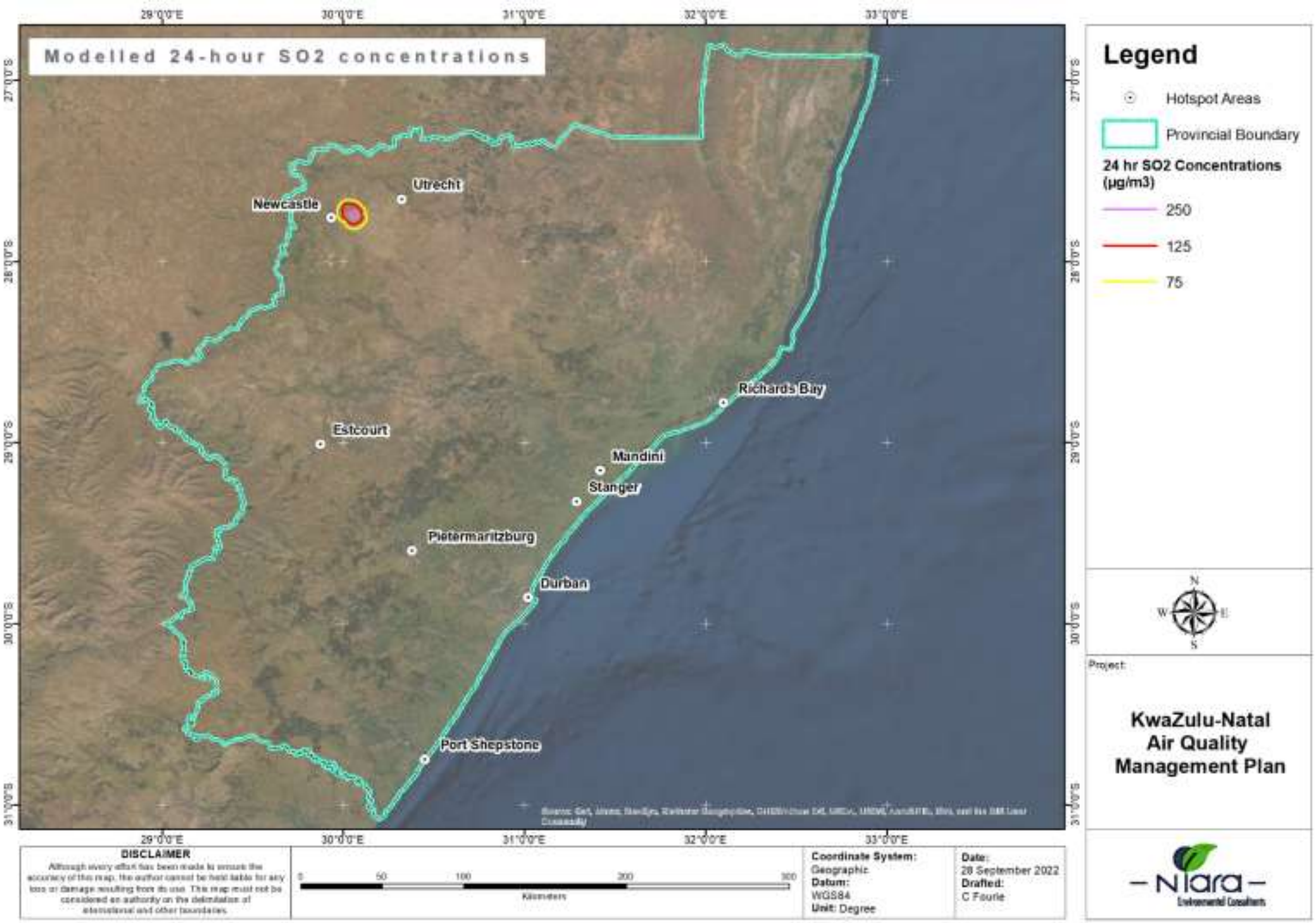


Figure 71: Modelled 24-hour SO2 Concentrations in KZN.

9 Geospatial Risk Assessment

A spatial assessment of air pollution risk is necessary for effective air quality management. Use of dispersion modelling only, leads to assessments that overemphasize sources which we know a lot about, while sources that are difficult to quantify are under-represented.

An alternative to air dispersion modelling is to use a proximity-based geospatial model that uses nearness to a particular pollution source as a proxy for exposure, similar to the method used by Wright and Diab (2009). A geospatial air quality risk assessment was conducted for KZN to assess the proximity of exposure to primary pollutants. Primary pollutants are described as pollutants directly emitted from a source such as emissions from waste burning, vehicles, industrial activities, and fossil fuel combustion (Yerramilli, 2011). This spatial assessment of air pollution risk is undertaken in adition to dispersion modelling to identify areas of elevated pollutant concentrations in relation to sensitive receptors.

The application of Geographic Information Systems (GIS) was used to include available source categories (landfills and wastewater treatment works, residential fuel burning, transportation and mining) as exposure layers. Varying buffers were placed around the different source groups, depending on the expected spatial extent of their impact. Source layers were integrated to develop spatial distribution of air quality exposure in the province. Each source category is represented as a weighted layer in the geospatial model. Industrial sources that had sufficient information available were modelled using CALPUFF. The sum off all the different layers results in an assessment of how many sources impact that particular conurbation. This exposure map is then combined with population demographics in order to assess risk. The study only assesses the risk of people living within the province being exposed to emissions from local sources. Transboundary Air Quality risk has not been assessed.

A. Sources with high uncertainty in their emissions

Residential solid fuel burning is one of the emissions with the greatest impact. Even if the total emissions are much lower than industrial emissions, particulate matter associated with domestic fuel burning is emitted close to ground level in areas with the highest population density (Piketh, 2014). Even a small number of domestic fuel-burning households can have a detrimental impact on the ambient air quality of the whole suburb. The only data available to estimate the number of domestic fuel-burning households is the census data. Therefore, although this has been proved to provide an imprecise depiction of the total domestic fuel burning households (Pauw, 2006) the 2011 census data (StatsSA, 2011) was used to calculate population density to identify areas where domestic fuel burning might be a concern.

Biomass burning emissions is another source with large uncertainties. Although satellite-based fire products are readily available, uncertainties in the land cover as well as the variability of the associated atmospheric emissions makes biomass burning very difficult to model explicitly.

Sand and coal mines are a significant source of particulate matter. Mining activities such as crushing and screening, wind entrainment from stockpiles and exposed land, and the use of vehicles on unpaved and paved roads for transporting material are factors that contribute to emissions from mines. Without a detailed assessment to characterise every mine and quarry activity the uncertainties are too large to model.

Traffic emissions along the national corridors have a potential to be an important local source. However, a bottom-up emissions inventory with spatial representation of emissions according to measured traffic volumes would be needed to more accurately identify hotspots.

B. Geospatial modelling of different source groups

The different source groups were modelled as spatial layers (Figure 72 and Figure 73). The different pollutant layers (CO, NO_2, $S0_2$, Pb and PM_{10}) were obtained from the dispersion modelling of industries in KZN who report to the NAEIS (NAEIS, 2019). Mining activities were identified through the 2020 land-cover dataset. A 1km and 3km buffer was placed around the mining areas as it is considered an area of high risk of exceedances of the NAAQS for PM_{10} and $PM_{2.5}$. Traffic pollution exposure was represented by a 300m buffer around all major roads, railways and commercial centres. Landfills and WWTW were modelled with a buffer of 1km. Domestic fuel burning areas were identified as areas that have a population density higher than 500 people per square kilometre (Figure 74).

Richards Bay was not identified as a hotspot area in the risk assessment due to limited reported data available from that region on the National Environmental Information System (NAIES). However, it should be noted that this is an anomaly, as Richards Bay has the potential to be a hotspot within the KwaZulu-Natal province. This is primarily due to the concentrated presence of mining and manufacturing industries, as well as the port, which is characterized by a significant influx of truck transportation and presence of industrial facilities such as coal mines terminal, aluminium smelters, and a fertilizer plant. These various sources of air pollution contribute to the air pollution risk and potential impact in the Richards Bay area. Another noteworthy anomaly was observed in the southern region of the province (Harry Gwala DM), where the modelled results indicated a high exposure of NO_2 and PM_{10} emissions. This can be attributed to the presence of two distinct types of sawmill facilities in that area. One of the facilities belongs to the pulp and paper manufacturing sector, while the other is associated with the petroleum sector. As a result of these industrial activities, the concentration of the two pollutants is significantly elevated in the region.

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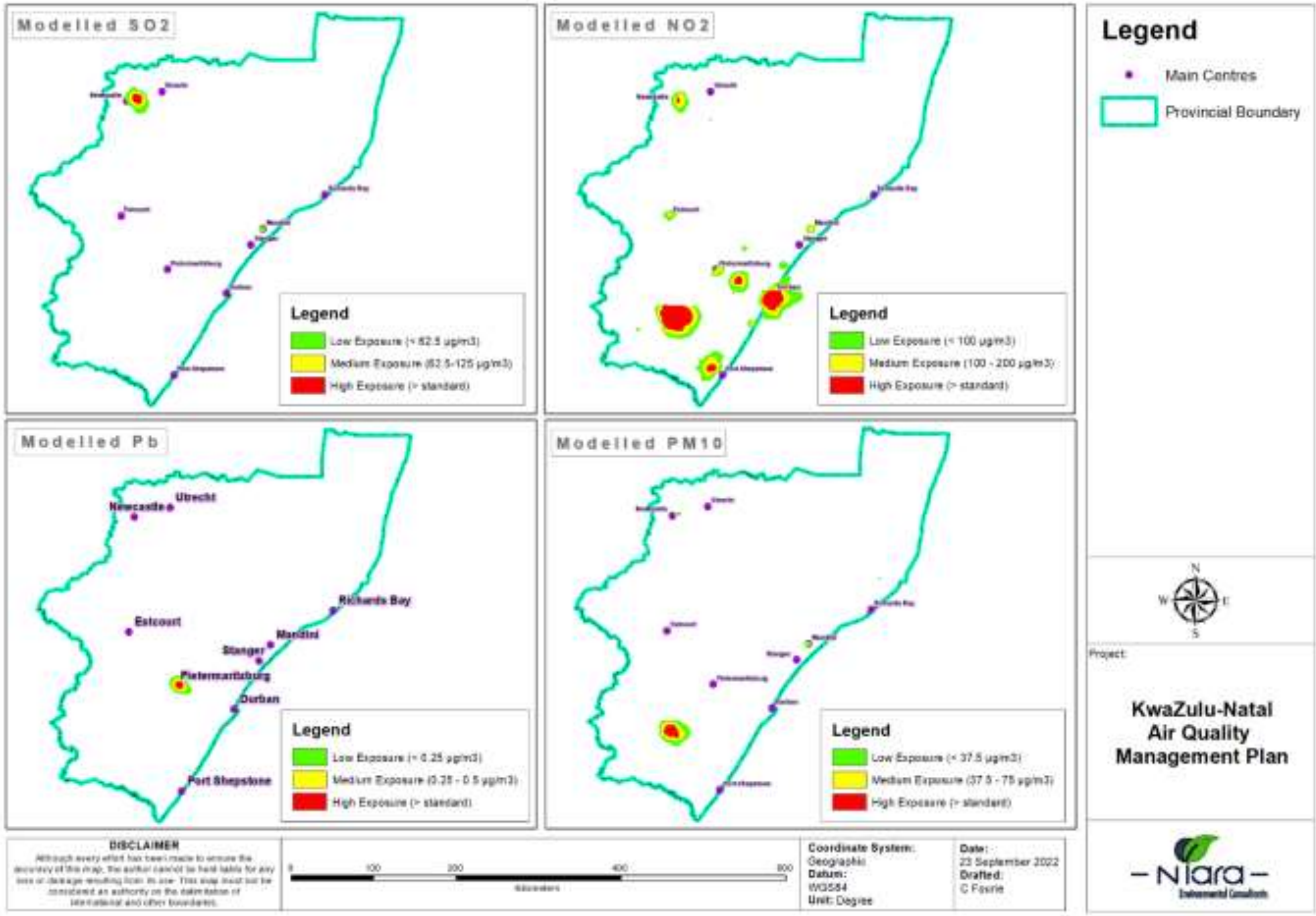

Figure 72: The different pollutants represented in the air pollution exposure assessment.

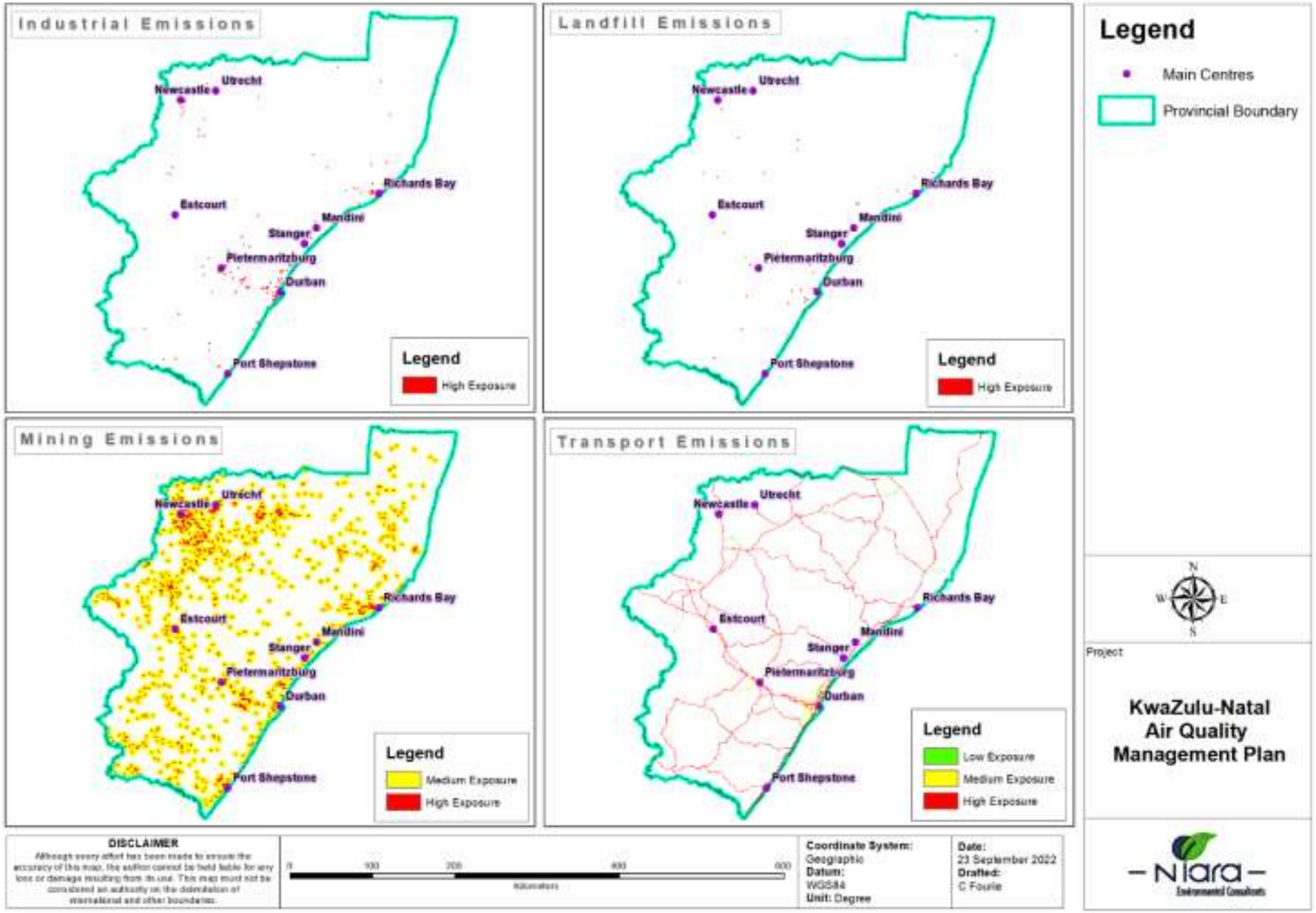

Figure 73: The different layers represented in the air pollution exposure assessment.

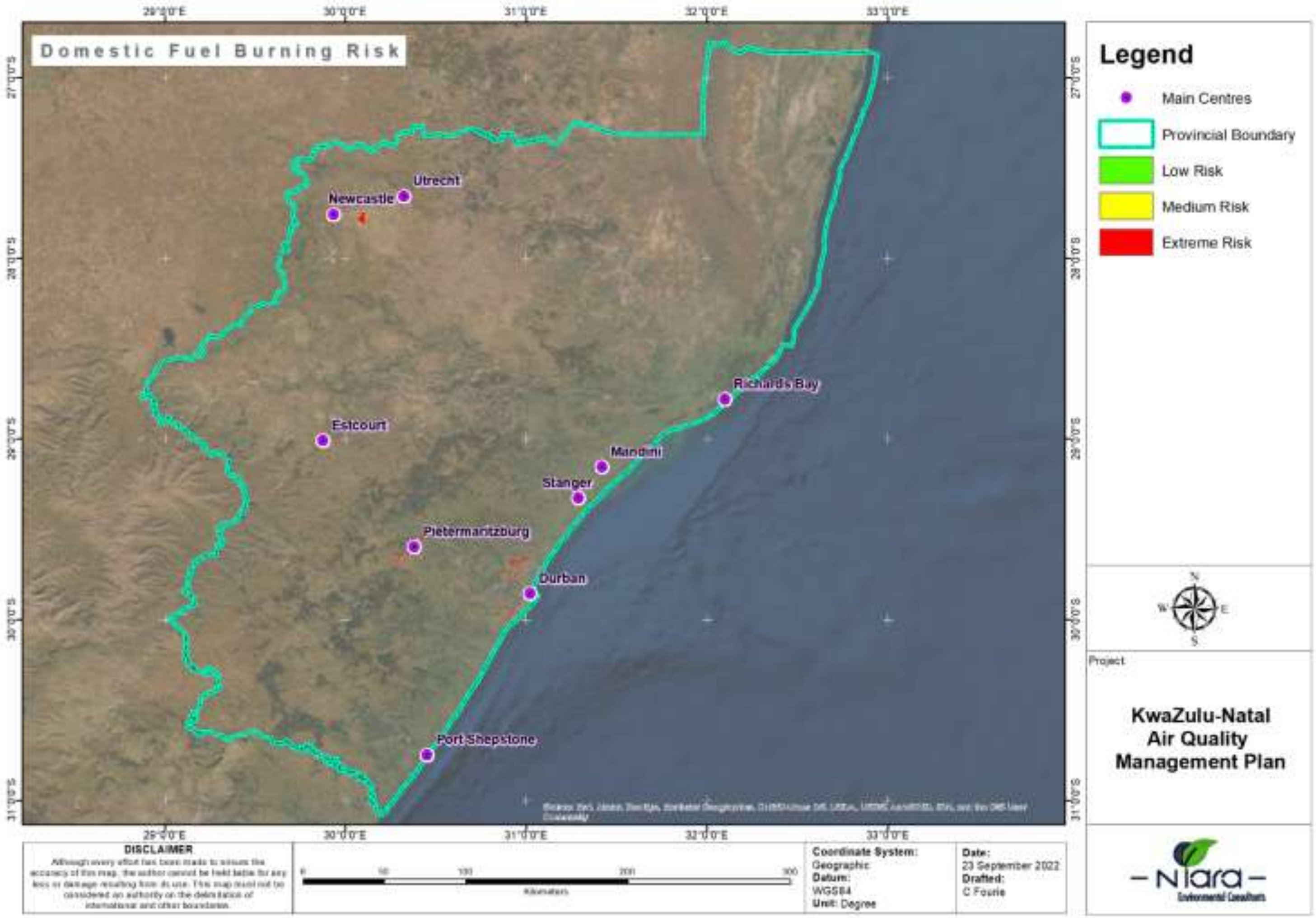

Figure 74: Domestic Fuel Burning Risk.

C. Probability of air pollution exposure

The probability of exposure to air pollution is shown in Figure 75. Emnambithi, eThekwini, Greater Kokstad, Hibiscus Coast, KwaDukuza, Mandeni, Newcastle, Msunduzi, and uMhlathuze, have the largest areas where a high probability of exposure is modelled. This implies that residents in these areas are exposed to a range of air pollution sources.

Areas with a high population density are at a higher risk of exposure to air pollution than areas with a low population density. The communities in the table below are exposed to multiple pollution sources and poor air quality in general due to their location in close proximity to pollution sources. Areas with a population density above 1000 people per square kilometre should be prioritised for investigation (APPENDIX 4:)

There are many uncertainties about the true extent of air pollution in KZN. Very little detailed data is available in some areas and sectors, and emissions are extrapolated from areas that might have some variation. Domestic solid fuel use dominates the potential impacts based on the assumptions made regarding emissions. The priority for KZN should be to confirm the high ambient levels of CO, NO_2, PM_{10} and SO_2 in dense, low-income areas of the province.

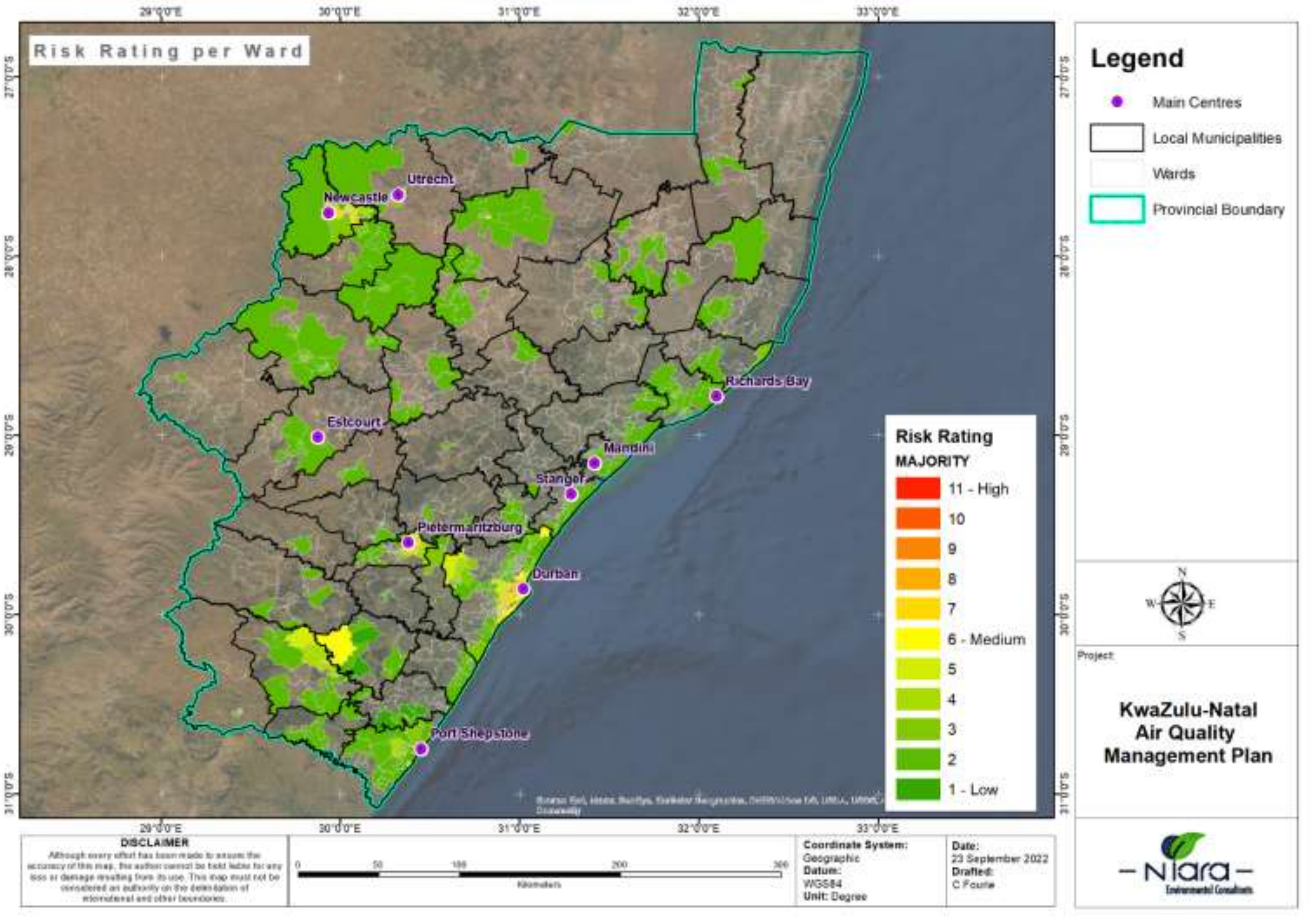

Figure 75: Spatial distribution of air quality exposure in KZN.

10 Air Quality Governance

10.1 Government Structure and Functions

In this section, the capacity for air quality management and control within KZN is assessed within the various spheres of Government.

10.1.1 Provincial Level

Within the KwaZulu-Natal Province, the Department of Economic Development, Tourism and Environmental Affairs (KZN EDTEA) is responsible for air quality related functions. The KZN EDTEA supports the functions of local and district municipalities and plays an oversight role within the province. In particular, the KZN EDTEA assists the district municipalities in the province with their AEL function.

A Provincial AQO has been designated by the KZN EDTEA. The AQO is responsible for the coordination of all air quality related matters within the province. This includes oversight of the development of provincial strategies and policies.

The approved organisational structure of the province's Air Quality Management Directorate is made up of Ambient Air Quality Monitoring services and Authorisations, Planning and Coordination services (Table 42). The current AQM structure in the province lacks dedicated technicians to manage and maintain the air quality monitoring network, highlighting a critical gap that needs immediate attention. There are currently two people working under this directorate: a designated provincial AQO, a Control Environment Officer. All other positions are currently vacant.

Table 42: KZN EDTEA AQM organisational structure

Post	Quantity
Director: Environmental Quality Management	1
Control Environmental Officer	2
Scientist Production	2
Candidate Scientist	1
Environmental Officer	1

10.1.1.1 Proposed Air Quality Management Function within KZN EDTEA

The project team recommends the establishment of a dedicated Air Quality Management (AQM) function within the provincial team to enhance the efficacy of air quality management efforts within the province. The suggested AQM unit aims to address critical concerns associated with air pollution and foster the achievement of cleaner and healthier air for the local communities. This specialised unit would encompass several divisions, including Policy and Planning, Monitoring and Assessment, Emission Control, Compliance and Enforcement, Public Awareness and Education, Stakeholder Engagement, Data Management and IT, and the inclusion of a Technician role. The structured approach allows for the development and enforcement of air quality policies, comprehensive monitoring and analysis, implementation of effective emission control strategies, adherence to regulatory compliance, engagement with stakeholders, public awareness campaigns, and efficient management of air quality data. By adopting this holistic approach, significant progress can be made towards improving air quality and safeguarding the well-being of communities in the province.

The following section presents a proposal for the implementation of an effective Air Quality Management (AQM) function within a provincial team:

1. Director/Manager of Air Quality Management Unit

- Provides overall strategic direction and leadership for the AQM unit.
- Coordinates with relevant government departments, stakeholders, and agencies.
- Manages budget and resource allocation.

2. Policy and Planning Division

- Develops and updates air quality policies, guidelines, and regulations.
- Conducts research and analysis to support policy development.
- Monitors and evaluates the implementation of air quality management plans.

3. Monitoring and Assessment Division

- Operates and maintains air quality monitoring stations.
- Analyses air quality data and prepares reports on pollution levels.
- Conducts source apportionment studies to identify pollution sources.

4. Emission Control Division

- Develops and enforces emission control strategies and regulations.
- Works with industries and businesses to ensure compliance with emission standards.
- Conducts inspections and audits to monitor emission sources.

5. Compliance and Enforcement Division

- Ensures compliance with air quality regulations and standards.

- Conducts inspections, investigations, and enforcement actions.
- Collaborates with other enforcement agencies and legal authorities.

6. Public Awareness and Education Division

- Develops and implements public awareness campaigns on air quality issues.
- Educates communities, schools, and industries on the importance of clean air.
- Engages with the public, NGOs, and community organizations.

7. Stakeholder Engagement Division

- Facilitates collaboration and engagement with relevant stakeholders.
- Consults with industry representatives, environmental groups, and community organizations.
- Establishes partnerships for joint initiatives and information sharing.

8. Data Management and IT Division

- Manages air quality data collection, storage, and analysis systems.
- Develops and maintains IT infrastructure for data management.
- Ensures data accessibility and quality control.

9. Technician

- Supports the operation and maintenance of air quality monitoring equipment.
- Conducts routine maintenance, calibration, and troubleshooting.
- Assists in data collection and quality assurance activities.

The proposed divisions responsibility can be divided into the Control Environmental Officer and Scientist role. Please note that the Technician role has been added within the Monitoring Assessment Division, as they primarily support the technical aspects of air quality monitoring. However, their role can vary based on the specific responsibilities assigned within the province.

District Level

As per Schedule 4, Part B, Section 156 of the Constitution, local municipalities have executive authority in respect of, and the right to administer air pollution (South Africa, 1996). It is recognised that air quality management and control is primarily a function of district municipalities with emission licensing and auditing functions undertaken in conjunction with the provincial department responsible for environmental affairs. The AQM unit of each district municipality is outlined below and a summary of the municipal AQM capacity is provided in APPENDIX 6:

- The Amajuba AQM unit consist of one person working under the planning and development services directorate designated as an Air Quality and Environmental Officer.
- eThekwini has a comprehensive AQM unit which consists of an air quality officer, an environmental officer that manages the air quality program, a meteorologist, a team of technicians, a data team and an AEL team.
- Harry Gwala has one designated District Air Quality Officer.
- iLembe has one District Air Quality Officer.
- The King Cetshwayo AQM unit consists of one District Air Quality Officer and two air quality officials.
- The Ugu District Municipality AQM unit consists of three officials: one air quality manager (designated Air Quality Officer) and two air quality officials.
- The uMgungundlovu AQM unit falls under the Social Development Directorate and currently has one air quality official and has one vacant position for an area manager for air quality.
- uMkhanyakude has one air quality management personnel for the district's AQM unit.
- uMzinyathi has one air quality management personnel for the district's AQM unit.
- uThukela has one acting Air Quality Officer for the district's AQM unit.
- Zululand has a designated Air Quality Officer for the district's AQM unit.

District municipalities that have an AQMP in place reported that they face challenges in implementing the AQMP due to financial, human resources and air quality management tools constraints.

10.1.2 Local Level

There are two local municipalities (Msunduzi and uMhlatuze) that manage Air Quality functions in their jurisdiction. The remaining local municipalities AQM functions are managed by the district municipality.

10.2 Human Resources

Within the KZN EDTEA, the Air Quality Management Unit is responsible for air quality management. Currently, the province has one Air Quality Officer and one Environmental Compliance Monitoring Officer. For the KZN AQMP to be effective, co-operative governance and political buy-in across all spheres of government, as well as increased capacity to enforce compliance with new legislation will be required. In order to increase capacity in Local Government, authorities need to invest both time and capital. For the province to fulfil their regulatory role in terms of air quality, dedicated Air Quality Officers (AQOs) and support personnel need to be appointed. The short- to medium-term provincial government capacity goals are to have adequate personnel in the following vacant AQM positions:

- Scientist Production in Ambient Air Quality Monitoring (Coastal).

- Scientist Production in Ambient Air Quality Monitoring (Inland).
- Control Environment Officer – Authorisations, Planning and Coordination.
- Candidate Scientist - Authorisations, Planning and Coordination.
- Environmental Officer - Authorisations, Planning and Coordination.

All personnel should undergo relevant training and be upskilled insofar as possible. All newly appointed AQOs should be trained and able to interrogate AEL applications and dispersion modelling results. This will contribute significantly to the assessment of AEL applications to ensure that current air quality is not further compromised. The KZN Province intends, over the next 5 years, to have a fully-fledged AQM Unit. This will progressively be achieved through interventions such as the appointment of interns to assist with environmental compliance and enforcement. Furthermore, it is a goal of KZN to ensure that every member of the AQM Unit is an Environmental Management Inspector (EMI).

At National level, the DFFE have been conducting the following Air Quality training programmes since 2012/13:

- Introduction to AQM Training Course.
- Emission Management Training Course.
- Ambient Air Quality Monitoring Training Course.
- National Atmospheric Emission Inventory System (NAEIS) Support Programme.
- South African Air Quality Information System (SAAQIS) Implementation Support Programme.
- System For the National Atmospheric Emission Licensing (SNAEL) Support Programme.

Provinces are also required to undertake monitoring, data analysis and reporting on ambient air quality as per their mandate as air quality authorities. Training on air quality monitoring will be required, as well as training on data acquisition and analysis. For this task, technical personnel may need to be appointed. Alternatively, this function needs to be outsourced.

10.3 Air Quality Management Tools

10.3.1 Municipal Air Quality Management By-Laws

According to Section 156(1) of the Constitution, a municipality has the executive authority in respect of, and has the right to, administer local government matters (listed in Part B of Schedule 4 and Part B of Schedule 5) that deal with air pollution. Section 156(2), read with section 13(a) of the Local Government: Municipal Systems Act, 2000 (Act No. 32 of 2000), makes provision for a municipality to make and administer by-laws for the effective administration of any matters that it has the right to administer, provided it does not conflict with national or provincial legislation.

In the Kwa-Zulu Natal Province, only four municipalities (eThekwini Metro, City of uMhlatuze LM, Ugu DM and uMgungundlovu DM.) out of a total of 54 have Air Quality By-laws within their jurisdiction. The by-laws include specific regulatory measures for smoke emissions caused by burning, compressed ignition, and emissions that cause a nuisance. These by-laws can be a fundamental air quality management tool.

10.3.2 Complaints Response Database

Air pollution complaints received from the public need to be recorded in a database, investigated and addressed within each level of Government. . Pollution complaints need to be logged into a centralised electronic pollution complaints database at provincial level to ensure the effective co-ordination and management of complaints received. Complaints reported to the KZN EDTEA are referred back to the specified municipality, unless the complaint is about the failure of the municpality to act on a complaint, then the province intervenes to file a compliance monitoring activity.

At the time of this assessment, the availability of such a system in the province was not confirmed. The system should:

(a) Record complaints, including contact details, type of complaint (smoke, odour, dust, etc.), location and other pertinent information.

(b) Assign the complaints to competent personnel to investigate. In terms of compliance and enforcement, verbal warnings are generally issued and, for more serious offences, written notices are served.

(c) Record findings of the investigation.

(d) Provide feedback to the complainant.

(e) Store relevant documents relating to the complaint (e.g., notices, letters, feedback, etc.).

The public must be made aware of this facility through suitable means, e.g., notices, websites, and short message services (SMSs). It is the intention that in the future, SAAQIS will be used as a centralised electronic database for the logging of all air pollution complaints to ensure the effective co-ordination and management of complaints received (Government Notice No. 1144, 2018).

Until such a system is implemented, it is recommended that the KZN EDTEA maintain a complete complaints system, keeping records of responses, letters, notices and feedback to the complainant. In terms of compliance and enforcement, verbal warnings are generally issued and, for more serious offences, written notices are served by the municipal air quality authority.

10.3.3 Emissions Inventory Database

For effective air quality management and control, an easily accessible, accurate, electronic emissions inventory of point, non-point and mobile sources is essential. The South African Atmospheric Emission Licencing and Inventory Portal (SAAELIP) provides the online platform to manage AEL applications and seamlessly integrates the National Atmospheric Emissions Inventory System (NAEIS). The combination of the AEL online applications and the NAEIS system provides the solution to improving the centralised access of emission sources. Authorities, industries, consultants and the general public have access to emission inventories and AEL applications. Access to a comprehensive emissions inventory serves the function of:

- Providing spatially resolved source strength data on each pollutant for dispersion modelling.
- Predicting environmental impacts.
- Helping in urban and regional planning.
- Supporting the design of regional monitoring networks.
- Contributing a basis for evaluating trends.
- Assisting in the formulation of air quality management policies.

The SAAELIP system is relatively new, and the database is currently being expanded; thus, not all sources are likely to be captured on the online system. As part of the South African Air Quality Information System phase two, all source and emissions data recorded within each Municipality and Province should be incorporated into the NAEIS, allowing for easy access and manipulation of data from any sphere of Government. Since the NAEIS was established, Atmospheric Emissions License holders have had to submit annual emissions inventory reports for the compilation of the national emission inventory profile (Government Notice No. 893, 2013).

10.3.4 Geospatial Air Quality Risk Assessment

A spatial assessment of air pollution risk is necessary for effective air quality management. Emission rates are the biggest uncertainty in dispersion modelling assessments. Sources that have sufficient information available, such as the reporting information required from Listed Activities, can be modelled using a dispersion model such as AERMOD or CALPUFF. Dispersion modelling is typically used to identify areas where the ambient concentrations of particular compounds exceed the national ambient air quality standards. This assists in health and environmental risk assessments. It also provides information for the positioning of ambient air quality monitoring networks and helps to assess source contributions to ambient air quality concentrations.

Although huge progress has been made towards better inventories of emissions to air in South Africa, we are a long way from having all the necessary information from all the important sources. This leads to assessments that overemphasize sources which we know a lot about and underrepresents sources that are difficult to quantify. Another problem with dispersion models is the inability to accurately assess intra-urban exposure from large area sources that emit at low temperatures, close to the ground, like residential solid fuel burning (Jerrett, 2005).

An alternative to air dispersion modelling is to use a proximity-based geospatial model, that uses nearness to a particular pollution source as a proxy for exposure, similar to that used by Wright and Diab (2009). This type of geospatial model represents each source category as a weighted layer. Varying buffers are placed around the different source groups, depending on the expected spatial extent of their impact. The sum of all the different layers, results in an assessment of how many sources impact on any particular conurbation.

10.3.5 Dispersion Modelling Software

Limited software and knowledge exists within each sphere of Government to support dispersion modelling. Dispersion modelling software is available at provincial and metropolitian level however no application of the software has been used by the province. The use of such modelling software is critical to the understanding of the temporal and spatial distribution of pollutants in the atmosphere.

Atmospheric dispersion modelling forms an integral component of air quality management and planning. Air quality models are used to establish a relationship between emissions and air quality. Dispersion models require the input of data which includes:

- Meteorological conditions such as wind speed and direction, the amount of atmospheric turbulence, ambient air temperature and the height to the bottom of any inversion layers in the upper atmosphere.
- Emission parameters such as source location and height, stack diameter, exit gas temperature and exit velocit.,
- Terrain elevations at the source and surrounding regions.
- The location, height and width of any obstructions (such as buildings).

Dispersion modelling is typically used to determine compliance with ambient air quality guidelines or standards and assist in health and environmental risk assessments. It also provides information for the positioning of ambient air quality monitoring networks and helps to assess source contributions to ambient air quality concentrations.

The Department of Forestry Fisheries and Environment (DFFE) has developed Air Dispersion Modelling Regulations and technical guidance under paragraph (p) of section 53 of the AQA to ensure that that dispersion modelling practices throughout South Africa are standardised (Government Notice No. R533, 2014).

10.3.6 Ambient Air Quality Monitoring

Currently, there are more than 30 operating AAQM stations in KZN (SAAQIS, 2022) that are operated by the Kwa-Zulu Natal Province, the District Municipalities, Industries and Non-governmental Organisations (Table 43). The co-ordinated transfer of data from the monitoring stations to a centralised database is critical to ensure the effective and efficient management and verification of the monitoring data. As part of the South African Air Quality Information System (SAAQIS), a centralised database has been developed at the South African Weather Services to which all ambient monitoring data is transferred. This database is useful for ensuring that industries report their emissions and for the authorities to monitor compliance. Data from the AAQM stations was made available for three years from 1 January 2019 to 31 December 2021, however, there are many gaps in the data.

An effective ambient air quality monitoring system consists of various hardware, software and communication systems as well as activities related to the ongoing maintenance and calibration of the system. However, other options of ambient monitoring do exist and are fit for purpose while not requiring the substantial financial and human resource outlay as required by continuous monitoring stations. Alterative air quality monitoring methods include passive sampling and low-cost sensors (commercial micro-sensors).

Table 43: AAQM stations in the KZN Province

Station	Municipality	Latitude	Longitude
Newcastle	Amajuba	-27.73417	29.980139
Alverstone	eThekwini	-29.77617	30.732139
Cato Ridge	eThekwini	-29.73575	30.587544
City Hall Durban NAQI	eThekwini	-29.85828	31.027286
Ganges-NAQI	eThekwini	-29.94852	30.964597
Grosvenor	eThekwini	-29.92179	31.00494
Hambanathi Tongaat	eThekwini	-29.55742	31.120064
Jacobs Balfour	eThekwini	-29.92886	30.973483
New Germany	eThekwini	-29.79865	30.876572
Prospecton	eThekwini	-30.00286	30.928778
Settlers-NAQI	eThekwini	-29.95874	30.978717
Southern Works	eThekwini	-29.95696	30.973266
Umkomaas	eThekwini	-30.20803	30.78202

Station	Municipality	Latitude	Longitude
Warwick	eThekwini	-29.85463	31.011631
Wentworth Reservior-NAQI	eThekwini	-29.93409	30.988622
Amazimtoti	eThekwini	-30.03323	30.890176
Stanger	iLembe	-29.34774	31.289078
Airport -RBCAA	King Cetshwayo	-28.73814	32.093333
Arboretum -RBCAA	King Cetshwayo	-28.75239	32.062738
Arboretum -Water Facility	King Cetshwayo	-28.761	32.07862
Brackenham-RBCAA	King Cetshwayo	-28.7313	32.039016
Brackenham-uMhlathuze	King Cetshwayo	-24.72931	32.035901
CBD-RBCAA -NAQI	King Cetshwayo	-28.74472	32.054809
eNseleni	King Cetshwayo	-28.66299	32.017791
eSikhawini	King Cetshwayo	-28.86524	31.911679
eSkhaleni	King Cetshwayo	-28.86887	31.909731
Felixton-RBCAA	King Cetshwayo	-28.82923	31.893536
Habour West-RBCAA	King Cetshwayo	-28.78729	32.027065
Scorpio -RBCAA	King Cetshwayo	-28.76969	30.034228
Empangeni Ngwelezane	King Cetshwayo		
Port Shepstone	Ugu	-30.75019	30.422556
Edendale	uMgungundlovu	-29.63797	30.344507
Pietermaritzburg - KZN	uMgungundlovu	-29.57525	30.404667
Pietermaritzburg - CBD	uMgungundlovu	-29.60206	30.380611
Pietermaritzburg Airport - ORIBI	uMgungundlovu	-29.63758	30.337389
Escourt	uThukela	-28.99967	29.873694

c) Continuous Ambient Air Quality Monitoring

Continuous ambient air quality monitoring requires, among other things, a set of trace gas analysers housed in a secure shelter, meteorological equipment and a data communication and acquisition system, as well as various other mechanical, civil and electrical structures such as an inlet manifold, fencing, a concrete plinth, an air conditioner, an uninterrupted power supply (UPS) and safety devices such as a lightning conductor (Figure 76). All ambient monitoring systems are required to comply with ISO/IEC 17025 (the latest version was published in 2017) which specifies the general requirements for the competence, impartiality and consistent operation of laboratories. SANAS has published supplementary requirements on how to set up and manage continuous AAQMS so that the quality of the data is assured (SANAS, 2012). The requirements for AAQMS include: the type of pollutant analysers and meteorological sensors; data management protocols; analyser and sensor calibration and maintenance; data management protocols; and siting requirements. All of these factors, when combined, result in high-quality, reliable and accurate air quality monitoring data. This data is required to inform air quality management strategies and plans.

Figure 76: Examples of continuous ambient air quality monitoring stations

The co-ordinated transfer of data from the monitoring stations to a centralised database is critical to ensure the effective and efficient management and verification of the monitoring data. As part of the South African Air Quality Information System (SAAQIS), a centralised database has been developed at the South African Weather Services to which all ambient monitoring data is transferred. This database is useful for ensuring that industries report their emissions and for the authorities to monitor compliance.

Limitations of this type of continuous monitoring are associated with spatial coverage, technical skills required for maintenance and calibrations, and the financial implications of operation.

d) Passive Diffusive Monitoring

Passive monitoring is an inexpensive method of monitoring over a large area and requires little human intervention. Passive badges can measure a range of pollutants including SO_2, NO_2, O_3, hydrogen sulphide (H_2S), hydrochloric acid (HCl), VOCs, and various aldehydes among others. Passive diffusive sampling calculates an average reading over a time period as opposed to the real-time data acquisition that continuous monitoring can provide. Passive badges (Figure 77) have to be sent away to an accredited laboratory for analysis, further extending the lag time in getting results (2 – 3 weeks). Passive sampling conforms to international methodologies and standards and can be used as a screening method in the placement of continuous AAQMSs and to validate dispersion modelling results.

However, there are limitations associated with passive monitoring. Extreme meteorological conditions such as high humidity and temperatures influence diffusion rates, and hence, affect concentrations. Given that passive badge monitoring is based on diffusion of pollutants, concentrations may be questionable, making comparison with ambient air quality guidelines/standards difficult.

Figure 77: Passive badge sampling equipment

e) Low-cost air quality sensors

Air quality monitoring networks can be expensive to establish and maintain, thus an alternative to the traditional air quality monitoring equipment is the low-cost air quality sensor technology that can be deployed in areas where ambient air quality data gaps exist. Low-cost sensors can assess air pollution at a finer spatial resolution than traditional air quality monitors, these sensors are generally small, mobile, energy efficient (can be powered by solar), measure concentrations of all criteria air pollutants and meteorological parameters. The low-cost sensors use a wireless data logging system and report on real-time ground-based measurement of emission concentrations (Figure 78). The instrument is an inexpensive alternative to measure exposure to ambient air quality and can assist in compiling epidemiological evidence-based air quality management policies.

The limitation to the low-cost sensors is that they are not approved international standard instruments, however, they can be calibrated using reference instruments that can give confidence intervals on the measurements. Furthermore, the instrument is sensitive to chemical interference and environmental conditions, and since it is commissioned outdoors, there are device safety concerns and power outages to take into account.

Figure 78: Example of various Low-cost air quality sensor equipment (Wernecke, et al., 2023)

f) Proposed Air Quality Monitoring for the KZN

There are currently 30 government-owned air quality monitoring stations in KZN. Screening should be performed in areas identified as hotspots as per the baseline assessment in order to identify areas where continuous monitoring is required. An effort should be made to ensure that all data and reports from Government and privately owned stations are published on SAAQIS. To this end, agreements should be drawn up with privately owned stations.

10.4 Air Quality Threat Assessment

A review of the latest available district Integrated Developmental Plan reports were assessed to determine whether proposed future development plans will affect the air quality in the province. It is important to outline developments that are underway, as they have the potential to increase the emission rates from the baseline assessment, and studies show that some pollutants can harm human health even at very low levels. Developments, potential threats, and recommendations are provided (Table 44).

No energy-related projects were outlined in the districts' IDPs. However, with the amendment to schedule 2 of the Electricity Regulation Act 4 of 2006, approving an increase in the threshold which a licence is not required for generation of electricity from 1 MW to 100 MW (Act No. 4, 2006), municipalities will be encouraged to include embedded energy generation in their municipal development plans in the short to medium term. Energy projects will require an environmental impact assessment process and will have to apply for an Atmospheric Emission Licence. It is recommended that nearby communities be invited for stakeholder engagement during the environmental authorisation process for the planned developments.

Table 44 outlines potential development projects that might impact the management of the air quality within the province. It is important to note that developments must comply with relevant regulations and standards to ensure the safety of the environment and the community. The emissions from these development projects need to inform future inventories in the next AQMP generation.

Table 44: KZN threat assessment based on future development plans.

Sector Projects	Project Activities	Geographical Extent	Potential threats	Exposure Period	Mitigation Measures
Industry	Construction of a new concrete manufacturing facility. Richards Bay Gas to Power project (1060 MW)	King Cetshwayo DM	Source of fugitive dust from the construction phase. The primary emissions from concrete manufacture, are PM, NO_X, SO_2, CO, and CO_2. The establishment of gas-to-power projects can lead to the discharge of substances such as nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM) into the atmosphere. These releases can have adverse effects on the quality of the air.	Long term	Cement production is a listed activity in terms of the NEM: AQA (Act No. 39 of 2004) and will be required to comply with the prescribed emission limits. Furthermore, during the manufacturing phase, district authorities need to ensure that dustfall monitoring is conducted to ensure that dustfall remains within the limits governed by the National Dust Control Regulations (Government Notice No. 517, 2018). The gas-to-power project must comply with relevant regulations and standards to ensure the safety of the environment and the community.

	Increase of open stockpiling and activities related to the handling of coal at the Richards Bay port.	King Cetshwayo DM	Fugitive dust from coal storage and material handling.	Long term	Storage and handling of coal must comply with the limits set out in the National Dust Control Regulations. Local Authorities need to enforce compliance monitoring at the port. Where exceedances occur mitigation measures need to be put in place such as covering loads on coal vehicles and increasing the volume and frequency of dust suppression.
Transport	Expansion/Construction of roads (paved/unpaved) Influx of coal trucks into the Richards Bay area.	Regional – eThekwini Metropolitan Municipality, uMkhanyakude DM, Harry Gwala DM	National road capacity improvement will result in an increase of road freight which increase gaseous and dust emissions from vehicles.	Long term	The relevant AQM authority should implement by-laws and regulatory processes with regards to the maintenance requirements for vehicles to reduce emissions. This could be linked to the annual licensing process. Rail transportation infrastructure needs to be improved so as to handle freight transport and consequently reduce road transport.

Waste	Construction/refurbishment of waste facilities (Wastewater treatment works/sewer infrastructure/ landfills)	Regional – Amajuba DM, eThekwini Metropolitan Municipality, uThukela DM, uMgungundlovu DM, Ugu DM, iLembe DM, Harry Gwala DM.	Construction of wastewater works, and solid waste facilities will potentially increase fugitive emissions. Construction sites increase particulate matter emissions which have potential human health impacts. Construction machinery and diesel/petrol-based generators used at these sites also contribute to fugitive emissions. Wastewater treatment works and landfills can also represent a localised risk of increased atmospheric emissions during operation.	Short – Long term	Construction of new facilities involves land clearing and materials handling. Thus, where EIA is not necessary, the district authorities with the relevant AQM function are required to ensure dust control measures are practiced to minimise potential impacts. Ensure that facilities are compliant with applicable air quality legislation such as NAAQS, odour and dust regulations. Operational maintenance of wastewater facilities must be ensured because deterioration of equipment results in an increase in gaseous/VOC emissions. Ensure new landfill and WWTW sites are licenced, and waste sites are operated in accordance with the regulated requirements for waste disposal. The location of the various waste facilities in close proximity to residential areas should be avoided.

10.5 Vision, Mission, and Commitment

The vision, mission, goals and objectives developed for KZN reflect the vision, mission and general approach for air quality management at the National, District and Local levels. The National Framework for Air Quality Management (Government Notice No. 1144, 2018) and the Manual for Air Quality Management Plans (DEA, 2012) were referenced during this process to ensure the province is in line with national requirements. The strategic goals have been numbered, and related objectives have been outlined in the AQMP implementation plan.

10.5.1 Vision

To attain and maintain good air quality for the benefit of all inhabitants and natural environmental ecosystems within KZN and develop into global leaders that are committed to addressing air quality problems for the betterment of our society.

10.5.2 Mission

- To improve the air quality in hotspot areas from the current grading of "poor" to "acceptable."
- Once acceptable air quality is achieved, to maintain good air quality in the province indefinitely through proactive and effective management principles that take into account the need for sustainable development into the future.
- To work in partnership with Government, communities and stakeholders to ensure that the air is healthy to breathe and is not detrimental to the well-being of persons in KZN.
- To ensure that future developments (industries, transportation, housing etc.) have minimal air quality impacts.
- To reduce the potential for damage to sensitive natural environmental systems from air pollution both in the short and long term.
- To facilitate intergovernmental communication at the local, provincial, and national levels to ensure effective air quality management and control in KZN.
- Implement effective air quality management planning through the monitoring of air quality, investigating areas of concern, and documentation/regulation of pollution sources and their impact on society.
- Maintaining good air quality within the boundaries, with specific emphasis on pollutants of concern (SO_2, NO_X, PM and Pb) in the province.

10.5.3 Commitment

- Integrating air quality considerations into the town planning mechanisms especially when considering housing, transportation and spatial planning developments.

- Raising awareness around air quality issues, thereby promoting community well-being and empowerment.

10.5.4 Strategic Goals and Objectives

1. Full implementation of the provincial air quality management function and effective intragovernmental relations.
2. Assign clear responsibilities and functions for air quality management. Develop extensive capacity building to ensure adequate and competent personnel within the province.
3. Ensure an effective air quality management system and emission inventory to support decision making in KZN.
4. Ensure compliance monitoring and enforcement of air quality legislation, policies and regulations are visible and effective.
5. Raise awareness and ensure information sharing on air quality issues in KZN.

10.6 Air Quality Management Implementation Plan

The Implementation Plan for the KZN Provincial AQMP is presented in the following tables. For each of the Goals, appropriate objectives were set. In turn, Activities necessary to achieve each objective were assigned, together with the responsible stakeholder(s) and the timeframes required to achieve the objective. Generic timeframes, ranging between short term (1 – 2 years), medium term (3 – 5 years) and long term (5 – 10 years), were assigned. Responsibilities have been allocated to relevant bodies. Indicators necessary to assess progress with implementation are assigned to each objective. The objectives captured in Table 45 to Table 49 encompass the five KZN strategic goals.

The AQO should advise the relevant departments regarding the review of the AQMP, preferably every 5 years. The AQO must ensure that an annual update report on the implementation of the AQMP is compiled. In addition, the AQO should advise the relevant departments if they have identified any changes that should be made in the AQMP, prior to the scheduled review of the document. The AQMP should be considered a living document that will require changes as they arise.

Table 45: Goal 1. Full implementation of the provincial air quality management function and effective intergovernmental relations.

1. Objectives: Goal	Action	Responsibility	Supporting agency	frequency	Timeframe	Indicators
1.1. Improve the intergovernmental relations between spheres of government and industry.	1.1.i. Promote consultation between provincial, district, and local authorities to take responsibility for their AQM activities.	KZN EDTEA	DFFE and COGTA	Annual	Short; Ongoing	Number of consultation meetings with various authorities (Management councils) convened.
	1.1.ii. Ensure that AQMP objectives, skills and experience are transferred, particularly from KZN EDTEA to the district.	KZN EDTEA	DFFE	Annual	Short	Cooperation mechanism established, AQMP objectives are highlighted, and regular meetings held.
	1.1.iii. Review the terms and reference of the current provincial AQO forum and extend invitations to broader stakeholders (sector departmental personnel) to discuss issues of air quality.	KZN EDTEA District AQM Units	DFFE	Immediate	Short, Ongoing	AQO forum reviewed and relations with broader stakeholders encouraged and maintained.
	1.1.iv. Invite industry to one of the provincial virtual air quality forum meetings for strategic discussions when required.	KZN EDTEA District AQM Units	DFFE	Annual	Short, Ongoing	Industry attending air quality forum meetings for strategic discussions.

1. Objectives: Goal	Action	Responsibility	Supporting agency	frequency	Timeframe	Indicators
	1.1.v. Prepare and submit air quality report to the national AQO.	KZN EDTEA		Annual	Short	Air quality report submitted.
	1.1.vi. Participate and report in national meetings such as working group 2.	KZN EDTEA	eThekwini Metropolitan Municipality		Quarterly	Attend and participate in AQ National meetings.
	1.1.vii. Prepare an annual report providing information on progress regarding the implementation of the AQMP and compliance with the provincial implementation plan to the National AQO as per Section 17 of the Air Quality Act.	KZN EDTEA		Annual	Short	Submit progress report on the provincial AQMP and implementation plan progress.
	1.1.viii. Engage with COGTA and SALGA to address specific financial and performance management needs for the implementation of the AQMP.	KZN EDTEA	COGTA SALGA District AQM units	Annual	Short	Consultation meetings held with COGTA and SALGA.
	1.1.ix. Participate in Air Quality Governance Lekgotla.	KZN EDTEA	District AQOs	Annual	Short	Attend and participate in National governmental conferences.

1. Objectives: Goal	Action	Responsibility	Supporting agency	frequency	Timeframe	Indicators
	1.1.x. Collaborate with District and Metropolitan municipalities to fulfil the AEL function	KZN EDTEA	District AQOs	Immediate	Short	Ensure that the Metropolitan and District Municipalities implement AEL functions as the AEL Authorities
	1.1.xi. Support municipalities in the adoption of their AQMPs by the relevant councils.	KZN EDTEA	DFFE		Short, ongoing	Number of municipalities supported in the adoption of their AQMPs by council.
	1.1.xii. Support municipalities to acquire funding for their AQM functions and implementation plans.	KZN EDTEA			Short - Long	Number of municipalities' implementation cost of AQMPs and AQM activities motivated.
	1.1.xiii. Contribute to the development and review of Metropolitan and District AQMPs.	KZN EDTEA	DFFE	Immediate	Short, Ongoing	KZN EDTEA attend and participate in the AQMP stakeholder process.
	1.1.xiv. Participate in departmental planning meetings and comment on district and metropolitan municipal planning documents.	KZN EDTEA	District AQOs	Immediate	Short, Ongoing	Communicate air quality benefits of improved service delivery.

Table 46: Goal 2. Assign clear responsibilities and functions for air quality management. Develop extensive capacity building to ensure adequate and competent personnel within the province.

Objectives: Goal 2.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
2.1. Designate a dedicated, full-time air quality officer.	2.1.i. Revise KZN EDTEA organogram to provide a post for a dedicated full time AQO.	KZN EDTEA		Immediate	Short	KZN organogram accommodates a dedicated AQO.
	2.1.ii. Ensure that the job description for the provincial AQO is aligned with the responsibility of AQOs in the act.	KZN EDTEA		Immediate	Short	Job description aligned with the National Air Quality Act.
	2.1.iii. Designate a dedicated full time provincial AQO.	KZN EDTEA		Immediate	Short	Full time Provincial AQO appointed.
	2.1.iv. Promote the designation of district and metropolitan AQOs.	KZN EDTEA	District AQ units	Immediate	Short	Designation of district and metropolitan AQOs.
2.2. Train AQO personnel on the air quality management function.	2.2.i. Assess AQM competency of AQOs and technical development needs.	KZN EDTEA		Immediate	Short, Ongoing	The AQM competency of incumbent and new staff as well as technical development needs are identified.
	2.2.ii. Include identified AQM training and development programs in the AQ department of the province.	KZN EDTEA	DFFE		Short - Long	AQM training needs included.
	2.2.iii. Identify appropriate technical training courses and	KZN EDTEA	DFFE	Immediate	Short - long	Technical training courses and related

Objectives: Goal 2.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
	related mechanisms for incumbent and new staff.					mechanisms are identified.
	2.2.iv. Undertake training as per assessment needs.	KZN EDTEA	DFFE		Short, Ongoing	Training completed as per assessment needs.
	2.2.v. Train metropolitan and district AQOs in use of the SAAELIP and the NAEIS for reporting of listed activities.	DFFE	KZN EDTEA		Short, Ongoing	Number of SAAELIP/NAEIS training workshop for metropolitan and district AQOs has been conducted.
	2.2.vi. Implement a continuous professional development program in ambient air quality monitoring and reporting and assess training needs for both current and new personnel.	KZN EDTEA	DFFE and SAWS		Short, Ongoing	Officials' continuous development is encouraged, and training needs are addressed.
	2.2.vii. Determine areas of research needed in AQM (e.g., Research on how emissions from industrial and biomass burning incidents can be measured.) and communicate to relevant research institutions and academia.	KZN EDTEA	DFFE and District AQ Units		Short - Medium	Number of engagements with research institutions and academia convened and development of a comprehensive study on the measurement of

Objectives: Goal 2.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
						emissions from incidents achieved.

Table 47: Goal 3. Ensure an effective air quality management system and emission inventory to support decision-making in KZN.

Objectives: Goal 3.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
3.1. Effectively implement the KZN provincial AQMP.	3.1.i. Review the AQMP every five years.	KZN EDTEA	DFFE, District municipalities' AQM units		Every 5 years	AQMP reviewed with current gaps addressed.
	3.1.ii. Escalate issues from the AQMP into the KZN development strategy.	KZN EDTEA		Immediate	Short, Ongoing	AQMP issues included in the province's developmental strategy.
	3.1.iii. Integrate air quality and climate change response to avoid unintended consequences.	KZN EDTEA	DFFE		Medium - Long	Air quality and climate change response integrated.
3.2. Improve the emission inventory system in the province.	3.2.i. Support district AQOs in ensuring that industries' (listed activities) emission reports are submitted directly into the NAEIS and quality checking is done in accordance with the requirements.	KZN EDTEA	DFFE	Immediate	Short, Ongoing	All listed activity emission information captured in the NAEIS. Emission reports must be made in the format required for the NAEIS and should be in accordance with the specific AEL or provisional AEL.
	3.2.ii. Ensure that AQOs verify AEL information before reporting into the NAEIS.	KZN EDTEA, District AQOs	DFFE	Immediate	Short, Ongoing	AEL information verified.

Objectives: Goal 3.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
	3.2.iii. Discuss issues of reporting requirements such as emission factors and QA/QC issues with DFFE where discrepancies are identified.	KZN EDTEA. District AQM Units	DFFE		Short, Ongoing	AEL information verified with the national department and possible discrepancies are addressed.
	3.2.iv. Promote the development of metropolitan and district AQMPs in line with the National Framework of Air Quality Management (NFAQM).	KZN EDTEA	DFFE		Short, Ongoing	AQMPs Developed.
	3.2.v. Support district municipalities in developing and regularly updating an electronic database of all controlled emitters operating within KZN which they need to report on at the AQ Forum.	KZN EDTEA			Short - Medium	Electronic database developed, and up to date, of all industries, their emissions and specifications. Updates are reported at the AQ Forum.
	3.2.vi. Maintain the emission inventory and update it based on measured emissions reported, to ensure it remains current and representative.	KZN EDTEA	District AQM unit		Short, Ongoing	Updated KZN emission database is available based on measured data.
	3.2.vii. Audit the emissions inventory that includes all point and diffuse sources for all significant pollutants.	KZN EDTEA, District AQOs			Short, Ongoing	Audited KZN emission database is available based on measured data.

Objectives: Goal 3.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
3.3. Identification & Management of priority areas in the province.	3.3.i. Develop and publish a process for declaring priority areas in the province.	KZN EDTEA	DFFE		Short	Process for declaring a priority area in the province established.
	3.3.ii. Review and engage industries about their emissions and identify districts or metros which should be declared as priority areas.	KZN EDTEA, District AQOs	DFFE		Short	Identify districts or metros which should be declared as priority areas.
3.4. Implement management interventions for the control of dust, noise, and odours.	3.4.i. Develop regulatory processes to manage offensive odours from various industrial processes.	KZN EDTEA	DFFE		Short - Medium	Establish and implement regulations on the management of offensive odours from industries.
	3.4.ii. Investigate industries/sources from which offensive odours emanate and engage with the industries to manage odour from their processes.	KZN EDTEA, Industries	District AQM Units	As per complaint	Short, ongoing	Number of odour complaints reduced.
	3.4.iii. Develop noise control regulations/by-laws to manage noise pollution.	KZN EDTEA	District AQM Units		Short - Medium	Establish and implement regulations on the management of noise pollution.
	3.4.iv. Investigate industries from which noise pollution emanates	KZN EDTEA	District AQM Units	As per complaint	Short, ongoing	Number of noise pollution complaints reduced.

Objectives: Goal 3.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
	and engage industries on noise control.					
	3.4.v. Ensure that listed activities comply with the National Dust Control Regulations. Any exceedances of the dustfall limits should be investigated and dealt with appropriately.	District AQM Units	KZN EDTEA	Annual	Short, ongoing	Number of dustfall exceedances from listed activities reduced.
3.5. Dispersion modelling optimised as an air quality management tool.	3.5.i. Use dispersion modelling to highlight hotspot areas and assist in planning and decision making.	KZN EDTEA, District AQM Units			Short	Modelling is carried out for KZN AQMP.
	3.5.ii. Ensure that all Air Quality Impact Assessment and Atmospheric Impact Reports are evaluated in terms of cumulative impacts. To do this, AERMOD input files of all point sources across the province should be set up (the information should be readily available as it should be submitted with each AQIA). Industries should be grouped by location, so that when a new AEL is applied for, the Licensing Authority assessing the application can run the model with	District AQM units	KZN EDTEA	Immediate	Short, Ongoing	All AQIAs for EIA, and all Atmospheric Impact Reports assessed with cognisance taken of other sources in the vicinity by the Licensing Authority.

Objectives: Goal 3.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
	all other point sources in the area to assess the cumulative impacts.					
3.6. Develop an Air Quality Monitoring strategy	3.6.i. Develop a realistic ambient air quality monitoring strategy for areas in the province where ambient monitoring is unavailable and where air quality impact is underestimated/unknown.	KZN EDTEA, District AQM Units	DFFE, SAWS		Short - Medium	Ambient air quality monitoring strategy developed for areas where ambient monitoring is unavailable.
	3.6.ii. Implement the monitoring strategy to establish an ambient air quality baseline and use passive monitoring/low-cost air quality sensors to assist in identifying areas of concern and investigate whether an AQMS is required for continual monitoring.	KZN EDTEA, District AQM Units			Short - Medium	Ambient air quality baseline established, and priority areas identified and investigated for continuous monitoring.
	3.6.iii. Report quality assured data from ambient monitoring stations to SAAQIS and Provincial AQO's forum.	KZN EDTEA, District AQM units		Immediate	Short, Ongoing	Ambient air quality monitored and reported to SAAQIS and Provincial AQO's forum.
	3.6.iv. Present ambient data from passive monitoring campaigns in the annual AQO's report.	KZN EDTEA, District AQM units		Every second year	Short - Medium	Ambient data from passive monitoring is presented in the annual AQO's report.

Table 48: Goal 4. Ensure compliance, monitoring and enforcement of air quality legislation, policies and regulations are visible and effective.

Objectives: Goal 4.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
4.1. Air quality complaints in the province are dealt with efficiently and effectively.	4.1.i. Stakeholders are aware of the procedure to report air quality related complaints.	KZN EDTEA, District AQM units			Short, Ongoing	Complaints procedure is publicised.
	4.1.ii. Record all air quality complaints in an electronic system and assign investigation of the complaints to the appropriate investigating authority as per current procedure.	KZN EDTEA, District AQM unit			Short, Ongoing	Complaints registers are current, and investigations are tracked.
	4.1.iii. Refer all environmental non-compliances to environmental management inspectors (EMIs) for enforcement.	District AQM units	KZN EDTEA		Short, Ongoing	Non-compliances are assigned to EMIs.
4.2. Compliance and enforcement	4.2.i. Develop air quality management by-laws that are aligned to the NEM: AQA using the model by-laws (Government Notice No. 579, 2010).	KZN EDTEA District AQM units				Air Quality Management By-Laws developed.
	4.2.ii. Publish contact details of relevant AQOs in communities.	KZN EDTEA, District AQM Units		Immediate	Short, Ongoing	Community is able to access AQM officials in emergencies.
	4.2.iii. Designate and train an Environmental Management	KZN EDTEA			Short - Medium	Air quality management personnel appointed,

	Inspector (EMI) for enforcement of AQM by-laws.					trained and designated as EMI.
	4.2.iv. Audit and monitor compliance to the AEL conditions of all listed activities in the province.	District AQOs	KZN EDTEA			Annual audit report of all AELs.
	4.2.v. Oversee district municipalities in the identification of all listed activities operating without AELs in the province.	District AQM Units	KZN EDTEA	Annual	Short, Ongoing	Listed activities without AEL identified and instructed to comply.
	4.2.vi. Institute a campaign to efficiently receive and process AEL applications from unlicensed facilities.	District AM Units	KZN EDTEA	Annual	Short, Ongoing	AELs are issued to all listed activities.

Table 49: Goal 5. Raise awareness and ensure information sharing on air quality issues in the KZN province.

Objectives: Goal 5.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
5.1. Ensure that Senior management and council, have knowledge of air quality management.	5.1.i. Present the AQMP to the relevant provincial council for adoption. If council rejects the AQMP, province will have to address the issues and get the AQMP adopted	KZN EDTEA	DFFE	Immediate	Short	AQMP presented and adopted by the relevant council.
	5.1.ii. Present the AQMP to the national AQO and metropolitan and district AQOs.	KZN EDTEA		Immediate	Short	AQMP presented to national, metropolitan and district AQOs
	5.1.iii. Enhance information sharing through incorporation of air quality management issues as a standing item in the quarterly air quality forum meetings.	KZN EDTEA	District AQM Units	Immediate	Short	Air quality management issues incorporated as a standing item in the quarterly AQO's forum.
	5.1.iv. Report progress on the implementation of the AQMP to the provincial AQO's forum.	KZN EDTEA		Annual	Short, Ongoing	Attendance and reporting at the provincial AQO's forum.
5.2. Province to support district municipalities in ensuring that broad	5.2.i. Identify stakeholder groups that will benefit by improving their knowledge and understanding of air quality issues.	KZN EDTEA	District AQM Units	Immediate	Short	Stakeholders in the DM identified.

Objectives: Goal 5.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
stakeholders in the community have knowledge of air quality issues.	5.2.ii. Simplify technical reports and management plans for public awareness programs e.g., infographics, posters, interactive media etc.	KZN EDTEA, District AQM Units			Short	Simplified technical information is available.
	5.2.iii. Identify the most appropriate mechanism for transferring knowledge, e.g., media, schools, pamphlets, newspaper articles, workshops, preferred language, etc.	District AQM Units	KZN EDTEA		Short - Medium	Knowledge transfer mechanisms are identified.
	5.2.iv. Ensure that the awareness program is included in the province's service delivery budget implementation plan.	KZN EDTEA		Annual	Short, Ongoing	Awareness program is included in the KZN province service delivery budget implementation plan.
	5.2.v. Develop information sharing programs and learning material accordingly.	District AQM Units	KZN EDTEA	Annual	Short, Ongoing	Information sharing programs and learning material developed.
	5.2.vi. Disseminate information and conduct knowledge sharing sessions with municipal communities.	District AQM Units	KZN EDTEA	Annual	Short, Ongoing	Air quality knowledge is disseminated appropriately.
	5.2.vii. Consult communities, local leaders, community organisations etc. as part of air quality related research process.		KZN EDTEA	As per research campaign	Short, Ongoing	Research conducted.

Objectives: Goal 5.	Action	Responsibility	Supporting agency	Frequency	Timeframe	Indicators
	5.2.viii. Incorporate indigenous information/ knowledge into air quality studies.	District AQM Units, Research institutions	KZN EDTEA	Annual	Short, Ongoing	Community knowledge is included in air quality studies.
	5.2.ix. Use stakeholder forums to provide communication platform to communities.	District AQM Units	KZN EDTEA	Annual	Short, Ongoing	Presentations at stakeholder forums.
	5.2.x. Create awareness campaigns around the negative health impacts of residential fuel burning.	District AQM Units	KZN EDTEA	Annual	Short, Ongoing	Awareness campaigns implemented.
	5.2.xi. Create awareness campaigns around the negative health impacts of waste burning.	District AQM Units	KZN EDTEA	Annual	Short, Ongoing	Awareness campaigns implemented.
	5.2.xii. Create awareness campaigns around the negative health impacts of biomass burning.	District AQM units	KZN EDTEA	Annual	Short, Ongoing	Awareness campaigns implemented.

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APPENDIX 1: WRF Modelled Wind Roses

Table 50: uMzinyathi DM wind analysis summary for Dundee (WRF Modelled Data).

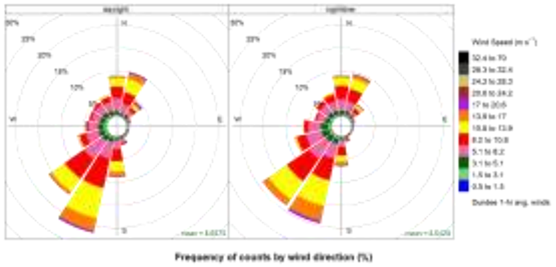
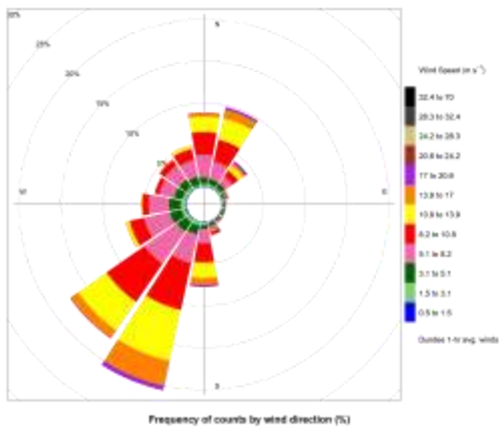
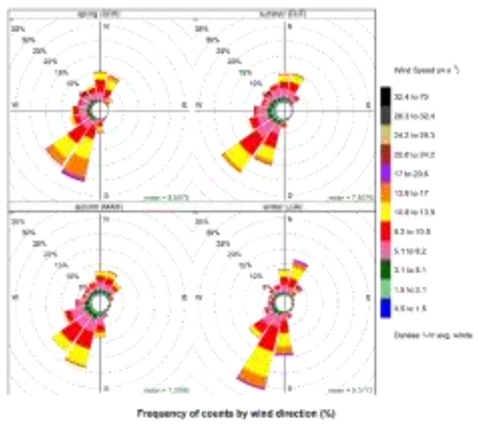
uMzinyathi District Municipality wind analysis at Dundee for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at Dundee located in the uMzinyathi DM for the years 2019-2021.
• The dominant wind speed: Moderate breeze (5.1 – 8.2 m/s) occurred 29% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: South-south-westerly and South-westerly directions • The highest wind speeds: Gale (17 – 20.6 m/s) • Average windspeeds: 8.6 m/s • Calm conditions (>0.5 m/s) occurred :0.1% of the measured time • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (8.7 m/s) than during the night (8.5 m/s) • Seasonal Wind Condition: The highest wind speeds are evident in spring and winter	
Wind roses of the average hourly winds at Dundee in the uMzinyathi DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at Dundee located in the uMzinyathi DM for the years 2019-2021.**
	

Table 51: iLembe DM wind analysis summary for KwaDukuza (WRF Modelled Data).

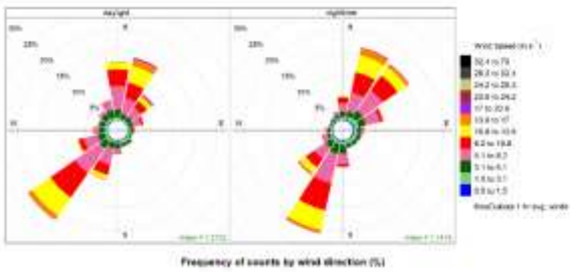
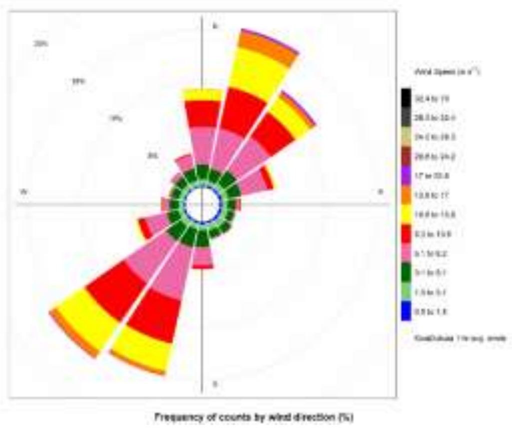
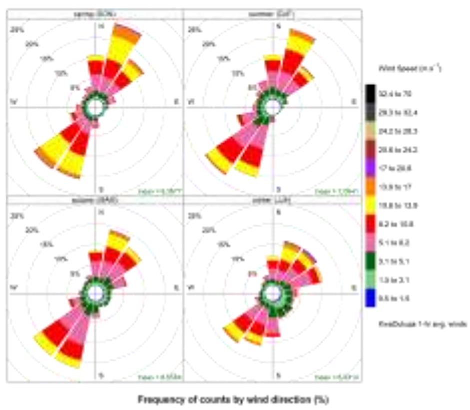
iLembe District Municipality Summary Wind Analysis at KwaDukuza for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at KwaDukuza located in the iLembe DM for the years 2019-2021.
• The dominant wind speed: Moderate breeze (5.1 – 8.2 m/s) occurred 36% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: North-north-easterly, North-easterly, South-south-westerly, and South-westerly directions. • The highest wind speeds: Gale (17 – 20.6 m/s) • Average windspeeds: 7.2 m/s • Calm conditions (>0.5 m/s) occurred in 0.4% of the measured period. • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (7.3 m/s) than during the night (7.1 m/s) • Seasonal Wind Condition: The highest wind speeds are evident in spring and summer.	
Wind roses of the average hourly winds at KwaDukuza located in the iLembe DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at KwaDukuza located in the iLembe DM for the years 2019-2021.**
	

Table 52: uMkhanyakude DM wind analysis summary for Mkuze (WRF Modelled Data).

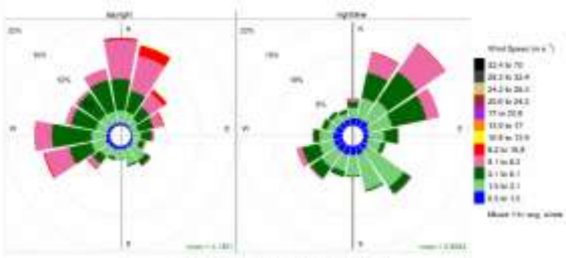
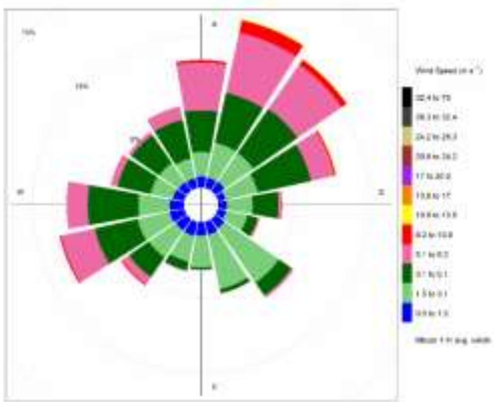
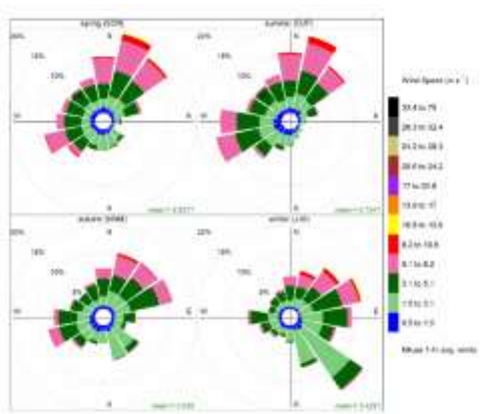
uMkhanyakude District Municipality Summary Wind Analysis at Mkuze for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at Mkuze located in the uMkhanyakude DM for the years 2019-2021.
• The dominant wind speed: Light breeze (1.5 – 3.1 m/s) occurred 32% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: North-north-easterly and North-easterly directions. • The highest wind speeds: Strong breeze (10.8 – 13.9 m/s) • Average windspeeds: 3.6 m/s • Calm conditions (>0.5 m/s) occurred in 2.3% of the measured period. • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (4.1 m/s) than during the night (3.0 m/s) • Seasonal Wind Condition: The highest wind speeds are evident in spring and summer.	
Wind roses of the average hourly winds at Mkuze located in the uMkhanyakude DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at Mkuze located in the uMkhanyakude DM for the years 2019-2021.**
 	

Table 53: Harry Gwala DM wind analysis summary for Ixopo (WRF Modelled Data).

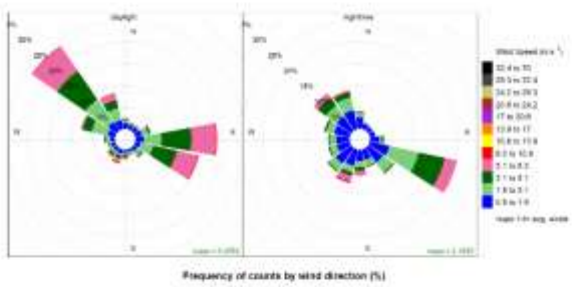
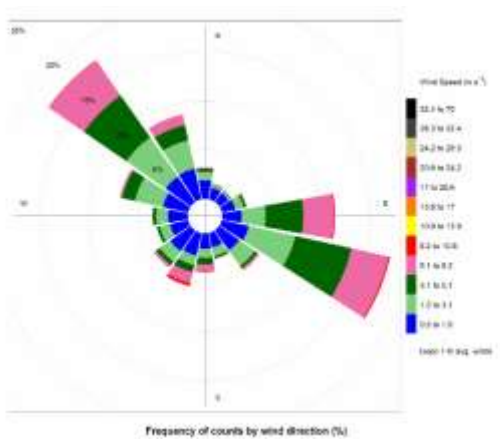
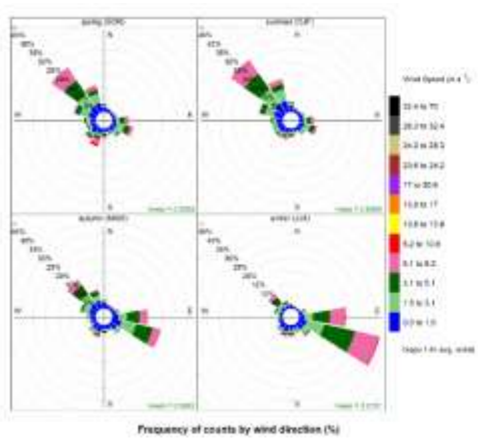
Harry Gwala District Municipality Summary Wind Analysis at Ixopo for the 2019 to 2021 period.	**Diurnal wind roses of the average hourly winds at Ixopo located in the Harry Gwala DM for the years 2019-2021.**
• The dominant wind speed: Light air (0.5 – 1.5 m/s) occurred 31% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: Easterly and East-south-easterly and North-westerly directions. • The highest wind speeds: Fresh breeze (8.2 – 10.8 m/s) • Average windspeeds: 2.9 m/s • Calm conditions (>0.5 m/s) occurred in 8.2% of the measured period. • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (3.5 m/s) than during the night (2.2 m/s) • Seasonal Wind Condition: The highest wind speeds are evident in spring and winter	
Wind roses of the average hourly winds at Ixopo located in the Harry Gwala DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at Ixopo located in the Harry Gwala DM for the years 2019-2021.**
	

Table 54: Amajuba DM wind analysis summary for Newcastle (WRF Modelled Data).

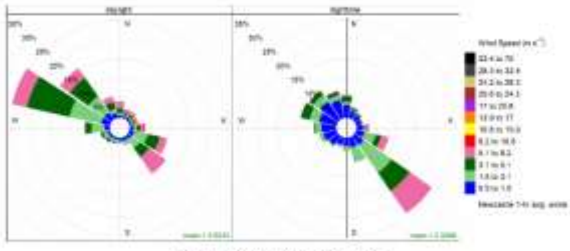
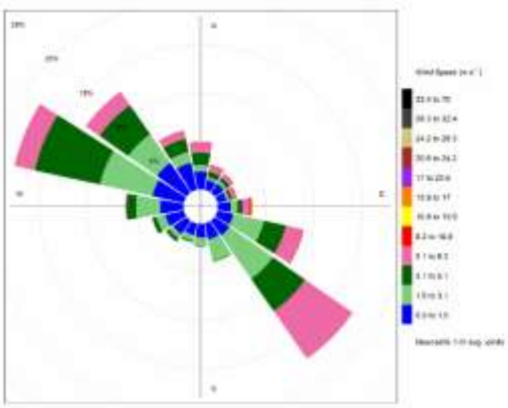
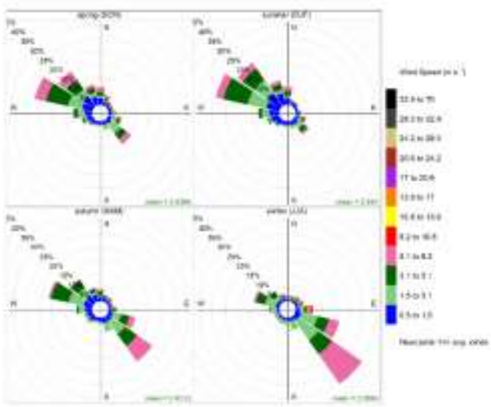
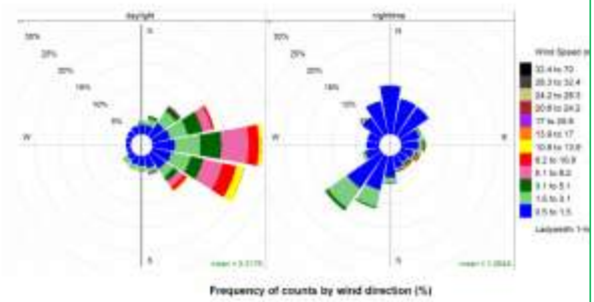
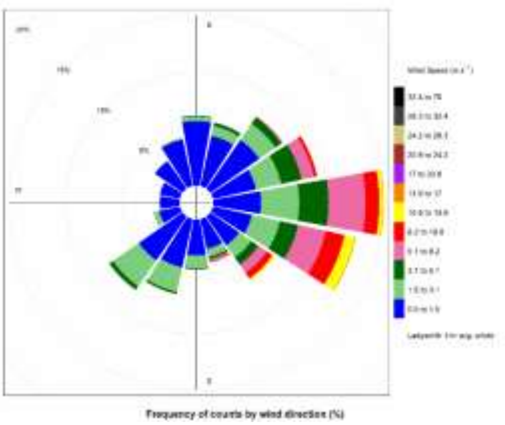
Amajuba District Municipality Summary Wind Analysis at Newcastle for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at Newcastle located in the Amajuba DM for the years 2019-2021.
• The dominant wind speed: Light air (0.5 – 1.5 m/s) occurred 28% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: South-easterly and West-north-westerly directions. • The highest wind speeds: Strong breeze (10.8 - 13.9 m/s) • Average windspeeds: 2.9 m/s • Calm conditions (>0.5 m/s) occurred in 8.9% of the measured period. • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (3.5 m/s) than during the night (2.3 m/s) • Seasonal Wind Condition: The highest wind speeds are evident in spring and winter •	
Wind roses of the average hourly winds at Newcastle located in the Amajuba DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at Newcastle located in the Amajuba DM for the years 2019-2021.**
 	

Table 55: uThukela DM wind analysis summary for Ladysmith (WRF Modelled Data).

uThukela District Municipality Summary Wind Analysis at Ladysmith for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at Ladysmith located in the uThukela DM for the years 2019-2021.
• The dominant wind speed: Light air (0.5 – 1.5 m/s) occurred 49% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: Easterly and East-south-easterly directions. • The highest wind speeds: Near gale (13.9 – 17 m/s) • Average windspeeds: 2.4 m/s • Calm conditions (>0.5 m/s) occurred in 15.3% of the measured period. • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (3.3 m/s) than during the night (1.3 m/s) • Seasonal Wind Condition: The highest average wind speeds are evident in all seasons, with autumn recording slightly higher average wind speeds.	
Wind roses of the average hourly winds at Ladysmith located in the uThukela DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at Ladysmith located in the uThukela DM for the years 2019-2021.**
	

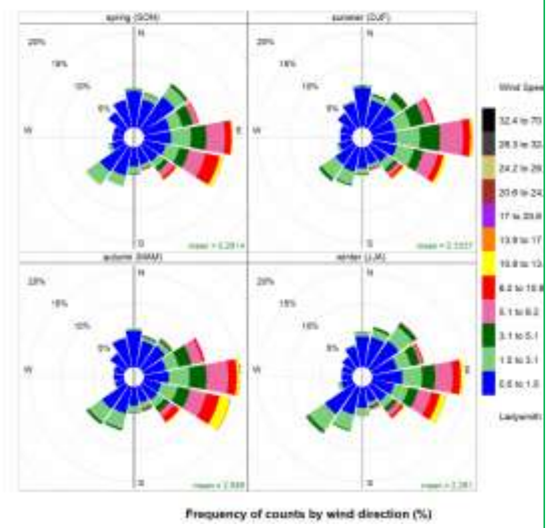
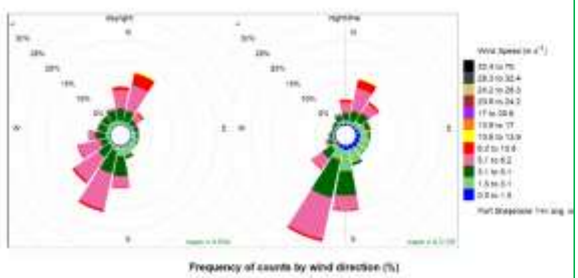
	

Table 56: Ugu DM wind analysis summary for Port Shepstone (WRF Modelled Data).

Ugu District Municipality Summary Wind Analysis at Port Shepstone for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at Port Shepstone located in the Ugu DM for the years 2019-2021.
• The dominant wind speed: Moderate (5.1 – 8.2 m/s) occurred 34% of the measured period. • The prevalent wind direction occurring at more than 10% frequency in three years: North-north-easterly, South, and South-south-westerly directions. • The highest wind speeds: Strong breezes (10.8 – 13.9 m/s) • Average windspeeds: 4.6 m/s • Calm conditions (>0.5 m/s) occurred in 0.7% of the measured period. • Diurnal Wind Variation: Average wind speeds are slightly higher in the day (4.9 m/s) than during the night (4.2 m/s) • Seasonal Wind Condition: The highest average wind speeds are evident in spring and summer.	

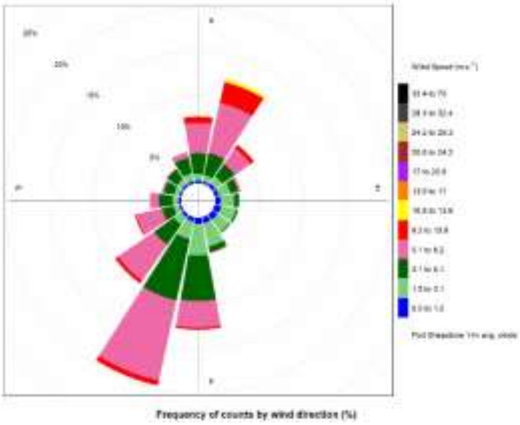
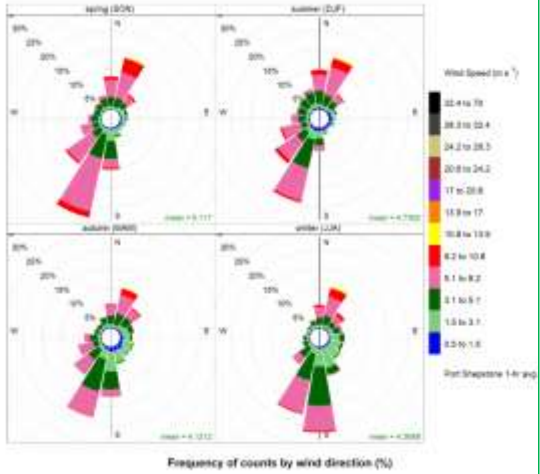
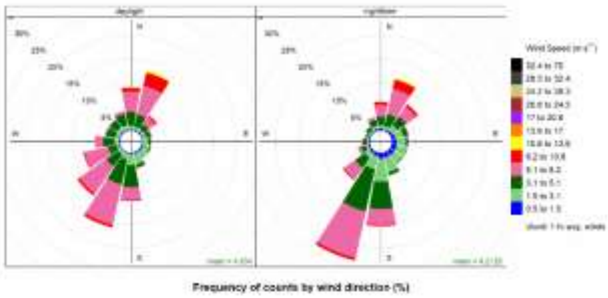
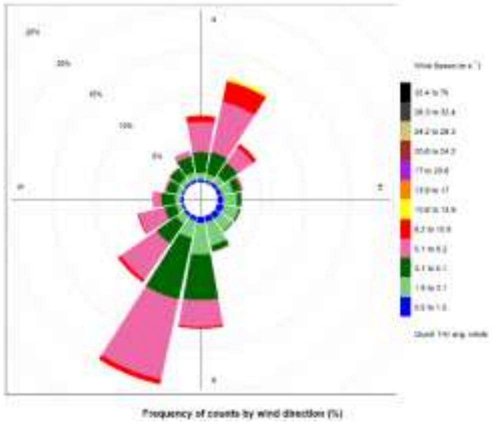
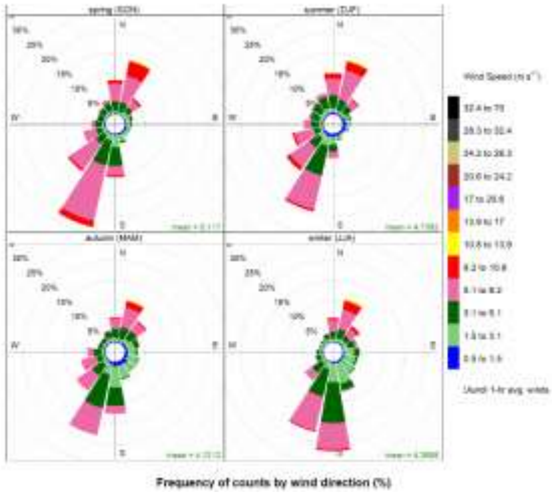
Wind roses of the average hourly winds at Port Shepstone located in the Ugu DM for the years 2019-2021.	Seasonal wind roses of the average hourly winds at Port Shepstone located in the Ugu DM for the years 2019-2021.
	

Table 57: Zululand DM wind analysis summary for Ulundi (WRF Modelled Data).

Zululand District Municipality Summary Wind Analysis at Ulundi for the 2019 to 2021 period.	Diurnal wind roses of the average hourly winds at Ulundi located in the Zululand DM for the years 2019-2021.
- The dominant wind speed: Moderate (5.1 – 8.2 m/s) occurred 28.4% of the measured period. - The prevalent wind direction occurring at more than 10% frequency in three years: North-north-easterly, South-south-westerly and South-westerly directions. - The highest wind speeds: Strong breeze (10.8 – 13.9 m/s) - Average windspeeds: 8.6 m/s - Calm conditions (>0.5 m/s) occurred in 0.2% of the measured period. - Diurnal Wind Variation: Average wind speeds are slightly higher in the day (4.9 m/s) than during the night (4.2 m/s) - Seasonal Wind Condition: The highest average wind speeds are evident in spring and summer.	
Wind roses of the average hourly winds at Ulundi located in the Zululand DM for the years 2019-2021.	**Seasonal wind roses of the average hourly winds at Ulundi located in the Zululand DM for the years 2019-2021.**


Frequency of counts by wind direction (%)


Frequency of counts by wind direction (%)

APPENDIX 2: AAQMS EXCEEDANCE TABLE

Table 58: KZN AQMS Exceedance Table for the period 2019 – 2021 (SAAQIS, 2022).

Station Name	Recorded Exceedances Per Pollutant													
	SO_2		PM_{10}		$PM_{2.5}$		NO_2		CO		O_3		C_6H_6	
Alverstone	2019													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		
	2020													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	2	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	4	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Arboretum	2019													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
Brackenham	2019													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020													

	1hr	37	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	
	24hr	3	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Cato Ridge	**2019**													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020													
	1hr	-	24hr	4	24hr	8	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021													
	1hr	-	24hr	2	24hr	5	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
CBD RBCAA	**2019 -**													
	1hr	-	24hr	-	24hr	14	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	2020 -													
	1hr	1	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr		1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	8	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	1	1yr	-	1yr	-	1yr	-	8hr	-		-		-

	1yr	-		-		-		-		-		-		-
City Hall Durban	**2019 -**													
	1hr	-	24hr	11	24hr	8	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	-	24hr	12	24hr	9	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	13	24hr	7	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Edendale	**2019 -**													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	2		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
eSikhaleni	**2019 -**													
	1hr	-	24hr	2	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-

	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	71	24hr	1	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	2	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	2	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Esikhawini	**2019 -**													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	2	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	2	24hr	3	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Felixton	**2019 -**													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													

	1hr	2	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	1	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	2	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Felixton E2	**2019**													
	1hr		24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020													
	1hr		24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021													
	1hr		24hr	-	24hr	17	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Ganges	**2019 -**													
	1hr	-	24hr	<100	24hr	<100	1hr	<10	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	2	1yr	1	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	-	24hr	4	24hr	-	1hr	<100	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	2	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	8	24hr	4	1hr	<100	1hr	-	8hr	-	1yr	-

	24hr	-	1yr	-	1yr	-	1yr	1	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Habour West	**2019 -**													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	1	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	13	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	2	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	51	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	4	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Hamban athi Tongaat	**2019**													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020													
	1hr	-	24hr	6	24hr	8	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021													
	1hr	-	24hr	10	24hr	12	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Scorpio	**2019 -**													
	1hr	3	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-

	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	84	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	10	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	35	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	7	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Settlers	**2019 -**													
	1hr	20	24hr	20	24hr	13	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	1	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	4	24hr	-	24hr	<20	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	1	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	-	24hr	<10	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Southern Works	**2019 -**													
	1hr	9	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	2	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-

	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Warwick	2019 -													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	-	24hr	-	24hr	-	1hr	<100	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	1	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													
	1hr	-	24hr	-	24hr	-	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
Wentworth Reservoir	2019 -													
	1hr	1	24hr	14	24hr	11	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	1	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2020 -													
	1hr	2	24hr	15	24hr	15	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	-	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-
	2021 -													

	1hr	-	24hr	15	24hr	12	1hr	-	1hr	-	8hr	-	1yr	-
	24hr	-	1yr	1	1yr	-	1yr	-	8hr	-		-		-
	1yr	-		-		-		-		-		-		-

Note:"-" Indicate no exceedance recorded in that period or no available data.

APPENDIX 3: KZN Listed Activities

Table 59 : Total emissions per listed activity/controlled emitter in KZN (NAEIS, 2019).

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
Amajuba District Municipality	KNAM0021	Metallurgical Industry	-	15 367	-	757	215 793	477 328	215 793	121 319
	KNAM0022	Metallurgical Industry	-	15 367	-	757	215 793	477 328	215 793	121 319
	KNAM0023	Metallurgical Industry	-	15 367	-	757	215 793	477 328	215 793	121 319
	KNAM0024	Metallurgical Industry	-	15 367	-	-	151 857	2 831 669	210 507	-
	KNAM0025	Metallurgical Industry	-	15 367	-	-	151 857	2 831 669	210 507	-
	KNAM0026	Metallurgical Industry	-	15 367	-	-	151 857	2 831 669	210 507	-
	KNAM0027	Metallurgical Industry	-	11 525	-	382	942	9 397	942	-
	KNAM0028	Metallurgical Industry	11	11 525	-	382	942	9 397	942	-
	KNAM0029	Metallurgical Industry	-	11 525	-	382	942	9 397	942	-
	KNAM00210	Metallurgical Industry	-	11 525	-	382	942	9 397	942	-
	KNAM00211	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00212	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00213	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00214	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00215	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00216	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00217	Metallurgical Industry	-	-	-	771	-	343	737	-
	KNAM00259	Metallurgical Industry	-	2 498 577	-	155 235	330	532 362	13 380	2
	KNAM00260	Metallurgical Industry	-	2 498 577	-	155 235	330	532 362	13 380	2

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNAM0041	Mineral Processing, Storage and Handling	-	-	-	-	-	-	7 001	-
	KNAM0042	Mineral Processing, Storage and Handling	-	-	-	-	-	-	1 359	-
	KNAM0043	Mineral Processing, Storage and Handling	-	-	-	124 003	-	16 131	195 996	-
	KNAM0044	Mineral Processing, Storage and Handling	-	-	-	-	-	-	222	-
	KNAM0045	Mineral Processing, Storage and Handling	-	-	-	-	-	-	222	-
	KNAM0046	Mineral Processing, Storage and Handling	-	-	-	-	-	-	6 616	-
	KNAM0047	Mineral Processing, Storage and Handling	-	-	-	-	-	-	290	-
	KNAM0048	Mineral Processing, Storage and Handling	-	-	-	-	-	-	145	-
	KNAM0049	Mineral Processing, Storage and Handling	-	-	-	-	-	-	27	-
	KNAM00410	Mineral Processing, Storage and Handling	-	-	-	-	-	-	387	-
	KNAM00411	Mineral Processing, Storage and Handling	-	-	-	-	-	-	140	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNAM00412	Mineral Processing, Storage and Handling	-	-	-	-	31	-	31	-
	KNAM0064	Metallurgical Industry	-	10	-	2	167	-	-	-
	KNAM0101	Inorganic Chemicals Industry	-	-	-	-	-	9	21	-
	KNAM0102	Inorganic Chemicals Industry	-	-	-	-	-	-	1	-
	KNAM0103	Inorganic Chemicals Industry	-	-	-	-	-	-	1	-
	KNAM0104	Inorganic Chemicals Industry	-	2 039	-	20 130	-	6 112	9 811	7
	KNAM0105	Inorganic Chemicals Industry	-	3 885	0	9 474	1 854	4 094	1 854	3
	KNAM0106	Inorganic Chemicals Industry	-	495	-	257	-	13	96	6 585
	KNAM0107	Inorganic Chemicals Industry	-	-	-	-	-	-	44	-
	KNAM0108	Inorganic Chemicals Industry	-	-	-	-	-	-	159	-
	KNAM0109	Inorganic Chemicals Industry	-	-	-	-	-	-	159	-
	KNAM01010	Inorganic Chemicals Industry	-	29 945	-	204 032	-	40 632	2 036	1 612
	KNAM01011	Inorganic Chemicals Industry	-	-	-	-	-	-	955	-
	KNAM01012	Inorganic Chemicals Industry	-	-	-	-	-	-	10	-
	KNAM01013	Inorganic Chemicals Industry	-	-	-	-	-	-	492	-
	KNAM01015	Inorganic Chemicals Industry	-	-	-	-	-	-	13	-
	KNAM01016	Inorganic Chemicals Industry	-	-	-	-	-	-	13	-
	KNAM01017	Inorganic Chemicals Industry	-	-	-	-	-	-	266	-
	KNAM01018	Inorganic Chemicals Industry	-	-	-	-	-	-	17	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNAM01019	Inorganic Chemicals Industry	-	-	-	-	-	-	980	-
	KNAM01020	Inorganic Chemicals Industry	-	-	-	-	-	-	1	-
	KNAM01021	Inorganic Chemicals Industry	-	10 538	-	30 768	-	546	955	1
	KNAM0146	Carbonization and Coal Gasification	-	-	-	4 864	3 871	304	3 871	-
	KNAM0159	Organic Chemicals Industry	-	33 437	1	73 562	9 897	1 707	-	-
	KNAM0301	Disposal of Hazardous and General Waste	-	205	-	263	-	-	1 135	-
	KNAM0302	Disposal of Hazardous and General Waste	-	39	-	227	-	-	62	-
	KNAM0303	Disposal of Hazardous and General Waste	-	60	-	290	-	-	309	-
			11	**5 216 110**	**1**	**787 535**	**1 123 198**	**11 101 254**	**1 550 283**	**372 168**
eThekwini Metropolitan Municipality	KNET0011	Organic Chemicals Industry	-	-	-	-	-	-	-	20 784
	KNET0012	Organic Chemicals Industry	-	-	-	-	-	-	-	10 547
	KNET0013	Organic Chemicals Industry	-	-	-	-	-	-	-	1 438
	KNET0014	Organic Chemicals Industry	-	-	-	-	-	-	-	898
	KNET0015	Organic Chemicals Industry	-	-	-	-	-	-	-	145
	KNET0021	Disposal of Hazardous and General Waste	-	98	3	-	17	-	64	4
	KNET0031	Metallurgical Industry	-	-	79	19 362	2 623	7 745	2 623	10 039
	KNET0032	Metallurgical Industry	-	-	79	19 362	2 623	7 745	2 623	10 039

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNET0033	Metallurgical Industry	-	-	79	19 362	2 623	7 745	2 623	10 039
	KNET0034	Metallurgical Industry	-	-	82	20 015	5 302	8 006	5 302	10 378
	KNET0035	Metallurgical Industry	-	-	82	20 015	5 302	8 006	5 302	10 378
	KNET0036	Metallurgical Industry	-	-	82	20 015	5 302	8 006	5 302	10 378
	KNET0037	Metallurgical Industry	-	-	79	68 120	20 021	13 624	20 021	10 007
	KNET0038	Metallurgical Industry	-	-	79	68 120	20 021	13 624	20 021	10 007
	KNET0039	Metallurgical Industry	-	-	79	68 120	20 021	13 624	20 021	10 007
	KNET00310	Metallurgical Industry	-	-	79	68 120	20 021	13 624	20 021	10 007
	KNET00313	Metallurgical Industry	-	-	-	33 289	88 775	73 236	-	-
	KNET00314	Metallurgical Industry	-	-	-	16 389	11 076	114 676	-	-
	KNET00315	Metallurgical Industry	-	-	-	2 366	6 390	2 894	-	-
	KNET00316	Metallurgical Industry	-	-	-	4 075	15 427	1 332	-	-
	KNET00317	Metallurgical Industry	-	-	-	-	38	-	2 120	-
	KNET0043	Organic Chemicals Industry	-	-	-	-	-	-	-	172
	KNET0051	Metallurgical Industry	-	-	-	0	-	0	122	-
	KNET0052	Metallurgical Industry	-	-	-	165	-	1	40	-
	KNET0053	Metallurgical Industry	-	-	-	152	-	2	51	-
	KNET009	Mineral Processing, Storage and Handling	-	-	-	-	210	-	-	-
	KNET0101	Petroleum Industry	0	80 904	-	134 609	6 520	50 421	6 674	-
	KNET0102	Petroleum Industry	-	22 972	-	76 577	1 867	13 668	1 895	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNET0103	Petroleum Industry	-	8 541	-	10 168	705	5 106	705	-
	KNET0104	Petroleum Industry	-	6 932	-	8 253	571	4 282	572	-
	KNET0105	Petroleum Industry	-	17 023	-	56 742	1 400	9 351	1 404	-
	KNET0106	Petroleum Industry	-	19 135	-	63 782	1 578	9 351	1 578	-
	KNET0107	Petroleum Industry	-	9 307	-	31 024	768	11 936	768	-
	KNET0108	Petroleum Industry	-	5 026	-	5 983	413	3 051	415	-
	KNET0109	Petroleum Industry	-	10 662	-	12 693	868	6 642	880	-
	KNET01010	Petroleum Industry	-	5 986	-	7 126	492	3 518	494	-
	KNET01011	Petroleum Industry	-	635 253	-	200 828	37 840	726 482	50 453	-
	KNET01012	Petroleum Industry	-	1 625	-	1 934	19	12 047	25	-
	KNET01013	Petroleum Industry	-	4 200	-	5 000	342	3 543	346	-
	KNET01014	Petroleum Industry	-	403	-	479	1 358	9 999	6	-
	KNET01015	Petroleum Industry	-	2 291	-	2 727	189	1 227	189	-
	KNET01016	Petroleum Industry	-	2 387	-	2 842	196	1 282	197	-
	KNET01017	Petroleum Industry	-	2 474	-	2 945	203	1 752	204	-
	KNET01018	Petroleum Industry	-	28 326	-	94 420	97	16 043	97	-
	KNET01019	Petroleum Industry	-	13 664	-	45 546	47	11 347	47	-
	KNET01020	Petroleum Industry	-	3 196	-	3 805	261	1 856	264	-
	KNET01021	Petroleum Industry	-	5 986	-	7 126	481	3 827	494	-
	KNET01022	Petroleum Industry	-	4 908	-	5 842	400	3 220	405	-

TOTAL EMISSIONS (Kg/ANNUM)										
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	KNET01023	Petroleum Industry	-	21 416	-	71 386	1 325	6 468	1 767	-
	KNET01024	Petroleum Industry	-	27 801	-	92 671	1 720	16 296	2 293	-
	KNET01025	Petroleum Industry	-	4 382	-	5 217	271	96 611	361	-
	KNET01026	Petroleum Industry	-	16 827	-	20 032	1 041	8 012	1 388	-
	KNET0151	Petroleum Industry	-	652	-	1 920	3 214	9 114	-	-
	KNET0152	Petroleum Industry	-	-	-	-	-	-	-	1
	KNET0154	Petroleum Industry	-	-	-	-	-	-	-	1
	KNET0155	Petroleum Industry	-	-	-	-	-	-	-	1
	KNET01547	Petroleum Industry	-	101	-	2 675	2 608	7 849	-	-
	KNET0201	Inorganic Chemicals Industry	-	-	-	-	-	-	1 184	-
	KNET0202	Inorganic Chemicals Industry	-	-	-	-	-	-	2 765	-
	KNET0203	Inorganic Chemicals Industry	-	-	-	-	-	280	967	-
	KNET02129	Organic Chemicals Industry	-	-	-	-	-	-	-	222
	KNET0234	Combustion Installations	-	7 455	0	20 957	150	-	150	-
	KNET024	Mineral Processing, Storage and Handling	-	-	-	-	116	1 607	145	0
	KNET0261	Metallurgical Industry	-	-	-	-	-	0	318	-
	KNET0271	Mineral Processing, Storage and Handling	-	-	504	-	1 767	-	1 920	-
	KNET0272	Mineral Processing, Storage and Handling	-	-	736	-	9 444	-	10 266	-

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	KNET0292	Metallurgical Industry	0	-	0	-	6 244	-	-	-
	KNET0295	Metallurgical Industry	0	600	-	150	30	-	-	0
	KNET0296	Metallurgical Industry	-	-	0	-	116	-	232	-
	KNET0297	Metallurgical Industry	0	-	0	-	320	-	641	-
	KNET0298	Metallurgical Industry	0	716	-	-	101	0	202	0
	KNET0299	Metallurgical Industry	0	-	0	-	63	0	125	-
	KNET03113	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	8 238	-	305 109	16 027	226 934	-	1 380
	KNET03114	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	74 625	-	461 114	47 036	174 307	-	3 438
	KNET03117	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	876	-	-
	KNET03118	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	88	-	-
	KNET03119	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	1 872	-	-

TOTAL EMISSIONS (Kg/ANNUM)										
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	KNET03120	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	60	-	-
	KNET03613	Organic Chemicals Industry	-	-	-	-	-	-	-	1
	KNET0371	Petroleum Industry	383	-	-	26 698	13 552	11 614	17 155	-
	KNET03745	Petroleum Industry	417	-	-	244	288	83 729	365	-
	KNET037181	Petroleum Industry	181	-	-	-	-	-	-	-
	KNET037182	Petroleum Industry	6	-	-	-	-	-	-	-
	KNET037197	Petroleum Industry	5 534	-	-	-	-	-	-	-
	KNET0411	Organic Chemicals Industry	-	-	-	-	-	-	-	4 521
	KNET0412	Organic Chemicals Industry	-	-	-	-	-	-	-	3 096
	KNET0413	Organic Chemicals Industry	-	-	-	-	-	-	-	595
	KNET0414	Organic Chemicals Industry	-	-	-	-	-	-	-	14
	KNET0415	Organic Chemicals Industry	-	-	-	-	-	-	-	0
	KNET0416	Organic Chemicals Industry	-	-	-	-	-	-	-	5
	KNET0417	Organic Chemicals Industry	-	-	-	-	-	-	-	1
	KNET0418	Organic Chemicals Industry	-	-	-	-	-	-	-	6
	KNET0419	Organic Chemicals Industry	-	-	-	-	-	-	-	401
	KNET04112	Organic Chemicals Industry	-	-	-	-	-	-	-	855
	KNET0475	Organic Chemicals Industry	-	241	-	803	22	2	-	21

TOTAL EMISSIONS (Kg/ANNUM)										
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	KNET0493	Petroleum Industry	-	55	-	609	295	6 329	-	-
	KNET0494	Petroleum Industry	-	166	-	1 826	884	18 986	-	-
	KNET0501	Organic Chemicals Industry	-	-	-	-	-	-	-	42 980
	KNET0502	Organic Chemicals Industry	-	-	-	-	-	-	-	42 980
	KNET0504	Organic Chemicals Industry	-	4 785	11	5 982	4 817	26 161	-	-
	KNET0505	Organic Chemicals Industry	-	-	-	-	-	-	-	64 470
	KNET0506	Organic Chemicals Industry	-	-	-	-	-	-	-	64 470
	KNET0508	Organic Chemicals Industry	-	-	-	-	-	-	-	103 932
	KNET0509	Organic Chemicals Industry	-	-	-	-	-	-	-	103 932
	KNET05010	Organic Chemicals Industry	-	-	-	-	-	-	-	25
	KNET0561	Metallurgical Industry	-	279	-	-	59	0	59	-
	KNET057	Disposal of Hazardous and General Waste	-	1 776	-	5 204	1 819	-	-	-
	KNET058	Petroleum Industry	-	486	-	263	219	53	-	39
	KNET0611	Inorganic Chemicals Industry	-	-	-	2	-	-	-	-
	KNET0612	Inorganic Chemicals Industry	-	-	-	0	-	0	-	9
	KNET0622	Organic Chemicals Industry	0	-	-	-	-	-	-	257 276
	KNET0623	Organic Chemicals Industry	0	-	-	-	-	-	-	265 722
	KNET0624	Organic Chemicals Industry	-	-	-	-	-	-	-	62
	KNET0625	Organic Chemicals Industry	-	-	-	-	-	-	-	40 548
	KNET0626	Organic Chemicals Industry	-	-	-	-	-	-	-	7 231

TOTAL EMISSIONS (Kg/ANNUM)										
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	KNET0627	Organic Chemicals Industry	-	-	-	-	-	-	-	1 919
	KNET0628	Organic Chemicals Industry	-	19 775	0	2 490	287	363	287	-
	KNET06217	Organic Chemicals Industry	-	-	-	-	855	-	-	240
	KNET0712	Metallurgical Industry	-	-	-	-	8	-	8	-
	KNET07310	Organic Chemicals Industry	-	-	-	8	98	-	98	-
	KNET07311	Organic Chemicals Industry	-	-	-	8	98	-	98	-
	KNET07313	Organic Chemicals Industry	-	-	-	-	-	-	-	4 316
	KNET0741	Combustion Installations	-	-	-	64 200	82 788	21 400	83 000	-
	KNET0742	Combustion Installations	-	-	-	-	-	-	-	-
	KNET0743	Combustion Installations	-	41 537	66	91 382	134 542	879	16 600	-
	KNET0811	Metallurgical Industry	-	-	-	-	4	-	4	-
	KNET0812	Metallurgical Industry	-	-	-	-	16	-	16	-
	KNET0813	Metallurgical Industry	-	-	-	-	71	-	71	-
	KNET08688	Petroleum Industry	-	23	-	2	12	247	-	13
	KNET0901	Disposal of Hazardous and General Waste	-	-	-	-	-	-	38	-
	KNET0902	Disposal of Hazardous and General Waste	-	2 672	-	753	-	92	349	-
	KNET0971	Organic Chemicals Industry	-	31	-	0	-	-	-	-
	KNET0972	Organic Chemicals Industry	-	1	-	0	1	-	1	-
	KNET0975	Organic Chemicals Industry	-	0	-	0	0	0	-	-
	KNET1003	Combustion Installations	-	70	0	803	394	6 026	-	-

TOTAL EMISSIONS (Kg/ANNUM)										
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	KNET1041	Disposal of Hazardous and General Waste	-	33	0	-	51	0	53	0
	KNET1042	Disposal of Hazardous and General Waste	-	15 138	0	-	312	0	321	0
	KNET1043	Disposal of Hazardous and General Waste	-	143	0	-	161	0	166	0
	KNET1045	Disposal of Hazardous and General Waste	-	70	0	-	74	0	76	0
	KNET1046	Disposal of Hazardous and General Waste	-	35	0	-	53	0	55	0
	KNET1117	Metallurgical Industry	-	-	-	-	50	-	-	-
	KNET1118	Metallurgical Industry	-	-	4	-	143	-	82	-
	KNET1119	Metallurgical Industry	-	-	-	-	3	5	2	3
	KNET1221	Metallurgical Industry	-	-	0	-	2	-	2	-
	KNET1222	Metallurgical Industry	-	-	0	-	6	-	6	-
	KNET1223	Metallurgical Industry	-	-	0	-	6	-	6	-
	KNET1224	Metallurgical Industry	-	-	0	-	6	-	6	-
	KNET1241	Organic Chemicals Industry	-	-	-	-	-	-	-	98
	KNET1242	Organic Chemicals Industry	-	-	-	-	-	-	-	7
	KNET1271	Disposal of Hazardous and General Waste	-	98	0	342	-	1	51	55
	KNET1272	Disposal of Hazardous and General Waste	-	147	0	244	-	0	72	52

TOTAL EMISSIONS (Kg/ANNUM)										
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	KNET12812	Petroleum Industry	-	-	-	-	-	-	-	28
	KNET12840	Petroleum Industry	-	285	-	9 420	573	42 416	12 672	-
	KNET12841	Petroleum Industry	-	210	-	6 668	932	48 511	15 180	-
	KNET1305	Metallurgical Industry	-	1 137	15	4 851 475	0	239	2 515	0
	KNET1331	Metallurgical Industry	-	-	-	-	6	-	6	-
	KNET1332	Metallurgical Industry	-	-	-	-	4	-	-	-
	KNET1341	Mineral Processing, Storage and Handling	-	-	-	24	-	77	667	-
	KNET1342	Mineral Processing, Storage and Handling	-	-	-	24	-	77	667	-
	KNET1343	Mineral Processing, Storage and Handling	-	-	-	20	5	-	735	-
	KNET1344	Mineral Processing, Storage and Handling	-	-	-	422	-	1 134	962	-
	KNET1345	Mineral Processing, Storage and Handling	-	-	-	-	327	-	665	-
	KNET1346	Mineral Processing, Storage and Handling	-	-	-	72	-	171	1 441	-
	KNET1371	Organic Chemicals Industry	-	-	-	-	-	-	-	1 845
	KNET1372	Organic Chemicals Industry	-	-	-	-	-	-	-	1 845
	KNET1373	Organic Chemicals Industry	-	-	-	-	-	-	-	1 845
	KNET1374	Organic Chemicals Industry	-	-	-	-	-	-	-	1 845
	KNET1375	Organic Chemicals Industry	-	-	-	-	-	-	-	1 845
	KNET1376	Organic Chemicals Industry	-	-	-	-	-	-	-	1 845

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNET1382	Organic Chemicals Industry	-	-	-	-	-	-	-	0
	KNET1383	Organic Chemicals Industry	-	-	-	-	-	-	-	6
	KNET1384	Organic Chemicals Industry	-	-	-	-	-	-	176	0
	KNET1385	Organic Chemicals Industry	-	-	-	-	-	-	36	0
	KNET1386	Organic Chemicals Industry	-	-	-	-	-	-	-	429
	KNET1387	Organic Chemicals Industry	-	-	-	-	-	-	-	86
	KNET13811	Organic Chemicals Industry	-	-	-	-	-	-	-	5
	KNET141	Metallurgical Industry	-	-	-	-	585	-	-	-
	KNET1523	Organic Chemicals Industry	-	-	-	-	-	-	-	15
	KNET1526	Organic Chemicals Industry	-	-	-	-	-	-	-	653
	KNET1531	Organic Chemicals Industry	-	-	-	-	-	-	-	294
	KNET1532	Organic Chemicals Industry	-	-	-	-	-	-	-	294
	KNET155	Petroleum Industry	-	-	-	-	-	4	15	-
	KNET1681	Organic Chemicals Industry	-	-	-	-	-	-	-	35
	KNET1683	Organic Chemicals Industry	-	-	-	-	-	-	-	4
	KNET1684	Organic Chemicals Industry	-	-	-	-	-	-	-	104
	KNET1691	Organic Chemicals Industry	-	-	-	-	-	-	-	15
			6 521	**1 143 304**	**2 136**	**7 278 714**	**618 428**	**2 022 732**	**353 871**	**1 163 247**
Harry Gwala District Municipality	KNSI0025	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	725	4	3 915	6 961	1 658	7 735	953

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNSI0026	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	39 933	4	615	8 342	2 192	9 269	953
	KNSI0027	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	158 798	4	8 032	34 231	1 090	38 035	953
	KNSI0028	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	14 604	0	7 239	15 625	792	17 361	48
	KNSI0051	Petroleum Industry	-	1 107 651	50	229 257	230 820	41 042	230 820	17 715
	KNSI0052	Petroleum Industry	-	101 606	269	1 669 997	2 062 446	41 750	2 062 446	95 203
			0	**1 423 317**	**330**	**1 919 054**	**2 358 426**	**88 525**	**2 365 666**	**115 824**
iLembe District Municipality	KNIL0051	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	-	-	-	96 238	95 198	-	-
	KNIL0056	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	101 575	0	91 417	38 598	457 086	40 630	-
	KNIL0061	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	-	-	-	214 860	3 099	-	-
	KNIL0091	Combustion Installations	24	3 427	0	1 257	319	34	-	12
	KNIL0092	Combustion Installations	15	2 109	0	773	197	21	-	7

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNIL0093	Combustion Installations	13	1 845	0	677	172	18	-	6
	KNIL013	Combustion Installations	-	-	-	1 464 098	1 884 961	98 202	1 478 707	-
	KNIL0142	Combustion Installations	-	0	9	0	0	0	-	256
	KNIL0143	Combustion Installations	-	0	10	0	0	0	-	279
	KNIL0144	Combustion Installations	-	0	7	0	0	0	-	208
	KNIL0171	Disposal of Hazardous and General Waste	-	21	0	201	-	25	50	-
	KNIL0172	Disposal of Hazardous and General Waste	-	-	0	-	-	25	49	-
			52	**108 978**	**26**	**1 558 423**	**2 235 345**	**653 708**	**1 519 436**	**768**
King Cetshwayo District Municipality	KNUT0038	Metallurgical Industry	-	82 847	-	233 922	-	143 997	55 541	1 574
	KNUT00310	Metallurgical Industry	-	8 220 717	-	3 048	1	1 247 363	39 169	95 344
	KNUT00311	Metallurgical Industry	-	12 515 035	-	2 829	1	1 201 600	54 365	37 677
	KNUT00312	Metallurgical Industry	-	11 477 492	-	2 786	1	1 511 556	46 305	115 982
	KNUT00313	Metallurgical Industry	-	12 003 662	-	2 698	1	1 354 690	46 358	94 258
	KNUT00314	Metallurgical Industry	-	12 420 024	-	2 575	1	840 995	35 049	63 203
	KNUT0106	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	10 308	0	67 437	29 068	880	-	1 288
	KNUT0107	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	10 308	0	67 437	29 068	880	-	1 288

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUT0108	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	10 308	0	67 437	29 068	880	-	1 288
	KNUT0109	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	0	2 562	-	9 998	206	9 865	-	3
	KNUT012	Mineral Processing, Storage and Handling	-	-	-	-	-	9 457	417	-
	KNUT01314	Mineral Processing, Storage and Handling	-	-	-	892	-	1 258	732	-
	KNUT0171	Mineral Processing, Storage and Handling	-	-	-	-	55 693	-	-	-
	KNUT0172	Mineral Processing, Storage and Handling	-	-	-	-	57 301	-	-	-
	KNUT0173	Mineral Processing, Storage and Handling	-	-	-	-	967	-	-	-
	KNUT0182	Mineral Processing, Storage and Handling	-	-	-	-	3 072	-	-	-
	KNUT0183	Mineral Processing, Storage and Handling	-	-	-	-	3 072	-	-	-
	KNUT0184	Mineral Processing, Storage and Handling	-	-	-	-	400	4	400	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUT0185	Mineral Processing, Storage and Handling	-	-	-	-	400	4	400	-
	KNUT0186	Mineral Processing, Storage and Handling	-	-	-	-	1 495	-	-	-
	KNUT0187	Mineral Processing, Storage and Handling	-	-	-	-	1 495	-	-	-
	KNUT0188	Mineral Processing, Storage and Handling	-	-	-	466	1 048	12	1 048	-
	KNUT0189	Mineral Processing, Storage and Handling	-	-	-	466	1 048	12	1 048	-
	KNUT01810	Mineral Processing, Storage and Handling	-	-	-	466	1 048	12	1 048	-
	KNUT01811	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-
	KNUT01812	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-
	KNUT01813	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-
	KNUT01814	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-
	KNUT01815	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUT01816	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-
	KNUT01817	Mineral Processing, Storage and Handling	-	-	-	-	3 092	497	3 092	-
	KNUT01818	Mineral Processing, Storage and Handling	-	-	-	-	825	23	825	-
	KNUT01819	Mineral Processing, Storage and Handling	-	-	-	-	825	23	825	-
	KNUT01820	Mineral Processing, Storage and Handling	-	-	-	-	825	23	825	-
	KNUT01821	Mineral Processing, Storage and Handling	-	-	-	-	825	23	825	-
	KNUT0199	Mineral Processing, Storage and Handling	3	938	2	397	1	12	619	735
	KNUT0231	Mineral Processing, Storage and Handling	-	-	1	-	1	-	-	-
	KNUT0232	Mineral Processing, Storage and Handling	-	-	1	-	1	-	-	-
	KNUT0233	Mineral Processing, Storage and Handling	-	-	1	-	1	-	-	-
	KNUT0255	Combustion Installations	-	7 083	-	3 060	105 723	27	2 671	-
	KNUT0271	Metallurgical Industry	-	-	-	8 672	-	1 367	1 753	70
	KNUT0272	Metallurgical Industry	-	-	-	3 698	-	918	1 333	66

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUT0273	Metallurgical Industry	-	-	-	3 673	-	1 142	1 365	113
	KNUT0274	Metallurgical Industry	-	-	-	8 252	-	3 916	1 735	530
			3	**56 761 283**	**6**	**490 209**	**345 119**	**6 334 415**	**316 295**	**413 421**
Ugu District Municipality	KNUU001	Inorganic Chemicals Industry	-	-	-	-	-	-	0	-
	KNUU0041	Metallurgical Industry	-	2 770	-	4 795	0	372	6 677	-
	KNUU0042	Metallurgical Industry	-	3 907	-	6 631	0	602	11 901	-
	KNUU0043	Metallurgical Industry	-	3 078	-	5 824	0	457	11 488	-
	KNUU0051	Combustion Installations	-	-	-	221 958	17 421	8 303	-	-
	KNUU0052	Combustion Installations	-	4 385	0	3 946	1 666	-	1 754	-
	KNUU0053	Combustion Installations	-	43 746	5	39 371	16 623	-	17 498	-
	KNUU0054	Combustion Installations	-	70 325	111	30 653	18 566	922	-	-
	KNUU0062	Combustion Installations	-	-	-	-	3 274	-	3 446	-
	KNUU0063	Combustion Installations	-	-	-	-	-	-	-	-
	KNUU0111	Mineral Processing, Storage and Handling	-	1 709 376	64	618 912	66 084	7	4 457 640	-
	KNUU0112	Mineral Processing, Storage and Handling	-	3 289 920	331	629 376	66 871	1 345	78 672	-
	KNUU0113	Mineral Processing, Storage and Handling	-	-	-	-	1 452	-	1 578	-
	KNUU0161	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	24 576	0	2 240	2 304	-	2 396	-
			0	**5 152 083**	**511**	**1 563 706**	**194 262**	**12 007**	**4 593 050**	**0**

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
uMgungundlovu District Municipality	KNUG001	Mineral Processing, Storage and Handling	-	-	-	-	-	34 872	1 113	0
	KNUG0051	Combustion Installations	-	-	-	1 227	134 994	4 355	-	-
	KNUG0052	Combustion Installations	-	8 146	5	206	3 096	-	3 259	-
	KNUG0061	Petroleum Industry	-	291	-	501	368	176	-	-
	KNUG0062	Petroleum Industry	-	891	-	456	51	182	-	-
	KNUG0063	Petroleum Industry	-	741	-	746	420	516	-	-
	KNUG0064	Petroleum Industry	-	170	-	772	513	2 171	-	-
	KNUG0065	Petroleum Industry	-	36 991	-	2 192	728	305	-	-
	KNUG0066	Petroleum Industry	-	-	-	-	-	-	-	18
	KNUG0069	Petroleum Industry	-	356	-	122	39	1 130	-	-
	KNUG00610	Petroleum Industry	-	356	-	122	39	1 130	-	-
	KNUG00686	Petroleum Industry	-	82	-	5 260	2 121	14 867	-	-
	KNUG00688	Petroleum Industry	-	712	-	244	77	2 260	-	-
	KNUG00689	Petroleum Industry	-	1 316	-	665	1 483	46 881	-	-
	KNUG00690	Petroleum Industry	-	712	-	244	77	2 260	-	-
	KNUG00691	Petroleum Industry	-	1 316	-	665	1 483	46 881	-	-
	KNUG00699	Petroleum Industry	-	712	-	244	77	2 260	-	-
	KNUG006100	Petroleum Industry	-	-	-	-	-	-	-	18

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUG006101	Petroleum Industry	-	712	-	244	77	2 260	-	-
	KNUG0071	Inorganic Chemicals Industry	-	-	-	1	-	0	-	-
	KNUG0072	Inorganic Chemicals Industry	-	-	-	0	-	0	-	-
	KNUG0081	Combustion Installations	-	26 762	14	47 102	5 334	11 240	-	-
	KNUG0091	Metallurgical Industry	-	-	-	17 894	-	135 775	11 325	44
	KNUG0092	Metallurgical Industry	-	-	-	-	-	-	-	26 140
	KNUG0093	Metallurgical Industry	-	-	-	-	-	-	-	29 713
	KNUG0101	Carbonization and Coal Gasification	-	-	-	-	-	-	241	-
	KNUG0102	Carbonization and Coal Gasification	-	-	-	-	-	-	-	293
	KNUG0103	Carbonization and Coal Gasification	-	-	-	-	-	-	589	-
	KNUG0104	Carbonization and Coal Gasification	-	-	-	-	-	-	-	293
	KNUG0105	Carbonization and Coal Gasification	-	-	-	-	-	-	-	195
	KNUG0106	Carbonization and Coal Gasification	-	-	-	-	-	-	-	69
	KNUG0111	Mineral Processing, Storage And Handling	-	1 643	-	14 377	4 382	54	-	96
	KNUG0112	Mineral Processing, Storage And Handling	-	1 643	-	14 377	4 382	54	-	96
	KNUG012	Combustion Installations	-	986	26	-	-	300	-	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUG0131	Metallurgical Industry	-	-	-	1	227	2	-	15
	KNUG0132	Metallurgical Industry	-	-	-	1	227	2	-	15
	KNUG015	Metallurgical Industry	-	-	-	-	-	-	397	-
	KNUG016	Disposal of Hazardous and General Waste	-	12	-	21	-	-	-	-
	KNUG0212	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	-	58	-
	KNUG0213	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	-	58	-
	KNUG0214	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	-	58	-
	KNUG0215	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	-	-	-	-	-	58	-
	KNUG0226	Pulp and Paper Manufacturing Activities, including By-Products Recovery	-	95 280	1	8 933	8 933	-	9 290	-
	KNUG0255	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	23 654	0	2 156	2 218	-	2 306	-

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
	KNUG0261	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	18 432	0	1 680	1 728	-	1 797	-
	KNUG0291	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	30 720	0	2 800	2 880	-	2 995	-
	KNUG0293	Pulp and Paper Manufacturing Activities, Including By-Products Recovery	-	19 968	0	1 820	1 872	-	1 947	-
	KNUG0381	Metallurgical Industry	-	-	-	17 419	-	460	11 201	9
	KNUG0382	Metallurgical Industry	-	-	-	15 303	-	404	1 242	4
	KNUG0383	Metallurgical Industry	-	-	-	10 021	-	265	1 991	25
	KNUG0384	Metallurgical Industry	-	-	-	3 286	-	87	796	2
	KNUG0385	Metallurgical Industry	-	-	-	2 887	-	76	2 735	2
	KNUG0386	Metallurgical Industry	-	-	-	2 214	-	59	4 179	8
	KNUG0387	Metallurgical Industry	-	2 766	9	-	-	2 500	1 244	77
	KNUG0388	Metallurgical Industry	-	-	-	4 532	-	35	203	-
	KNUG0389	Metallurgical Industry	-	-	-	4 966	-	38	222	-
	KNUG03810	Metallurgical Industry	-	-	-	5 718	-	44	256	-
	KNUG03812	Metallurgical Industry	-	-	-	1 360	-	10	482	8
			0	**275 371**	**58**	**192 777**	**177 823**	**313 911**	**60 041**	**57 142**

TOTAL EMISSIONS (Kg/ANNUM)										
MUNICIPALITIES	Facility ID	SECTOR	REPORTED BENZENE (kg/annum)	REPORTED CO (kg/annum)	REPORTED LEAD (kg/annum)	REPORTED NO_x (kg/annum)	REPORTED PM_{10} TOTAL (kg/annum)	REPORTED SO_2 (kg/annum)	REPORTED TSP (kg/annum)	REPORTED VOC (kg/annum)
uMkhanyakude District Municipality	KNUK0031	Combustion Installations	-	756	1	945	19 606	13	-	-
	KNUK0032	Combustion Installations	-	1 020	1	1 275	41 153	17	-	-
	KNUK0033	Combustion Installations	-	1 020	1	1 275	89 246	17	-	-
			0	**2 796**	**4**	**3 495**	**150 004**	**47**	**0**	**0**
Umzinyathi District Municipality	KNUZ002	Mineral Processing, Storage and Handling	-	38 000	7	24 225	682	1 377	-	1 140
			0	**38 000**	**7**	**24 225**	**682**	**1 377**	**0**	**1 140**
Uthukela District Municipality	KNUH00211	Petroleum Industry	0	-	-	-	-	-	-	2 171
	KNUH00212	Petroleum Industry	-	-	-	-	-	-	-	18
			0	**0**	**0**	**0**	**0**	**0**	**0**	**2 190**
Zululand District Municipality	KNZU006	Combustion Installations	-	10	1	10	10	10	11	1
			0	**10**	**1**	**10**	**10**	**10**	**11**	**1**
KZN Total in Kilograms (kg)			**6 587**	**70 121 252**	**3 079**	**13 818 148**	**7 203 297**	**20 527 987**	**10 758 653**	**2 125 901**
KZN Total in Tonnes (t)			**7**	**70 121**	**3**	**13 818**	**7 203**	**20 528**	**10 759**	**2 126**
Note: "-" Indicate no data available										

- **The facility ID as used by the NAEIS consists of 4 letters followed by a 3-digit number. Numbers have been added at the end of the facility IDs to identify the different stacks at each facility for modelling purposes.**

APPENDIX 4: Risk of Exposure to Air Pollution

Table 60: Areas identified with a medium to high probability of air pollution exposure.

Municipality Name	Ward Number	Population	Population Density	Risk Classification
Dannhauser	52504007	8094	573	High
	52504011	10232	431	Medium
Emadlangeni	52503002	5290	74	Medium
Emnambithi/Ladysmith	52302002	7377	5179	Extremely High
	52302003	10557	3329	High
	52302012	6495	1055	High
	52302015	7960	895	High
	52302001	8569	3300	High
	52302005	8874	3148	High
	52302006	9547	3344	High
	52302009	10415	1350	High
	52302016	7301	434	High
	52302027	14473	505	Medium
	52302021	8538	912	Medium
	52302022	10384	912	Medium
Endumeni	52401004	8390	3166	High
	52401005	9825	799	Medium
eThekwini	59500031	33111	5736	Extremely High
	59500063	34023	1701	Extremely High
	59500065	42805	2171	Extremely High
	59500064	35735	2382	Extremely High
	59500068	39356	6627	Extremely High
	59500075	21669	3069	Extremely High
	59500030	37545	6048	Extremely High
	59500025	39024	4672	Extremely High
	59500082	29223	9032	Extremely High
	59500089	31762	5369	Extremely High
	59500101	25460	3831	Extremely High
	59500069	32592	4066	Extremely High
	59500074	22879	6417	Extremely High
	59500076	19388	6030	Extremely High
	59500079	38984	11194	Extremely High
	59500090	26296	1232	Extremely High
	59500029	33831	4898	Extremely High
	59500070	29978	3992	Extremely High
	59500081	24682	11867	Extremely High
	59500088	35549	9682	Extremely High
	59500080	30678	9176	Extremely High

Municipality Name	Ward Number	Population	Population Density	Risk Classification
	59500033	31928	4339	High
	59500028	23170	6942	High
	59500066	30855	1704	High
	59500067	44875	1638	High
	59500034	37213	2179	High
	59500041	35332	10672	High
	59500042	38844	9867	High
	59500085	32111	7002	High
	59500004	37964	601	High
	59500006	27805	2606	High
	59500043	33212	6687	High
	59500048	30079	4059	High
	59500015	39344	1643	High
	59500016	36576	2193	High
	59500019	43521	3745	High
	59500020	23536	5595	High
	59500023	30590	2207	High
	59500091	35257	2588	High
	59500092	27639	2206	High
	59500005	28601	650	High
	59500024	33455	1745	High
	59500035	31085	1195	High
	59500038	38952	6891	High
	59500039	24614	27210	High
	59500044	41979	2414	High
	59500045	38693	6602	High
	59500055	43056	7774	High
	59500012	27055	3852	High
	59500014	26829	4079	High
	59500022	25534	11229	High
	59500057	35633	7714	High
	59500037	40778	4078	High
	59500093	36025	1979	High
	59500094	29969	3028	High
	59500086	34033	8259	High
	59500087	26620	9495	High
	59500032	22125	869	High
	59500026	34600	4910	High
	59500073	31454	3524	High
	59500036	31159	1943	High

Municipality Name	Ward Number	Population	Population Density	Risk Classification
	59500097	25072	1441	High
	59500011	48704	4488	Medium
	59500013	35708	3001	Medium
	59500046	29458	10138	Medium
	59500047	30924	9831	Medium
	59500049	36168	5406	Medium
	59500050	28546	6805	Medium
	59500052	35294	7435	Medium
	59500051	40217	5501	Medium
	59500054	31179	7413	Medium
	59500071	36394	5921	Medium
	59500018	28459	1064	Medium
	59500021	26981	3289	Medium
	59500078	28385	11426	Medium
	59500053	35857	6363	Medium
	59500010	22249	521	Medium
	59500017	36731	2822	Medium
	59500059	45343	905	Medium
	59500072	39324	2842	Medium
	59500077	46048	6396	Medium
	59500040	30043	14194	Medium
	59500095	38546	4100	Medium
	59500098	46511	1070	Medium
	59500083	36251	11278	Medium
Greater Kokstad	54303001	11441	10471	High
	54303005	3437	4460	High
	54303007	6937	6500	High
	54303004	11614	2832	High
	54303008	8821	9998	High
	54303003	6775	849	Medium
Hibiscus Coast	52106019	5804	674	High
	52106004	8534	881	High
	52106006	9115	1277	High
	52106017	8356	1472	High
	52106021	7126	1117	High
	52106022	8436	1241	High
	52106023	6523	2723	High
	52106026	12821	2047	High
	52106028	6938	3680	High
	52106009	12015	708	High

Municipality Name	Ward Number	Population	Population Density	Risk Classification
	52106018	8004	826	Medium
	52106020	14855	777	Medium
	52106016	7519	571	Medium
	52106010	10636	603	Medium
	52106024	9789	939	Medium
	52106007	8551	322	Medium
Indaka	52303005	8966	1388	Medium
KwaDukuza	52902008	7897	11549	High
	52902010	10216	2222	High
	52902012	11450	2383	High
	52902015	11716	1347	High
	52902023	11159	5458	High
	52902016	9570	1855	High
	52902018	8081	8403	High
	52902014	8210	3751	High
	52902006	7611	994	High
	52902020	3506	1428	High
	52902005	7867	3091	Medium
	52902013	8528	3245	Medium
	52902019	7962	812	Medium
Mandeni	52901007	9516	3842	High
	52901013	3560	8029	High
	52901014	9774	8249	High
	52901015	4059	5851	High
Mfolozi	52801006	7652	2093	High
	52801008	10666	349	Medium
Mtubatuba	52705001	5839	3128	High
	52705002	15302	1442	High
Ndwedwe	52903012	10870	535	Medium
	52903015	6724	258	Medium
Newcastle	52502026	7181	4297	Extremely High
	52502027	11031	6702	Extremely High
	52502028	7398	5439	Extremely High
	52502022	8777	4970	Extremely High
	52502023	9794	6680	Extremely High
	52502029	11065	6919	Extremely High
	52502014	14381	6724	Extremely High
	52502015	11236	1286	High
	52502017	11179	7143	High
	52502009	14513	4728	High

Municipality Name	Ward Number	Population	Population Density	Risk Classification
	52502030	12491	2399	High
	52502003	8182	1339	High
	52502008	9124	4835	High
	52502004	9193	1314	High
	52502005	9958	824	High
	52502010	10641	4245	High
	52502016	14795	1094	High
	52502018	12835	4007	High
	52502019	10018	3680	High
	52502024	12717	2819	High
	52502025	13469	557	High
	52502002	10354	749	High
	52502012	9420	1505	Medium
	52502011	10444	4242	Medium
	52502031	11379	383	Medium
	52502013	8542	6556	Medium
	52502020	14684	652	Medium
Richmond	52207007	10785	1291	High
	52207002	10285	1453	Medium
Msunduzi	52205033	12908	2055	Extremely High
	52205031	12095	3624	Extremely High
	52205032	15973	2936	Extremely High
	52205034	21408	5823	Extremely High
	52205035	16842	1167	Extremely High
	52205022	14666	4825	High
	52205015	18542	4608	High
	52205028	20581	3938	High
	52205029	18982	2814	High
	52205013	21953	3473	High
	52205016	21232	6051	High
	52205017	21531	4293	High
	52205019	16445	6878	High
	52205023	14384	2247	High
	52205030	20087	2118	High
	52205021	9972	6149	High
	52205010	14152	3635	High
	52205027	13037	2140	High
	52205026	17786	743	Medium
	52205024	16181	1382	Medium
	52205036	19480	1543	Medium

Municipality Name	Ward Number	Population	Population Density	Risk Classification
	52205002	18433	1070	Medium
	52205008	15290	677	Medium
	52205001	18770	1387	Medium
	52205012	11775	2299	Medium
	52205020	13667	1961	Medium
Ubuhlebezwe	54304001	7693	71	High
	54304002	5694	28	High
	54304006	7580	400	High
Ulundi	52606018	9069	698	Medium
	52606012	6263	840	Medium
Umdoni	52102006	6078	2448	High
	52102008	9211	667	High
	52102009	6731	670	Medium
	52102001	7455	621	Medium
uMhlathuze	52802014	12315	3090	High
	52802006	12544	1354	High
	52802003	9058	1491	High
	52802007	5896	4533	High
	52802008	5137	5635	High
	52802016	7801	7086	High
	52802020	8552	4806	High
	52802030	11359	1752	High
	52802009	13558	2115	High
	52802017	10463	5071	High
	52802021	6950	6913	High
	52802027	8873	3687	High
	52802028	7440	1992	High
	52802004	12472	1332	Medium
	52802010	11310	558	Medium
	52802023	10703	272	Medium
uMlalazi	52804012	5638	3437	Medium
uMngeni	52202002	1266	780	Extremely High
	52202011	7320	7645	High
	52202010	5307	4820	High
	52202001	7661	1742	Medium
	52202008	13507	1051	Medium
uMshwathi	52201011	7392	222	Medium
Umzimkhulu	54305016	8742	962	Medium
Umzumbe	52103019	9735	1300	High
	52103017	7699	1533	Medium

Municipality Name	Ward Number	Population	Population Density	Risk Classification
Vulamehlo	52101002	7322	265	Medium

APPENDIX 5: Listed Activity Interventions

Table 61: Interventions for Listed Activities (DEA, 2012)

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
Additives can be mixed into the fuel to reduce emissions (for example, lime can reduce SO_2 emissions from the combustion of solid fuels).	✓									
Using coal with lower sulphur content can reduce sulphur dioxide emissions.					✓					
Fugitive emissions from materials receiving, handling and pre-processing can be reduced by:										
• Water/suppressant spraying/misting at points of transfer and on stockpiles (however, in the case of solid biomass combustion installations this may result in odorous emissions) (solid fuel/material).	✓			✓	✓					
• Enclosing the area in which materials receiving, handling, pre-processing and/or storage occurs and using suction to send air to particulate abatement equipment (solid fuel/material).	✓			✓	✓					

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
• Placing suction hoods at transfer points which lead to particulate abatement equipment (solid fuel/material).	✓			✓	✓					
• Ensuring adequate seals are in place (liquid/gas fuel/material).	✓									
• Using vapor return systems where appropriate (liquid/gas fuel/material).	✓									
• Trucks/wagons should be covered with tarpaulins when in transit.					✓					
• Unpaved surfaces should be wetted, paved or have binders applied to them.					✓					
Flue gases can be cleaned using:										
• Scrubbers to reduce PM, SO_2 and NO_x (also HF, VOCs, CH_5N, CH_2CHCN, Cl_2, NH_3, HCN, H_2S, Fluorides, HCl, gaseous metals, NH_4, CO, CO_2, PCDD/CPDF and SO_3 where applicable) emissions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
• Cyclones to reduce PM (and particulate metals where applicable) emissions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
- Baghouses to reduce PM (and particulate metals where applicable) emissions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
- Electrostatic precipitators to reduce PM (and particulate metals where applicable) emissions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
- Flue gas desulphurization to reduce SO_2 emissions.	✓			✓	✓					
- Selective/non-selective catalytic reduction to reduce NO_x emissions.	✓			✓	✓					
- Rapidly cooling flue gas to below 200ºC to avoid formation of Dioxins, Furans and other POPs.					✓					
PM should be collected and returned to the material stream by abatement equipment.				✓	✓					
Waste materials (for example ash and recovered PM) should be handled correctly, and the disposal area managed properly.	✓	✓	✓			✓				
Drying of solid biomass (using steam from the combustion plant, waste heat from the combustion exhaust gases or electrical heating) before combustion can reduce particulate emissions.	✓									

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
Emission of VOCs should be reduced by flaring, absorption, adsorption scrubbers and/or captured, condensed and returned to bulk storage.		✓	✓		✓	✓		✓		
A leak detection and repair program approved by the licensing authority should be instituted.		✓				✓				
Sleeves must be fitted to roof legs, slotted pipes and/or the dipping well on floating roof tanks to minimise emissions.		✓				✓				
Periodic tests should be done on relief valves on pressurized storage.		✓				✓				
Vapour recovery units must be fitted to installations with a throughput of 5 000m^3 per annum or higher (liquid/gas fuel/material).		✓								
Vapours from the distillation and pyrolysis processes should be treated by scrubbers.		✓								
Coke oven gas can be recovered for reuse as an energy source and/or to produce by-products.			✓							

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
Off-gases should be cleaned by cooling/condensing (to remove drop out H_2O, tar and organics with low boiling points) and/or scrubbers (to remove PM, SO_2, H_2S and NO_X).			✓							
During the coal gasification process, use of a lock chamber, which removes gas from the chamber and sends it to the gasifier or syngas stream before the chamber is opened to take in a new batch of coal, will reduce the release of gaseous and particulate matter emissions.			✓							
Emissions from the sinter strand should be collected by a wind box and sent to abatement.				✓						
PM should be removed from air in the cooling circuit before it is released.				✓						
Fumes and vapours emitted during production processes should be captured by extraction hoods over the areas in which they are emitted and abated by scrubbers, cyclones or electrostatic precipitators.				✓						

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
Odorous compounds should be abated through combustion or adsorption using scrubbers.										✓

APPENDIX 6: Capacity Analysis Summary

Table 62: Summary of Capacity Analysis in KZN

Air Quality Management Unit	Human Resources and skills	Air Quality Monitoring Equipment and Programmes	Complaints database	Available Emissions Inventory	Dispersion modelling capacity	Quality assurance and quality control programme	Capacity issues that require attention
KZN Province (KZN EDTEA)	Two personnel in the AQM unit (one designated AQO and one Control Environmental Officer)	6 AAQMS monitoring PM, SO_2, NOx	No, complaints handled by municipalities. Incident files are kept at regional office	None available in the department, dependent on NAEIS	No dispersion modelling software or capacity	None	Concerns in the reporting emissions from incidence
Amajuba District Municipality	One Air quality Management personnel	3 AAQMS	No feedback at the time of the report	Emission Inventory available in the 2018 AQMP	None	No feedback at the time of the report	No feedback at the time of report
eThekwini Metropolitan Municipality	18 personnel in the AQM unit, two vacant positions (Air Quality Manager and Instrumentation Technician)	Available AAQMS network Dust monitoring programmes conducted by industries	Yes	Vehicle Emission, Household Fuel Burning EI (2016)	AERMOD and CALPUFF	Envista ARM	Training of technicians on method validation, uncertainty of measurement (calibration) and laboratory systems (ISO/IEC 17025) preferably by the National Laboratory

Air Quality Management Unit	Human Resources and skills	Air Quality Monitoring Equipment and Programmes	Complaints database	Available Emissions Inventory	Dispersion modelling capacity	Quality assurance and quality control programme	Capacity issues that require attention
							Association of South Africa
Harry Gwala District Municipality	One designated District AQO	None	Available complaints database and complaints attended as it received	None, currently in the process of developing the district's AQMP.	None.	None.	The establishment of the fully functionally stand-alone component responsible for Air Quality Management, so that the allocation of budget for issues related to AQM will be taken into consideration. For now, the EHP's do both functions of Municipal Health Services and Environmental Management.
iLembe District Municipality	One personnel, appointment for an	One AAQMS monitoring SO_2,	No	None available in	CALPUFF	None	Ambient air quality monitoring,

Air Quality Management Unit	Human Resources and skills	Air Quality Monitoring Equipment and Programmes	Complaints database	Available Emissions Inventory	Dispersion modelling capacity	Quality assurance and quality control programme	Capacity issues that require attention
	assistance awaiting council approval	O_3, PM_{10} and $PM_{2.5}$		the department, dependent on AELs and NAEIS reports			data reporting, emissions inventory, dispersion modelling and human resources
King Cetshwayo	Three personnel in the AQM unit	13 AAQMS (3 owned by the uMhlathuze LM and 10 privately owned), however There are no ambient monitoring stations at Nkandla, Mlalazi, Mthonjaneni, and uMfolozi Local Municipalities.	Limited	Emission Inventory available in the 2022 Draft AQMP	None	Limited	Human resource capacity limited and financial resources are limited and is determined by the available budget instead of the need to effectively manage air quality in the district
Ugu	Two personnel, one of which is the designated AQ officer	One provincial AAQMS and one upcoming	Records of Complaints are available	No due to limited funds	No due to limited funds	No due to limited funds	Review of the districts AQMP and would request province

Air Quality Management Unit	Human Resources and skills	Air Quality Monitoring Equipment and Programmes	Complaints database	Available Emissions Inventory	Dispersion modelling capacity	Quality assurance and quality control programme	Capacity issues that require attention
		monitoring station.					assistance in terms of funding.
uMgungundlovu District Municipality	One Air quality Management personnel	Four AAQMS	Available but not exclusive to air quality complaints	Emission Inventory available in the 2016 AQMP, latest information not available	None	None	Air quality management funding, human resource capacity and structure
uMhlathuze Local Municipality	Eight personnel in the AQM Unit consist of one air quality control manager, deputy manager, four Air Quality Specialists, one instrument technician and one administrative assistant	3 AAQMS, Passive Sampling, Outsourcing of calibration and repairs. Quarterly Council Reports, School and Community Awareness Campaign	Yes	Provided by the King Cetshwayo District Municipality	Not applicable to local municipality	Not applicable	Employee shortage and reporting structures

Air Quality Management Unit	Human Resources and skills	Air Quality Monitoring Equipment and Programmes	Complaints database	Available Emissions Inventory	Dispersion modelling capacity	Quality assurance and quality control programme	Capacity issues that require attention
uMkhanyakude District Municipality	One Air Quality Management personnel	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report
uMzinyathi District Municipality	One Air quality Management personnel	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report	No feedback at the time of the report
uThukela District Municipality	One Air Quality Management personnel (acting air quality officer) needs to undergo some training and do site visit for practical.	5-Year Policy Plan	Yes	Available through companies	No dispersion modelling software or capacity	Not applicable	Human resources, training on environmental management inspection and other relevant air quality training.
Msunduzi Local Municipality	15 personnel (There is an Air Quality Officer, a Deputy Air Quality Officer and a Laboratory Technician and 12 Environmental Health	3 AAQMS monitoring CO, SO_2, NOx, O_3, PM_{10} and $PM_{2.5}$, Passive Sampling	Yes	Emissions Inventory compiled in 2019	No dispersion modelling software or capacity	AAQMS monitored via real-time software daily, routine maintenance every two weeks	None

Air Quality Management Unit	Human Resources and skills	Air Quality Monitoring Equipment and Programmes	Complaints database	Available Emissions Inventory	Dispersion modelling capacity	Quality assurance and quality control programme	Capacity issues that require attention
	practitioners that assist for the operation of the network and all other air quality matters complaint within the City.)						