Mopani District Municipality

REVIEWED AIR QUALITY MANAGEMENT PLAN (AQMP)

JUNE 2023

ACKNOWLEDGEMENTS

The Mopani District Municipality gratefully acknowledges all people and organisations who contributed to the reviewing of this plan. A special word of appreciation goes to the key stakeholders (industrial sector, community members, NGOs, Local Authorities, Provincial Authorities and National Government) who collaborated in providing the necessary technical information required in the review process. A special thanks to the following teams for their contribution towards the preparation of this document:

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Greater Letaba Local Municipality

Greater Tzaneen Local Municipality

Maruleng Local Municipality

Ba-Phalaborwa Local Municipality

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FOREWORD BY THE EXECUTIVE MAYOR

The Constitution of South Africa remains the supreme law of this country, and every other law is guided by what is contained in the Constitution. It places an obligation on local government to promote a safe and healthy environment. Section 24 of the Constitution, in particular deals directly with issues of environment, and dictates that everyone has a right to an environment that is not harmful to their health and well-being. It further states that we have an obligation to have the environment protected for the benefit of present and future generations.

What the Section does is to place an obligation on everyone to prevent pollution and other forms of damage to the environment. The Air Quality Management Plan brings the Municipality closer to fulfilling this constitutional imperative.

The National Environment Management: Air Quality Act (Act no. 39 of 2004) dictates that Municipalities develop Air Quality Management Plans that clearly outline their plans for achieving the prescribed air quality standards. In line with the objectives of this Act, we have developed the Air Quality Management Plan which will guide our work around the protection of the environment by providing reasonable measures for the protection of and enhancement of the quality of air in the district space.

CLLR. PJ SHAYI
EXECUTIVE MAYOR

EXECUTIVE SUMMARY

Mopani District Municipality (MDM) is one of the 5 districts of Limpopo province of South Africa, located in the north-eastern part of the country. It is home to more than 1.2 million inhabitants, with the mining sector contributing more than 30% of the economy of the region. Due to the excessive SO_2 emissions in the Ba-Phalaborwa area, the Mopani District Municipality was rated as one of the district municipalities having poor or potentially poor air quality. In 2015, the Mopani District Municipality developed and published an Air Quality Management Plan for the region as a strategic plan for the implementation of air quality interventions in this area. The plan provided a strategic direction for the implementation of air quality interventions in the Mopani District Municipality, as well as an essential blueprint for action to reduce emissions in the area.

The National Framework for Air Quality Management in South Africa (DEA 2017) and the Manual for Air Quality Management Planning in South Africa (DEA 2012) recommend that the Air Quality Management Plan be reviewed at least every 5 years. so as to identify shortfalls and reprioritise resources. In this regard, the purpose of the Mopani District Municipality Air Quality Management Plan review is, therefore, to amongst other things:

- Update the emission inventory;
- Assess changes in ambient air quality since the publication of the Air Quality Management Plan;
- Review progress on the previous implementation of reduction strategies; and
- Provide recommendations to strengthen the implementation of the interventions.

Air Quality Management Plan Review Process

The process to review and update the Mopani District Municipality Air Quality Management Plan follows the process defined in the Manual for Air Quality Management Planning (DEA 2012) and outlined in the National Framework for Air Quality Management (DEA 2017) for the development of an Air Quality Management

Plan. The following steps were taken in reviewing the 2015 Air Quality Management Plan for the Mopani District Municipality:

Step 1: Assess whether air quality has improved in the Mopani District Municipality

This involved conducting a baseline air quality assessment in which measured concentrations over the Mopani District Municipality were analysed over a specific time period.

Step 2: Identify if there is a need to update information or include any new information in the Air Quality Management Plan

This involved updating the current emissions inventory for the Mopani District Municipality as well as performing dispersion modelling to assess the spatial distribution of pollutants over the Mopani District Municipality.

Step 3: Identify the challenges experienced in implementing the Air Quality Management Plan and how to address them

The AQMP implementation challenges experienced in the Mopani District Municipality were identified through an institutional capacity assessment. Goals were revisited and redefined, strategies reassessed and the implementation plan for the Mopani District Municipality was updated.

In this regard, the review of the 2015 Air Quality Management Plan focused on assessing the following aspects of the 2015 Mopani District Municipality Air Quality Management Plan:

- Ambient Air Quality Measurement and Monitoring
- Emission Inventory
- Dispersion Modelling
- Operational Capacity

Ambient Air Quality Measurement and Monitoring

The monitoring network in the Mopani district is limited in providing sufficient information to support adequate air quality management for the greater Mopani region.

Currently, there are only four operational ambient air quality monitoring stations in the MDM, which are concentrated in the Ba-Phalaborwa region. Of the four stations, one is managed by the Limpopo Department of Economic Development, Environment and Tourism and the remaining three stations are privately owned and managed by the Phalaborwa Mining Company.

The status of ambient air quality was assessed for the Mopani District Municipality so as to determine whether the area is in compliance with the National Ambient Air Quality Standards (NAAQS). Trend analyses for the period 2015-2019 were conducted for the Mopani District Municipality using data obtained from 4 air quality monitoring stations. Overall, air quality in the Mopani District Municipality has not significantly improved as shown in the main findings below:

- Annual average SO_2 concentrations in the Ba-Phalaborwa region were compliant with the NAAQS (all the years except 2018). However, 1-hour and 24-hour ambient SO_2 concentrations were in exceedance of the NAAQS at most of the stations for most of the years.
- Long-term trends in annual PM_{10} and $PM_{2.5}$ concentrations at the Phalaborwa AQMS showed compliance with the NAAQS. Daily averages for PM_{10} and $PM_{2.5}$ at the Phalaborwa AQMS were in exceedance of the NAAQS in 2018 and 2019.
- Hourly averages for NO_2 concentrations at the Phalaborwa AQMS were in compliance with the NAAQS for most of the period assessed. Annual average NO_2 concentrations were compliant with the NAAQS.
- Long-term trends for O_3 concentrations at the Phalaborwa AQMS showed non-compliance with the 8-hour-running average NAAQS. The highest concentrations of O_3 were mainly observed during spring and summer as the intensity of sunlight needed for the photochemical reactions is highest during this time.

Mopani District Municipality Emission Inventory

An emission inventory was developed for the 2015 Mopani District Municipality Air Quality Management Plan, and the sources which were considered in the inventory include industrial, mining, and transport (motor vehicles). An assessment of the 2015

Mopani District Municipality Air Quality Management Plan emissions inventory revealed some inadequacies, which include, but are not limited to:

- Emissions were reported for only three sources (industries, mining, and transport) which is not an adequate representation of the total emissions in the Mopani District Municipality;
- Poor and/or no descriptions of methodologies used to quantify emissions;
- Calculation discrepancies in industrial emissions, specifically for smelters, small boilers and chemical fertiliser production.

The Air Quality Management Plan review sought to address these challenges by updating the emission sources previously quantified in the 2015 Mopani District Municipality Air Quality Management Plan, introducing new emission sources that were not previously quantified and providing a better description of the updated methodologies applied in the review.

Below is a summary of the updated emissions for industry, mining and transport as well as the newly quantified emissions in the Mopani District Municipality for the year 2019.

Emission Inventory summary for all sources within the MDM (tonnes/annum) for the year 2019

Emission Source	CO	NO_x	NMVOC	SO_2	$PM_{2.5}$	PM_{10}	NH_3	CH_4
On Road Vehicles	240	814	14	12	16	-	-	-
Domestic Waste Burning	8 510	649	-	256	1 848	1 955	-	-
Domestic Fuel Burning	83 238	2 367	8 687	5 832	-	12 663[a]	-	-
Wind Blown Dust	-	-	-	-	326[b]	-	-	-
Biomass Burning	168 053	1 135	-	7 079	5 552	6 630	47 160	-
Industry	593	1 143	2 036	713	1 664	2 919	-	-
Mining	-	-	-	-	125	758	-	-
Biogenic VOC	-	-	82 119	-	-	-	-	-
Agricultural Ammonia	-	-	-	-	-	-	1 814	-
Wastewater treatment	-	-	-	-	-	-	-	7 417
Landfills	-	-	-	-	-	-	-	7 930
Total	**260 634**	**6 108**	**92 856**	**13 892**	**9 184**	**12 262**	**48 974**	**15 347**

Note: (a) Emissions are estimated as the sum of PM_{10} and $PM_{2.5}$

: (b) Emissions are estimated as $PM_{1.8-3}$

Based on the updated emissions inventory, it is evident that biomass burning is the largest contributor of CO, SO_2, PM_{10}, $PM_{2.5}$ and NH_3 in the Mopani District Municipality, accounting for approximately, 64% of CO, 32% of SO_2, 35% of $PM_{2.5}$ and 96% of NH_3. Biomass burning is also an important contributor to PM_{10} emissions in the Mopani District Municipality. Residential fuel burning activities are the largest contributors to NOx and PM_{10} emissions in the Mopani District Municipality, accounting for 36% of NOx and 33% of $PM_{2.5}$. Residential burning activities are also an important source of CO and SO_2 emissions in the Mopani District Municipality. Residential waste burning activities and industries are important contributors to $PM_{2.5}$ emissions. Industries are also an important source of NOx emissions in the Mopani District Municipality. Overall, industries, residential fuel burning, and biomass burning are the key contributing sources to air pollutant emissions in the Mopani District Municipality.

Atmospheric Dispersion Modelling

Atmospheric dispersion modelling is an important process in air quality management as it is used to assess compliance to NAAQS on a larger spatial scale than what can be provided with monitoring stations. Areas of elevated concentrations in relation to sensitive receptors can be identified for expanded monitoring and health impact assessments. No atmospheric dispersion modelling was performed during the development of the 2015 Mopani District Municipality Air Quality Management Plan. For this review, atmospheric dispersion modelling was carried out for the Mopani District Municipality. The goal of atmospheric dispersion modelling within the context of the Air Quality Management Plan review was to model the dispersion of emission sources (that were quantified for the year 2019) in the Mopani District Municipality to the extent that the interventions for the 2015 Mopani District Municipality Air Quality Management Plan can be realigned.

The CALPUFF dispersion model was used to simulate ambient air quality concentrations over the Mopani District Municipality. CO, SO_2, NOx, PM_{10} and $PM_{2.5}$ ambient concentrations were generated for each emission source. The main findings of this modelling exercise were:

- Annual SO_2, PM_{10}, and $PM_{2.5}$ exceedances occur in the western section of the Greater Tzaneen local municipality and the northern corner of the Greater Letaba local municipality. The exceedances are mainly from biomass burning activities. Predicted NO_2 concentrations from biomass burning emissions were well within the NAAQS.
- Domestic fuel burning activities are also an important source in the Mopani District Municipality as they contribute significantly to annual $PM_{2.5}$ exceedances taking place in the western section of the Mopani District Municipality (Greater Tzaneen, Greater Letaba and Greater Giyani), in the Phalaborwa region and small section in the southwestern corner of Maruleng local municipality.
- 24-hr and annual PM_{10} and $PM_{2.5}$ exceedances occur in the Phalaborwa area and are due to industrial and mining emissions.

- 1-hr SO_2 and NO_2 exceedances are experienced in the Phalaborwa region but are below the tolerated frequency of exceedances of ambient air standards. These exceedances are mainly from industrial emissions.
- There are no CO exceedances experienced in the Mopani District Municipality.
- No exceedances of the ambient air quality concentrations were simulated for residential waste burning.
- No exceedances of the ambient air quality concentrations were simulated for motor vehicle emissions within the Mopani District Municipality region.

Based on the simulated results, intervention strategies should be realigned to focus on reducing the impacts associated with industries, domestic fuel burning and biomass burning emissions within the Mopani District Municipality airshed.

Operational Capacity

An Institutional Capacity assessment across all spheres of government within the Mopani District Municipality was conducted in order to determine capacity issues and gaps that may need interventions for the district and local municipalities to effectively implement air quality management functions in the district. The major findings from the air quality management capacity assessment are summarised below:

- Apart from the Mopani District Municipality, there is no clear and defined plan for managing air quality in the local municipalities.
- There are no dedicated municipal departments for air quality management in the local municipalities and this inhibits air quality management functions from being carried out efficiently.
- Mopani District Municipality has appointed an Air Quality Officer and two personnel from the Greater Giyani local municipality are responsible for managing air quality issues.
- The skill base for air quality management at the local municipal level is lacking and this prevents important activities such as emissions inventory compilation, atmospheric dispersion modelling and ambient air quality monitoring from being performed.
- There is a lack of financial support to perform air quality management functions at the local municipal level.

Mopani District Municipality Emission Reduction Plan

Emission Reduction strategies were developed for the Mopani District Municipality based on the findings from the updated emission inventory and the atmospheric dispersion modelling exercise. The strategies were formulated in line with national strategies (e.g., National Green Transport Strategy) and regulations. These emission reduction strategies targeted specific sectors and sought to improve the air quality management system in the Mopani District Municipality. The goals for the strategies are as follows:

Goal 1: *All Listed Activities will be compliant with the minimum emission standards (MES) by 2025, and fugitive emissions would have been reduced such as to ensure compliance with NAAQS.*

Goal 2: *Mining emissions, specifically for* PM_{10} *and* $PM_{2.5}$*, will be reduced to ensure compliance with NAAQS and National Dust Control Regulations (NDCR).*

Goal 3: *Reduce emissions from domestic fuel burning to ensure compliance with NAAQS.*

Goal 4: *Reduce emissions from biomass burning through veld management measures and quick response times.*

Goal 5: *Increase awareness on air quality challenges and mobilise resources to tackle these challenges.*

The Emission Reduction plan for achieving each of these goals is shown in the following tables where the strategies were prioritised based on the significance of the problem necessitating the set intervention, the likelihood of implementation, the cost and the risks linked to the intervention.

Emission Reduction plan for Industries

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce emissions from industries	Compliance with the existing MES.	Industries	By 2030	Submission of monitoring reports (compliance monitoring activities).
	Processing of AEL applications within legislated timeframes.	District Municipalities	By 2030	AEL applications processed. Compliance with AEL requirements.
	Establish incentive schemes for energy efficiency improvements and fuel switching that directly reduce air emissions.	DTIC	By 2030	Fuel switched. Improved energy efficiency.
	Foster closer working relationships between DTIC and small industries on improving standards in industrial processes.	DFFE	By 2030	Partnerships formed. Adherence to emission standards.
Reduce emissions from Category 2 industries	Identify energy-saving opportunities and improve overall operational energy efficiency.	Industries (Category 2)	By 2030	Opportunities identified and implemented. Improved energy efficiency.
	Install energy-efficient boiler systems and kilns, including the replacement of old boilers with new ones.	Industries (Category 2)	By 2030	% installation of energy-efficient boiler systems and kilns.
Reduce emissions from Category 4 industries	Use biocarbon reductants (e.g., charcoal and wood) instead of coal/coke.	Industries (Category 4)	By 2030	Reduced coal/coke use.

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce emissions from Category 7 Industries	Replace coal-fired partial oxidation processes with natural gas-fired steam reforming production.	Industries (Category 7)	By 2030	Coal-fired partial oxidation processes replaced.
Reduce emissions from Category 9 Industries	Fuel switch: convert fuel from coal to biomass/ residual wood waste so as to reduce emissions from fossil fuels in pulp and paper production.	Industries (Category 9)	By 2030	Reduced coal use.

Notes: DTIC – Department of Trade, Industry and Competition, DFFE – Department of Forestry, Fisheries and the Environment

Emission Reduction plan for Mines

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce emissions from mines	Timeous review and approval of dust management plans	Regulatory authorities	By 2030	Number of dust management plans approved
	Develop and implement the Dust Management Plan. Under the plan the following measures should be considered: • Keep surfaces of stockpiles damp where windblown dust could potentially be generated. • Have height limits for debris/waste or gravel stockpiles. • Minimise or cease dust generating activity during periods of high wind. • Wetting coal products during transport along conveyor belts. • Wetting the coal in the crusher and stage loader area.	Mines	By 2030	Submission of implementation progress reports.

Objectives	Activities	Responsibility	Timeframes	Indicators
	• Sheeting of all dust load products immediately after vehicle loading. • Enforce low speed limits for vehicular traffic. • Increase the distance between vehicles travelling the haul road so as to allow road dust dissipation.			
	Initiation of dustfall monitoring programmes.	Mines	By 2030	Submission of dustfall monitoring reports
	Conduct yearly inspections of mines for adherence to environmental requirements.	DMRE	By 2030	Mines inspected. Mines adhering to environmental requirements.

Notes: DMRE – Department of Mineral Resources and Energy

Emission Reduction plan for Domestic Fuel Burning

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce domestic fuel burning emissions	Improve public awareness on air pollution and involve communities in developing solutions that suit their socio-economic circumstances.	Local Municipalities, DOH	By 2030	Number of awareness campaigns conducted.
	Promote the use of clean/green fuels.	DMRE	By 2030	% of households have converted to or added clean/green fuels to their energy mix.
	Collaborate and engage with communities to introduce low energy systems for residential heating.	DMRE	By 2030	% of households that are using low energy residential heating systems.
	Strengthen the Intergovernmental Relations (IGR) to ensure environmental health (air pollution) is included in all planning and policies	DOH	By 2030	Partnerships have been formed.
	Train Environmental Health Practitioners (EHPs) on the implementation of the Indoor Air Quality (IAQ) guidelines in provinces and municipalities.	DOH	By 2030	% of EHPs trained and educated.
	Establish Air Quality and Health focus groups in provinces and municipalities.	DOH	By 2030	Number of Air Quality and Health focus groups that have been established.
	Foster closer working relationships between municipalities and stakeholders on designing and implementing possible emissions reduction measures.	DFFE	By 2030	Partnerships have been formed.
	Initiate pilot projects that encourage social upliftment with air quality benefits e.g., fitting RDP houses with sufficient insulation.	DHS	By 2030	Number of pilot projects initiated and finalised.

Objectives	Activities	Responsibility	Timeframes	Indicators
	Create partnerships with industries to retrofit or assist with retrofitting houses with sufficient insulation) in close proximity to industries as part of their cooperate social responsibility.	DFFE, Industries	By 2030	% of households retrofitted.
	Create partnerships with industries to provide clean fuels/green fuels to houses in close proximity to industries as part of their cooperate social responsibility.	DFFE, Industries	By 2030	% of households that have converted to or added clean/green fuels to their energy mix.
	Develop a targeted communications campaign to promote best practices in the use of wood stoves and fireplaces so as to reduce exposure to pollutants.	DFFE	By 2030	Number of awareness campaigns conducted.

Notes: DHS – Department of Human Settlements, DOH – Department of Health, DMRE – Department of Mineral Resources, DFFE – Department of Forestry, Fisheries and the Environment

Emission Reduction plan for Biomass Burning

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce biomass burning emissions	Establish Fire Protection Associations that will enforce the veldfires act.	Municipal Fire Services, Traditional leaders	By 2030	Number of registered Fire Protection Associations. Fire Protection Associations enforcing the veldfires act.
	Conduct education and awareness campaigns in the communities on the impact and prevention of veld fires.	Fire Protection Associations	By 2030	Number of awareness campaigns conducted.
	Publish outdoor burning best practice guidance so as to reduce the risk of veldfires.	Fire Protection Associations	By 2030	Outdoor burning best practice guidance implemented. Reduced number of uncontrolled veld fires.
	Promote the establishment of strategic firebreaks across the high fire risk areas.	Fire Protection Associations	By 2030	Firebreaks established and maintained.
	Ensure there is sufficient resource capacity for quick and sustained response to veld fires.	Municipal Fire Services	By 2030	Quick response to veld fire outbreaks.

Implementation Plan for education, awareness and resource mobilisation

Objectives	Activities	Responsibility	Timeframes	Indicators
To promote education, awareness and mobilise resources	Follow up on plans/ programmes and reduction commitments to ensure that the emission reduction commitments in the plans of stakeholders are fully implemented.	MDM, Local Municipalities	By 2030	Submission and review of progress reports. Implementation of recommendations from progress reports.
	Mobilisation of private capital for environmentally sustainable investments that support the zero pollution objectives.	NGOs, CBOs	By 2030	Funds availed. Implementation of emission reduction measures.
	Provide updated best practices to make tangible progress in identifying and reducing exposure to environmental risks in vulnerable groups.	NGOs, CBOs	By 2030	Updated best practices updated and implemented
	Support better governance on air pollution by offering new insights into overall pollution levels and impacts and by monitoring whether emission reduction plans implementation is on track to achieve the agreed objectives.	DFFE/DOH	By 2030	Submission and review of progress reports. Implementation of recommendations from progress reports.
	Enable local authorities to share best practices, success stories and experiences to drive improvement.	DFFE	By 2030	Number of air quality forums. Implementation of recommendations from air quality forums.
	Capacitate authorities and stakeholders.	DFFE	By 2030	% of authorities trained and educated.

Notes: NGO – Non-Government Organisations, CBO – Community Based Organisations, DFFE – Department of Forestry, Fisheries and the Environment

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ABBREVIATIONS, SYMBOLS AND UNITS

°C	Degree Celsius
amsl	Above Mean Sea Level
AAQ	Ambient Air Quality
AEL	Atmospheric Emissions License
AIR	Atmospheric Impact Report
APPA	Atmospheric Pollution Prevention Act
AQA	National Environmental Management: Air Quality Act (Act No. 39 of 2004)
AQMP	Air Quality Management Plan
AQMS	Ambient Air Quality Monitoring Station
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DEA	Department of Environmental Affairs, South Africa
DFFE	Department of Environment, Forestry and Fisheries, South Africa
DMRE	Department of Mineral Resources and Energy
EPA	United States Environmental Protection Agency
g/kg	Gram per kilogram
GHGs	Greenhouse Gases
GLCs	Ground Level Concentrations
GN	General Notice
$kg.yr^{-1}$	Kilograms per year
$\mu g/m^3$	Micro grams per cubic meter (concentration)

MES (S21)	Minimum Emission Standards (S21 MES): List of Activities which Result in Atmospheric Emissions from the National Environmental Management: Air Quality Act (Act No 39 of 2004)
MSW	Municipal Solid Waste
N/A	Not applicable
n/ap	Not applicable
n/av	Not available
NAAQS	National Ambient Air Quality Standards (South Africa)
NAQO	National Air Quality Officer
NEM: AQA	National Environmental Management: Air Quality Act
NO	Nitrogen Oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of Nitrogen (expressed as NO_2)
PM	Particulate Matter
PM_{10} / PM10	Particulate Matter with an aerodynamic diameter of ≤ 10 micrometres
$PM_{2.5}$ / PM2.5	Particulate Matter with an aerodynamic diameter of ≤ 2.5 micrometres
PMT	Project Management Team
ppm	Parts per million (g/Mg)
PSD	Particle Size Distribution
SO_2	Sulphur dioxide
TOC	Total Organic Compounds
TSP	Total Suspended Particulates – Also refers to Particulate Matter with reference to this report
US / USA	United States of America

US-EPA	United Stated Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organization

GLOSSARY OF TERMS

Air dispersion modelling	A series of mathematical simulations of how air pollutants disperse in the ambient atmosphere and is performed with computer programs that solve the mathematical equations and algorithms which simulate the dispersion of pollutants
Air Quality Act	National Environmental Management: Air Quality Act (Act No 39 of 2004)
Air Pollutant	This means any substance specified in the definition of "air pollution" that causes or may cause air pollution
Air Pollution	This means any change in the composition of the air caused by smoke, soot, dust, fly ash, cinders, solid particles of any kind, gases, fumes, aerosols, and odorous substances
Dispersion Modelling Regulations	Regulations regarding Air Dispersion Modelling (Government Notice No. 533, 11 July 2014) published in terms of the National Environmental Management: Air Quality Act (Act No 39 of 2004)
Emission factors	An emission factor is a quantity of a pollutant emitted relative to an activity metric. It is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere, with an activity associated with the release of that pollutant
Particulate Matter (PM)	PM is a mixture of organic and inorganic particles, with varying sizes and shapes. They are sub-divided into coarse (Total Suspended Particulates (TSP)) and fine particulate matter (PM_{10} and $PM_{2.5}$)
$PM_{2.5}$	Particles which pass through a size-selective inlet with a 50% efficiency cut-off at 2.5µm aerodynamic diameter.
PM_{10}	Particles which pass through a size-selective inlet with a 50% efficiency cut-off at 10µm aerodynamic diameter. PM_{10} corresponds to the "thoracic convention" as defined in ISO

	7708:1995, Clause 6. These particles are associated with health impacts due to their potential for deposition in, and impairment of, the lower airways and gas-exchanging portions of the lungs.
Sulphur Dioxide (SO_2)	SO_2 is a colourless gas, that smells like burnt matches. SO_2 can be oxidised to sulphur trioxide, which in the presence of water vapour is readily transformed into sulphuric acid mist. SO_2 can be oxidized to form acid aerosols. SO_2 is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere.

1 INTRODUCTION

1.1 Background

Mopani District Municipality (MDM) is one of the 5 districts of Limpopo province of South Africa (Figure 1), located in the north-eastern part of the country. It is home to more than 1.2 million inhabitants, with the mining sector contributing more than 30% to the economy of the region (MDM, 2022). Due to the excessive SO_2 emissions in the Ba-Phalaborwa area, the MDM was rated as one of the district municipalities having poor or potentially poor air quality, this was confirmed through the dispersion modelling findings in the Limpopo AQMP (LEDET 2013). This may have significant impacts on people's health and well-being if the situation remains persistent and not properly managed. It is therefore important that environmental issues and more specifically, air quality considerations, are recognised and incorporated into all aspects of decision-making processes in the MDM.

Section 15 (2) of the National Environmental Management: Air Quality Act (Act No.39 of 2004, (NEM: AQA) requires municipalities to develop an air quality management plan (AQMP) as part of their Integrated Development Plan (IDP), in terms of Chapter 5 of the Local Government: Municipal Systems Act (Act 32 of 2000). AQMP provide definitive objectives, strategies, plans and procedures for the relevant spheres of government to manage and improve air quality according to the requirements of the Bill of Rights. An AQMP must achieve the following: (i) improve air quality; (ii) reduce negative impacts on human health and the environment; (iii) address the effects of fossil fuels in residential applications; (iv) address the effects of emissions from industrial sources; (v) address effects from emissions from any point or non-point sources of air pollution; (vi) implement the republic's obligations in respect of international agreements; and, (vii) give effect to best practice in air quality management.

In 2015, the MDM developed and published an AQMP for the region as a strategic plan for the implementation of air quality interventions in this area. The plan provided a strategic direction for the implementation of air quality interventions in MDM, as well as an essential blueprint for action to reduce emissions in the area. The National Framework for Air Quality Management in South Africa (DEA 2017) and the Manual for Air Quality Management Planning in South Africa (DEA 2012) recommend that the AQMP be reviewed at least every 5 years. so as to identify shortfalls and reprioritise resources. In this regard, the purpose of the MDM AQMP review is, therefore, to amongst other things:

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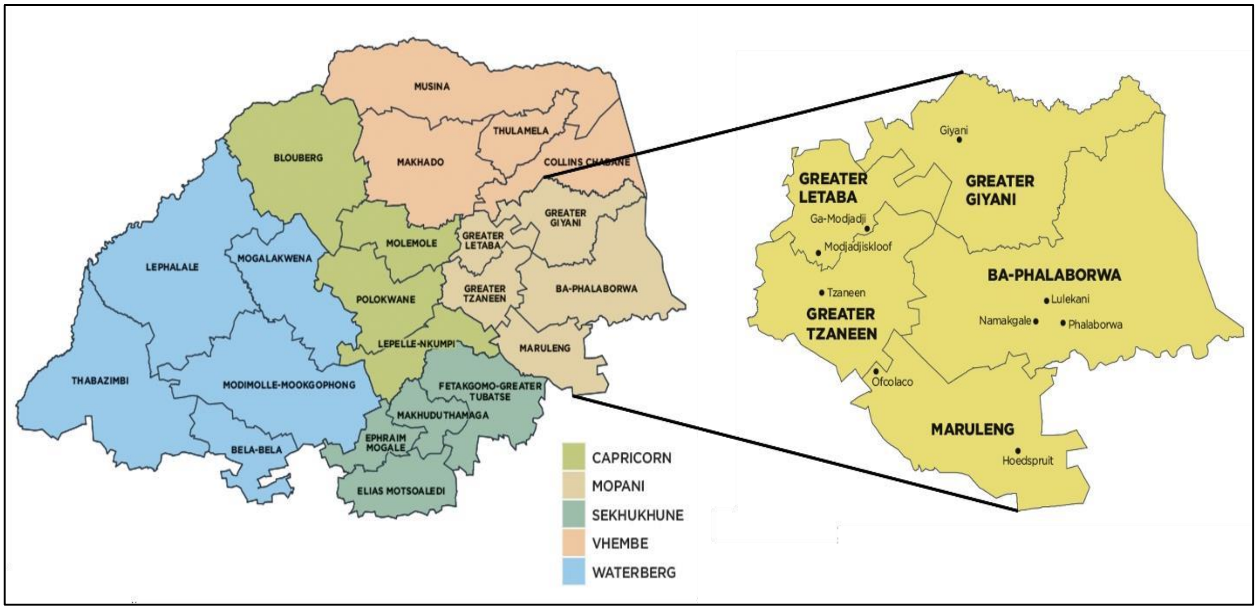


Figure 1: Map depicting the geographical extent of the MDM.

1.2 General description of the Mopani District Municipality

1.2.1 Geography and Demographics

The MDM is located within the North-eastern quadrant (Longitudes: 29° 52´E to 31° 52´E and Latitudes: 23° 0´S to 24° 38´S) of the Limpopo Province (South Africa's northernmost province), 70 km and 50 km from Polokwane city. It is bordered in the east by Mozambique, in the north, by Vhembe District Municipality through Thulamela & Makhado municipalities, in the south, by Mpumalanga province through Ehlanzeni District Municipality (Bushbuckridge, ThabaChweu and Greater Tubatse) and, to the west, by Capricorn District Municipality (Molemole, Polokwane & Lepelle-Nkumpi), in the south-west, by Sekhukhune District Municipality (Fetakgomo). The district spans a total area of 20 011 km^2, inclusive of a portion of Kruger National Park from Olifants to Tshingwedzi camps or Lepelle to Tshingwedzi rivers.

1.2.2 Topography

The MDM is characterised by mountainous, inaccessible terrain in the western bushveld region, and un-even topography (gentle slopes) in the eastern lowveld region. The mean altitude of the eastern lowveld is about 436 m whilst that of the western bushveld averages 811 m above mean sea level separated by the north-eastern escarpment. On the western end, the highest elevation is higher than 1800 m falling to below 400 m in the river valleys of the eastern end (Figure 2).

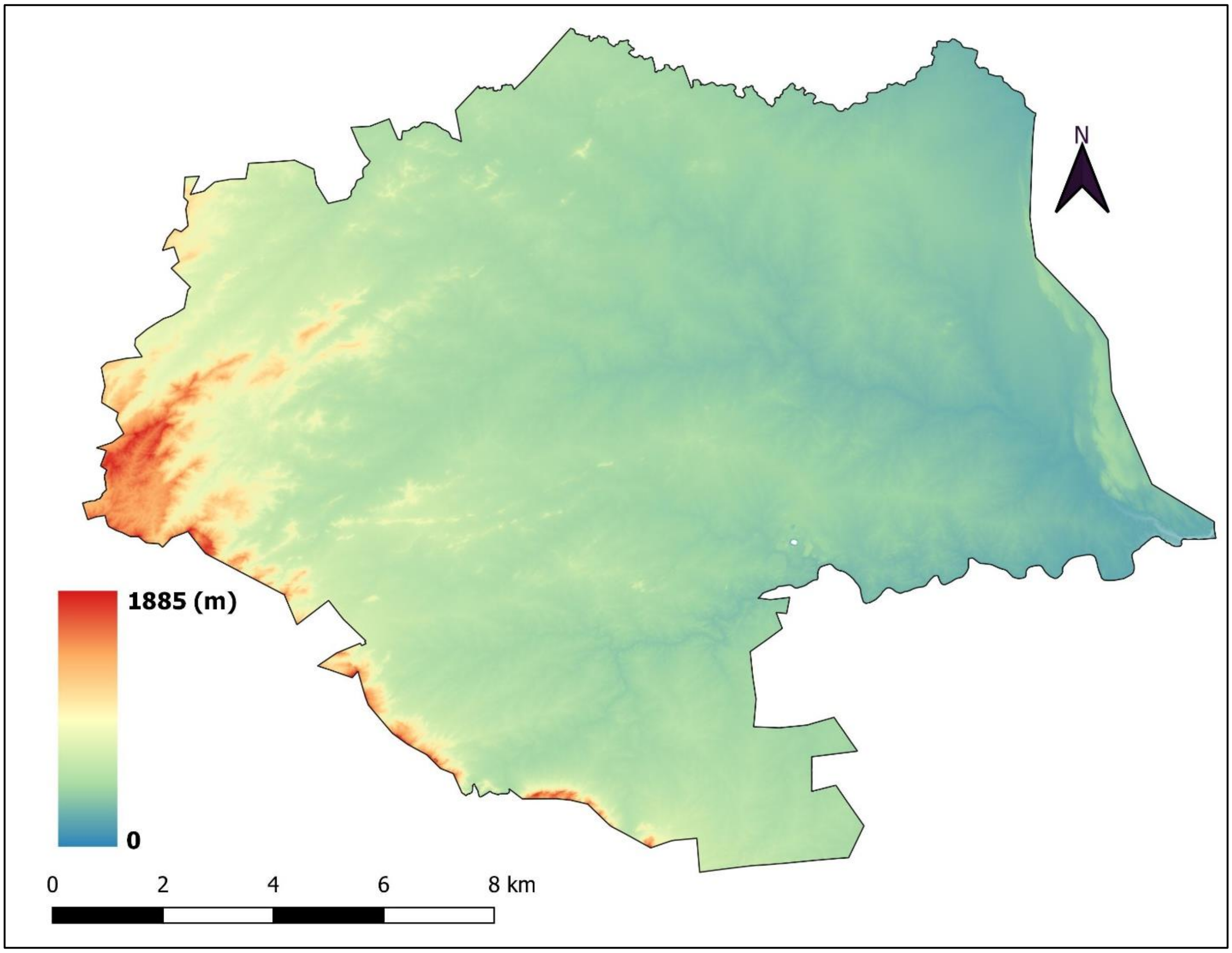


Figure 2: Topography of the MDM.

1.2.3 Land Cover

Forest and cultivated land are the dominant land cover types in the MDM, together, covering over 70% of the total land cover (Figure 3). Most of the cultivated land and residential areas are located in the western half of the district. Grassland land covers a significant portion of the landcover in the north-eastern portion of the MDM. There is a heavy presence of mines and quarries in the Ba-Phalaborwa region.

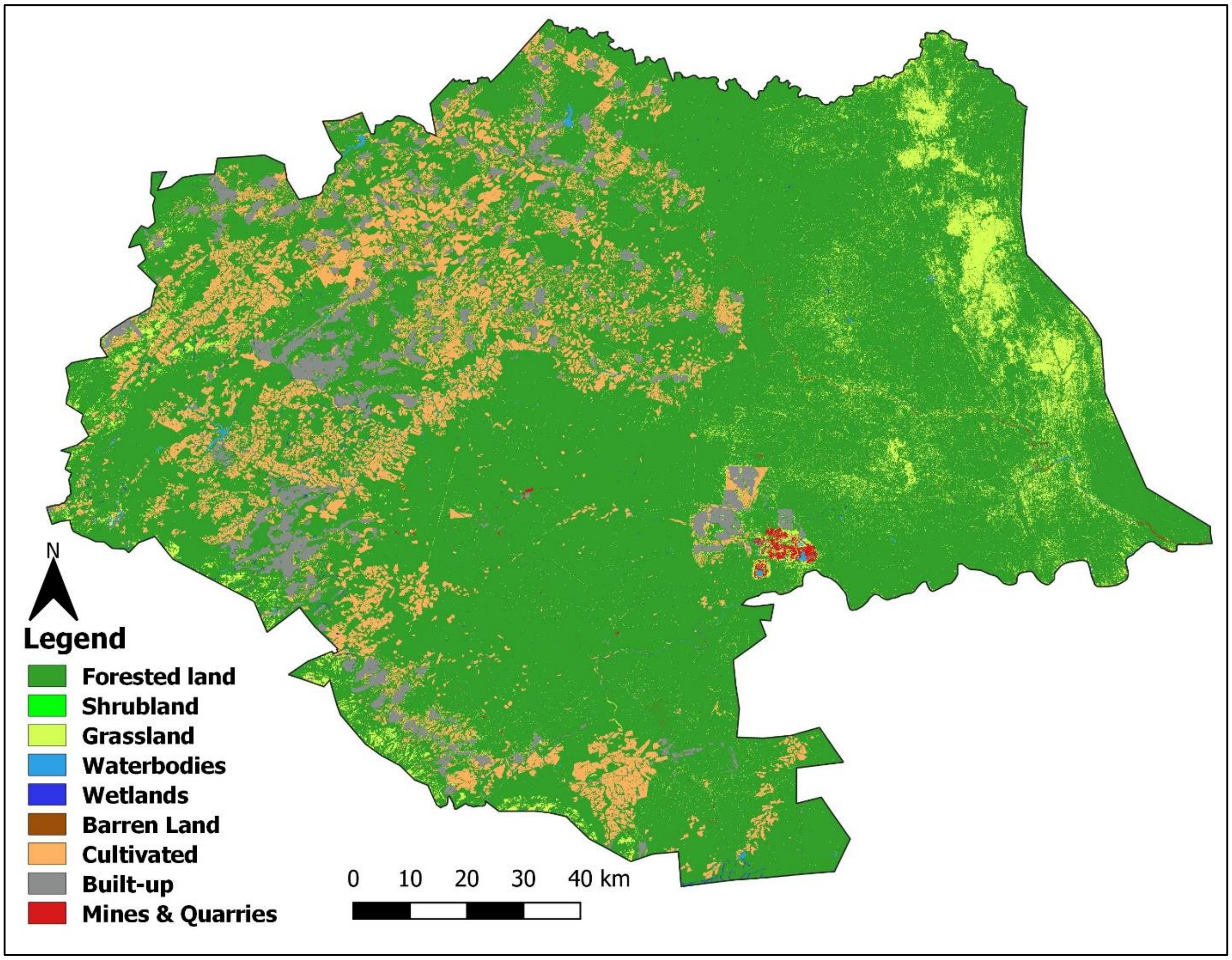


Figure 3: Landcover map of the MDM.

1.2.4 Population Distribution

There are 16 urban areas (towns and townships), 354 villages (rural settlements) and a total of 129 Wards. The reconciled total population of the MDM has increased from 1 061 107 (Census 2001) to 1 092 507 (Census 2011). By 2016, the population within the MDM had risen to 1 159 185, a 6% growth over five years (Table 1). Out of the entire district population, 81% reside in rural areas, 14% in urban areas and 5% stay on farms. The population densities vary from one municipality to another, but the average is 23 people/ ha. Indicating that people are sparsely populated with sufficient land around them. However, there is a problem of land shortage for economic development due to the vast land occupied for dwelling purposes, leaving much little for economic growth areas (Mopani IDP 2022).

Table 1: MDM Local Municipalities and the respective populations in each local municipality.

Local and District Municipalities	Community Survey 2016 Population
Greater Giyani	256 127
Greater Letaba	218 030
Greater Tzaneen	416 488
Ba-Phalaborwa	168 937
Maruleng	99 605
Mopani	**1 159 185**

1.2.5 Regional Climate and Atmospheric Dispersion Conditions

The MDM has a temperate climate with rainfall predominantly occurring in the summer months (80%) from November to March. On average the MDM receives between 400 mm over the dry Savannah areas and up to 2000 mm of rain per annum over the Great escarpment areas. The temperature ranges from a maximum average of 21°C in the mountainous areas, to 25°C in the dry lowveld areas (Mopani IDP, 2022), with north-easterly to south-easterly winds frequently observed (Mopani AQMP, 2015).

1.2.5.1 Surface Wind Field

Figure 4 presents the characteristics of surface winds from four monitoring stations from the period 2015 to 2020, exploratory analysis of monitored data reveals that the general wind pattern in the MDM indicates a dominance of south-easterly to easterly winds for all the years and at all monitoring sites.

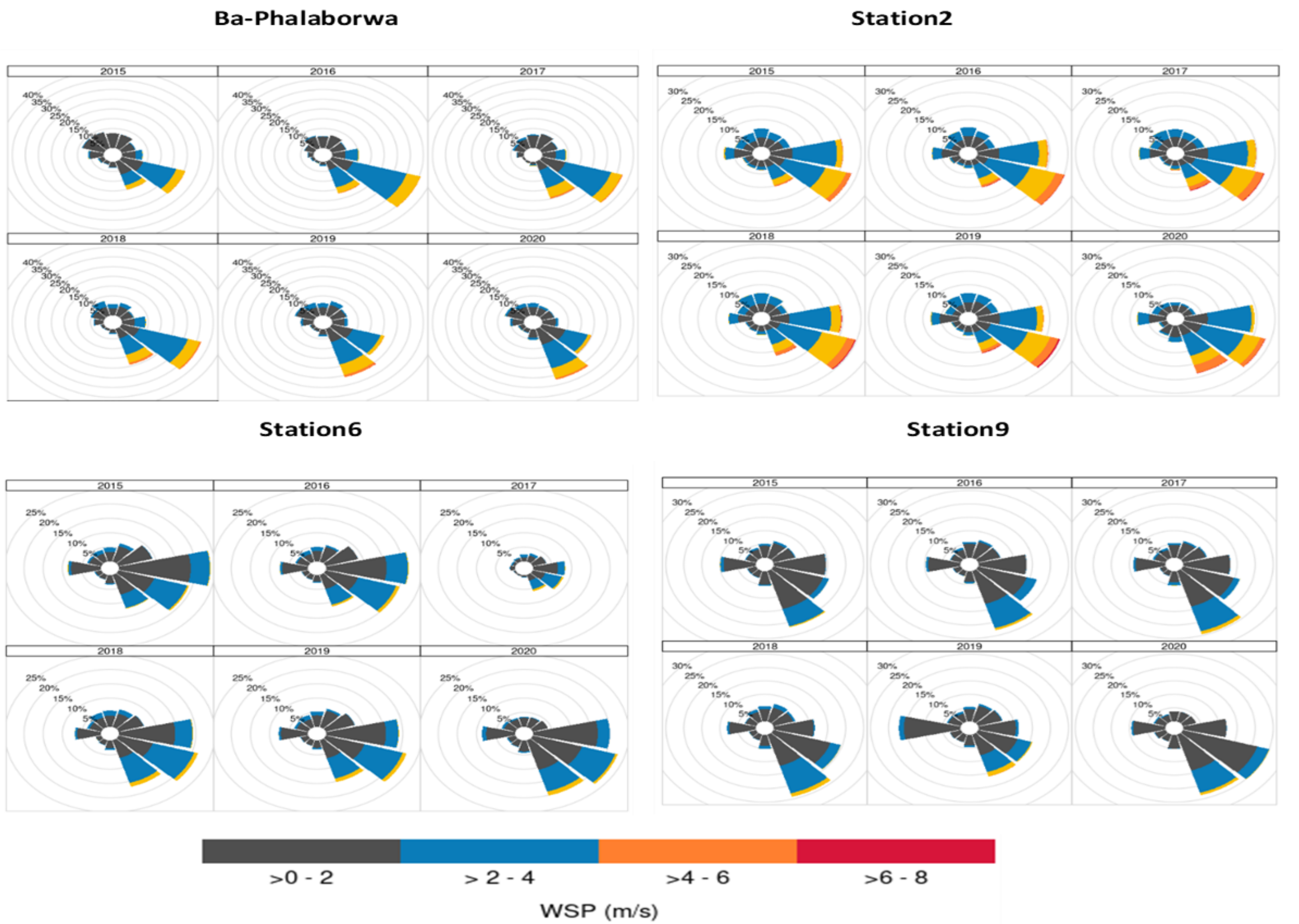


Figure 4: MDM Wind Roses for 2015 to 2020.

1.2.5.2 Temperature

Temperatures (Table 2) are generally warmer in the MDM with annual average temperatures ranging between 21 °C to 26 °C at most monitoring stations. Maximum temperatures can reach up to 45.5 °C depending on the station and year. Station 9 is an exception to this as it tends to continually record mild (between 12.96 to 13.83 °C) temperatures.

Table 2: Maximum, Average and Minimum Temperatures at MDM monitoring stations.

Station	2015	2016	2017	2018	2019	2020
Phalaborwa						
Maximum Temperature (°C)	41.2	43.3	39.2	40.6	41.8	40.5
Average Temperature (°C)	22.6	25.8	23.9	22.6	22	20.8
Minimum Temperature (°C)	8.3	12.2	11.7	9.17	5.8	5.6
Station2						
Maximum Temperature (°C)	43.3	44.1	42.8	45.5	45	42.3
Average Temperature (°C)	24	23.7	23	23.7	24	24.1
Minimum Temperature (°C)	6.5	8	9	8	7	9
Station6						
Maximum Temperature (°C)	43.8	42.9	40.5	42.9	43.9	41
Average Temperature (°C)	24	23.6	23.2	24.9	23.9	24.5
Minimum Temperature (°C)	7.6	8.8	9.9	10.4	7.6	10
Station9						
Maximum Temperature (°C)	13.8	13.9	13.8	13.8	13.8	13.8
Average Temperature (°C)	13.7	13.8	13.7	13.7	13.8	13.7
Minimum Temperature (°C)	13	13.5	13.1	13	13.1	13.3

1.2.5.3 Rainfall

Rainfall data were not analysed as there was no data reported at all the monitoring stations except for one monitoring site (Station 2) where rainfall data is reported but with huge gaps and only a few incidences having valid rainfall values which could not be used.

2 AIR QUALITY MANAGEMENT PLAN REVIEW PROCESS

The process to review and update the MDM AQMP follows the process defined in the Manual for Air Quality Management Planning (DEA 2017) and outlined in the National Framework for Air Quality Management (DEA 2012) for the development of an AQMP. The following steps were taken in reviewing the 2015 AQMP for the MDM:

Step 1: Assess whether air quality has improved in the MDM

This involved conducting a baseline air quality assessment in which measured concentrations over the MDM were analysed over a specific time period.

Step 2: Identify if there is a need to update information or include any new information in the AQMP

This involved updating the current emissions inventory for the MDM as well as performing dispersion modelling to assess the spatial distribution of pollutants over the MDM.

Step 3: Identify the challenges experienced in implementing the AQMP and how to address them

The AQMP implementation challenges experienced in the MDM were identified through an institutional capacity assessment. Goals were revisited and redefined, strategies reassessed and the implementation plan for the MDM was updated.

In this regard, the review of the 2015 AQMP focused on assessing the following aspects of the 2015 MDM AQMP:

- Air Quality Measurement and Monitoring
- Emission Inventory
- Dispersion Modelling
- Operational Capacity

3 AIR QUALITY MEASUREMENT AND MONITORING

The monitoring network in the Mopani district is limited in providing sufficient information to support adequate air quality management for the greater Mopani region. Currently, there are only four operational ambient air quality monitoring stations in the MDM, which are concentrated in the Ba-Phalaborwa region (Figure 5). Of the four stations, one is managed by the Limpopo Department of Economic Development, Environment and Tourism (LEDET) and the remaining three stations are privately owned and managed by the Phalaborwa Mining Company (PMC). Table 3 provides a description of the parameters monitored at each station.

There is an ambient air quality monitoring station located in Tzaneen managed by the MDM, however, this station is currently not functional due to technical problems. The monitoring station in the Ba-Phalaborwa area, managed by LEDET, measures (continuous measurements) most of the criteria pollutants including sulphur dioxide (SO_2), nitrogen dioxide (NO_2), oxides of nitrogen (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), Carbon Monoxide (CO), and BTEX VOC compounds as well as meteorological parameters. The three stations owned by PMC measure only SO_2 and meteorological parameters.

Ambient air quality monitoring data from the four operational stations in the Ba-Phalaborwa region are currently being logged in the South African Air Quality Information System (SAAQIS) and can be processed online for air quality information graphs. Some quality control is carried out, but the data still requires further processing. An air quality assessment was conducted using data obtained from these four stations. The purpose of the assessment was to assess, through a trend analysis, whether air quality has improved in the MDM since the publication of AQMP for the MDM. Overall, air quality in the MDM has not significantly improved as shown in the findings in sections 3.1 to 3.5.

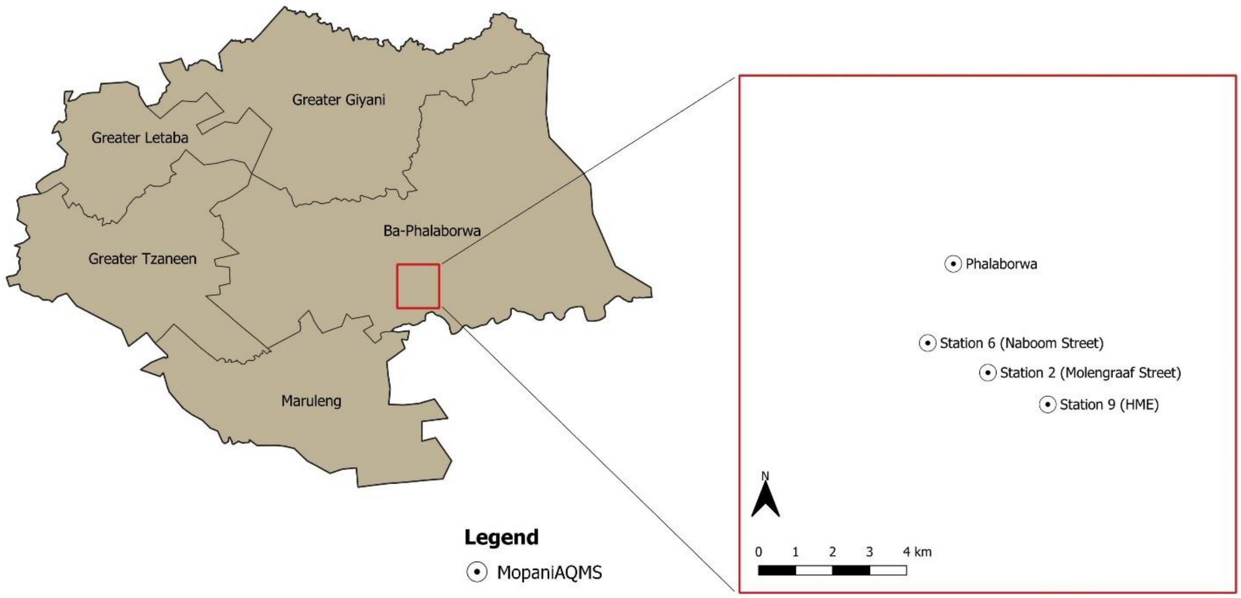


Figure 5: Location of ambient air quality monitoring stations in the MDM

Table 3: Description of air quality monitoring stations in the MDM

Station Name	Type	Owner	Location	Parameters
Tzaneen	Urban	MDM	23.841S, 30.153E	SO_2, NO_2, NO, O_3, CO, $PM_{2.5}$, PM_{10}, met*
Phalaborwa	Residential – Medium/Upper income	LEDET	23.932S, 31.140E	SO_2, NO_2, NO, O_3, CO, $PM_{2.5}$, PM_{10}, met
Station 2 (Molengraaf Street)	Urban	Phalaborwa Mining Company	23.960S, 31.149E	SO_2, met
Station 6 (Naboom Street)	Urban	Phalaborwa Mining Company	23.953S, 31.133E	SO_2, met
Station 9 (HME)	Urban	Phalaborwa Mining Company	23.970S, 31.165E	SO_2, met

*met-meteorological parameters

3.1 Sulphur Dioxide (SO_2)

SO_2 is the only parameter with concentrations monitored and reported at all 4 stations. The analysis of the available monitored data (2015-2019) showed that 1-hour and 24-hour ambient SO_2 (Figures 6 and 7) concentrations are still elevated over the Ba-Phalaborwa region. Exceedances are experienced more for 1-hour concentrations than 24-hour concentrations. With the exception of the Phalaborwa AQMS, there are no annual SO_2 exceedances experienced in the Ba-Phalaborwa region throughout the 2015-2019 period. Generally, there is a decrease in annual SO_2 concentrations in the Ba-Phalaborwa region from 2015 to 2019.

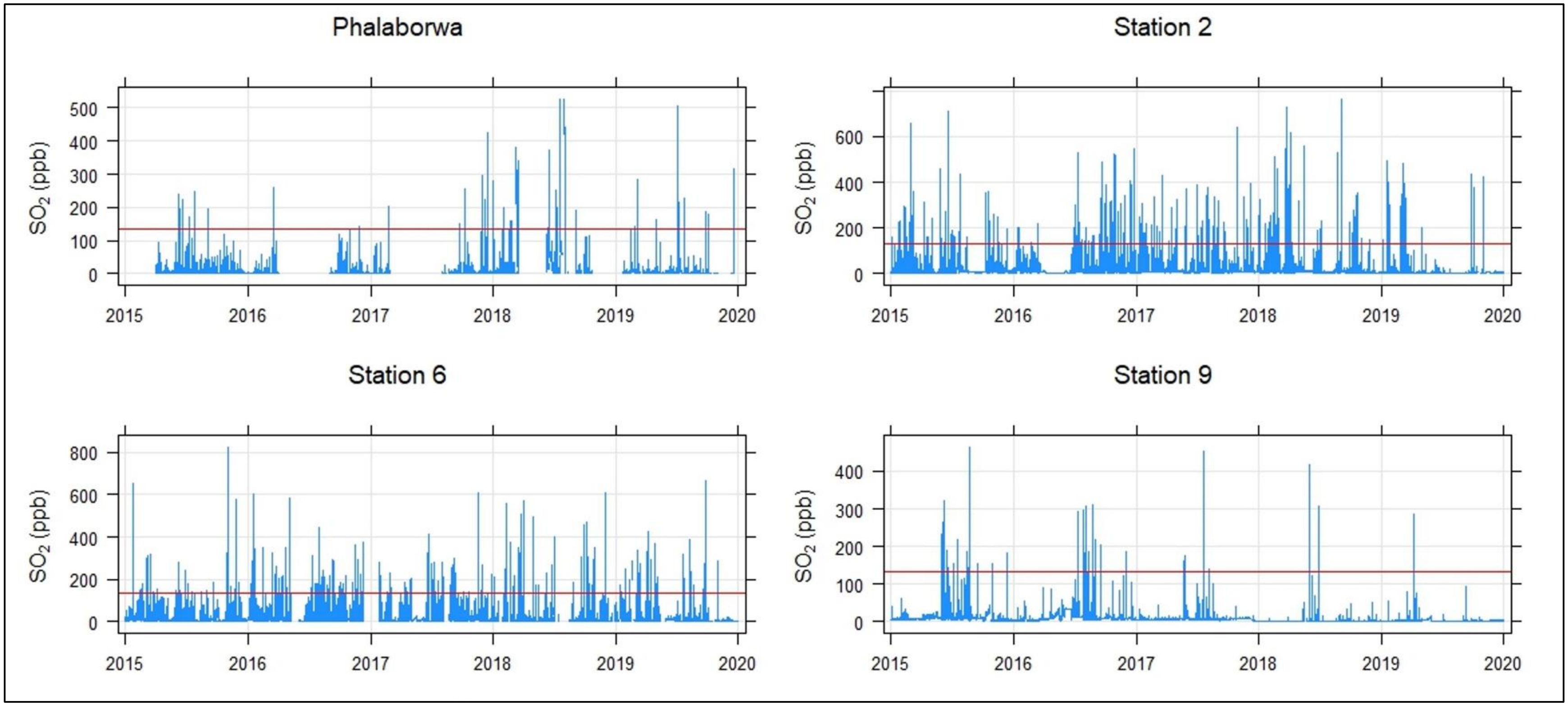


Figure 6: 1-hour average SO_2 concentrations at the MDM air quality monitoring stations between 2015 and 2019 (NAAQS [red solid line]:134 ppb)

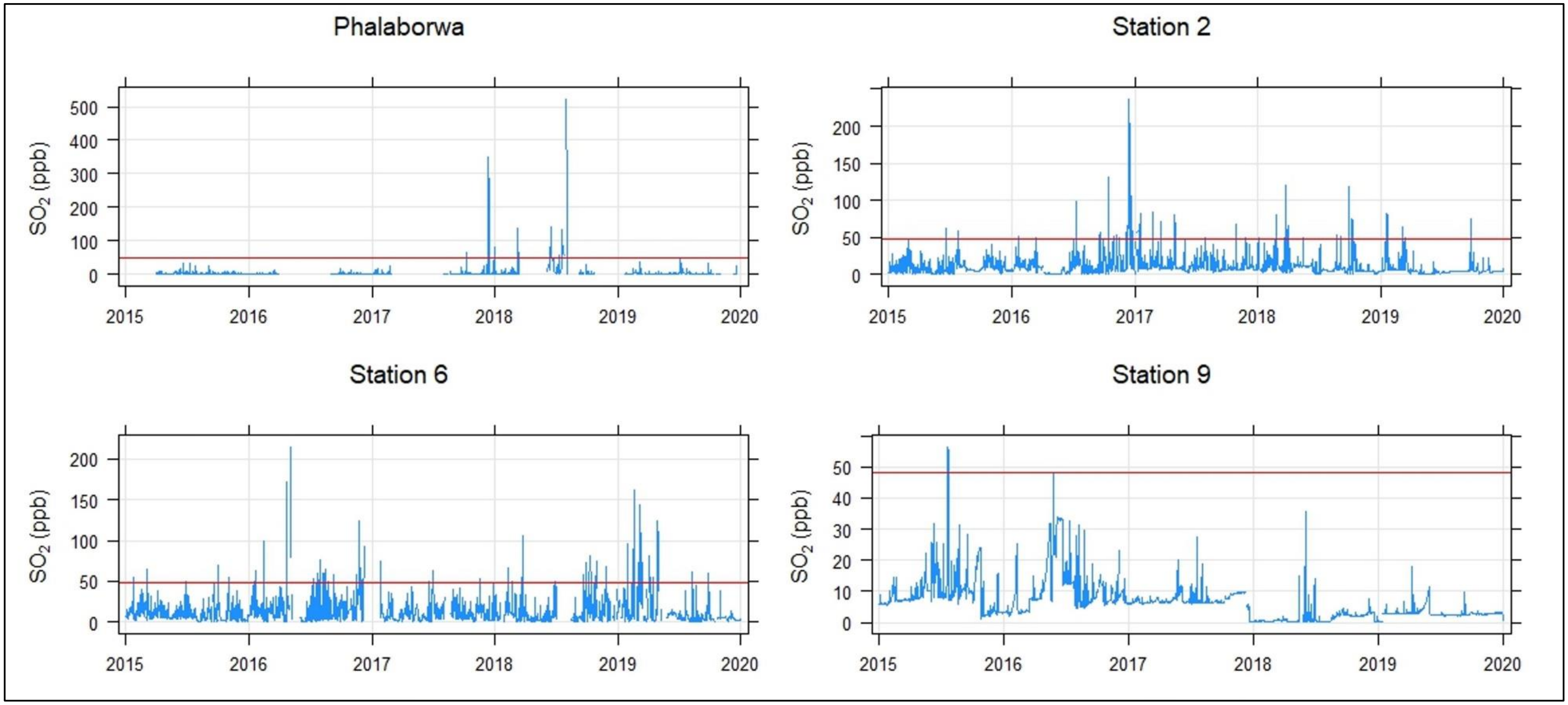


Figure 7: 24-hour average SO_2 concentrations at the MDM air quality monitoring stations between 2015 and 2019 (NAAQS [red solid line]:48 ppb)

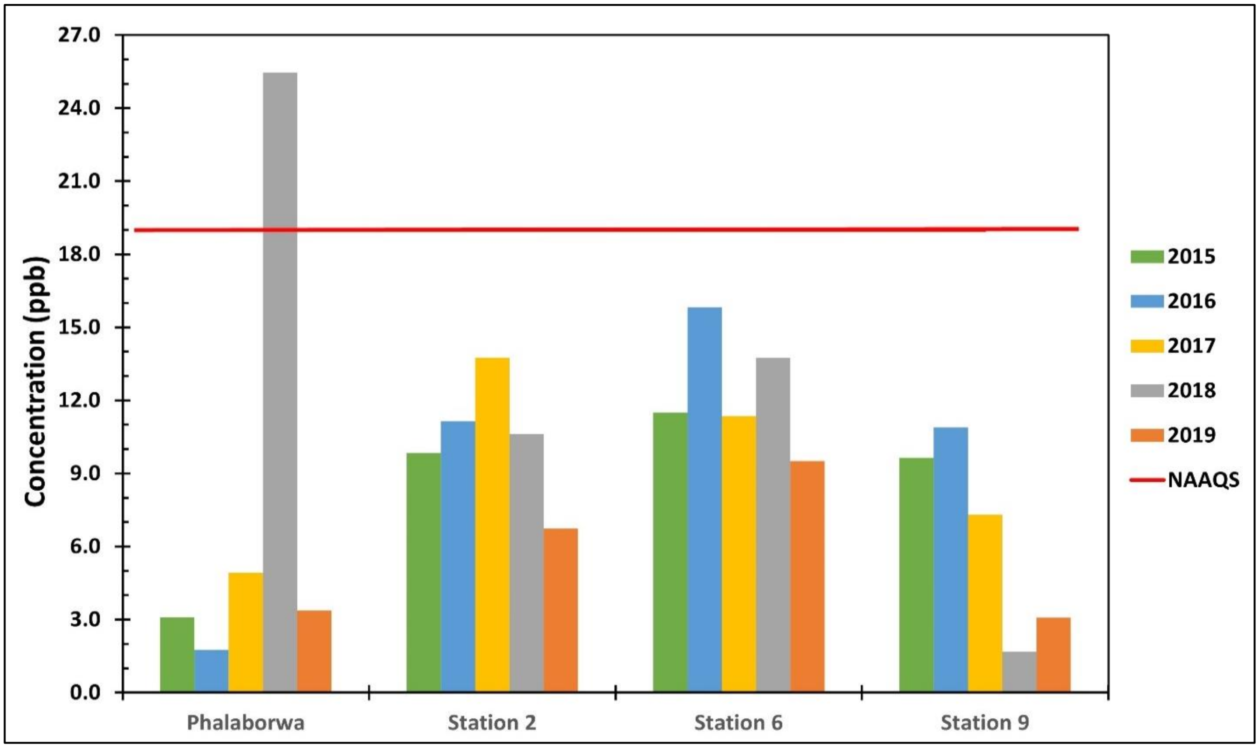


Figure 8: Annual average SO_2 concentrations at the MDM air quality monitoring stations between 2015 and 2019 (NAAQS:19 ppb)

3.2 Particulate Matter (PM_{10})

Analysis of the daily averages for PM_{10} at the Phalaborwa AQMS indicates that were exceedances taking place in 2018 and 2019. There is an increase in annual PM_{10} concentrations taking place between 2018 and 2019, however, annual PM_{10} concentrations are still below the NAAQS.

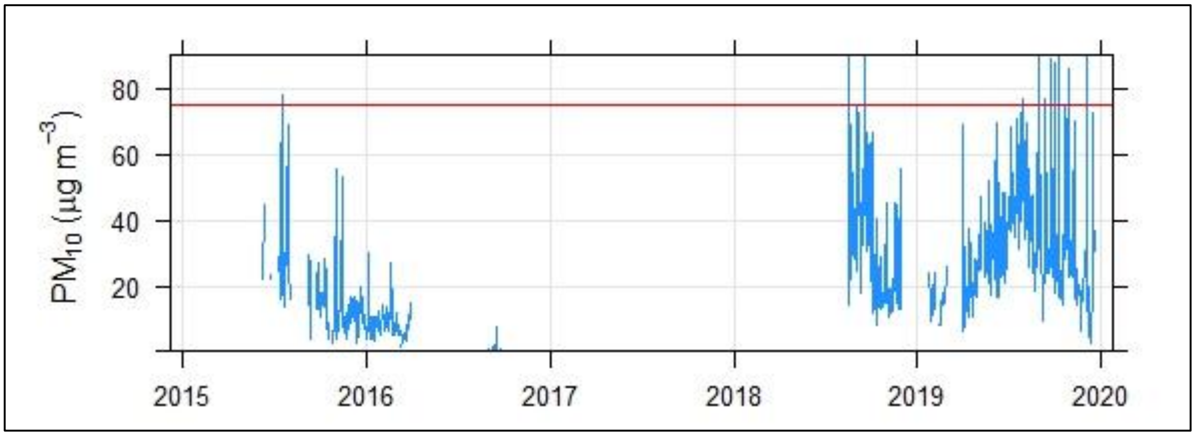


Figure 9: 24-hour average PM_{10} concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS [red solid line]:75 µg.m^{-3})

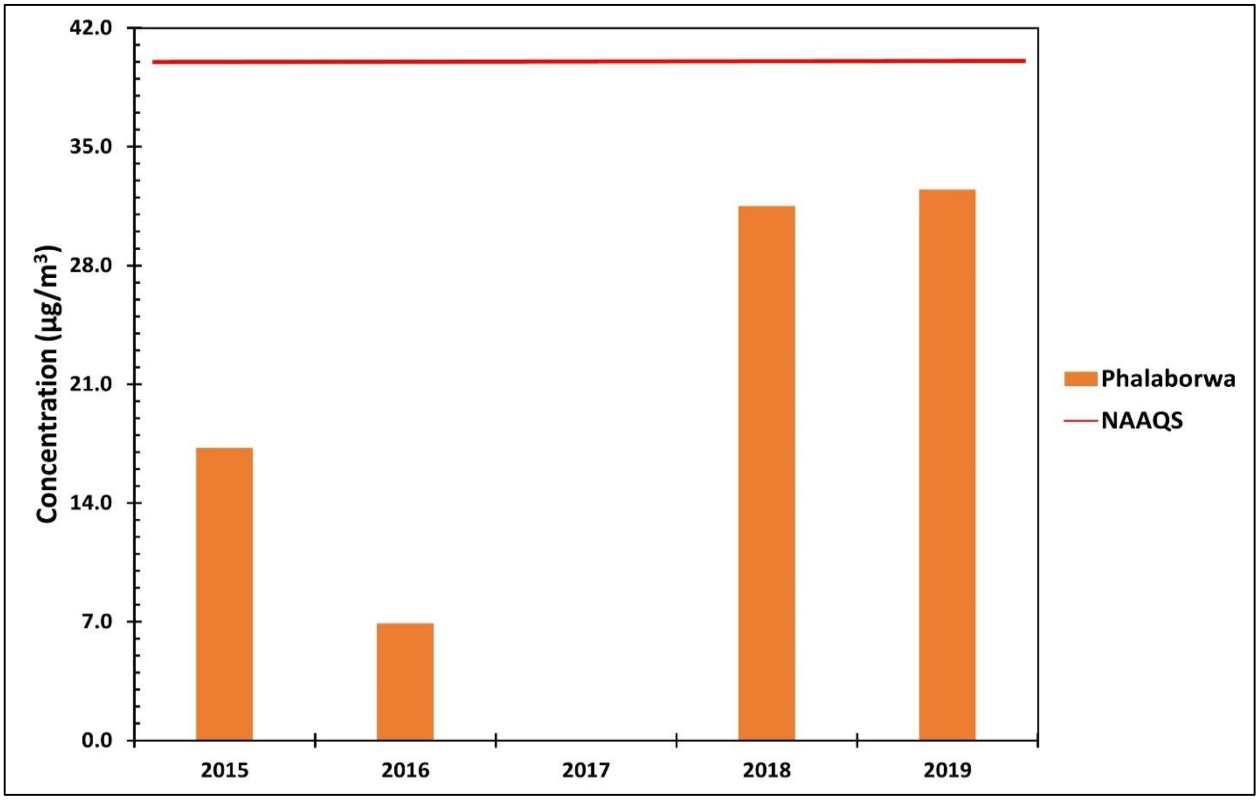


Figure 10: Annual average PM_{10} concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS:40 µg.m^{-3})

3.3 Particulate Matter ($PM_{2.5}$)

Similar to PM_{10}, daily averages for $PM_{2.5}$ at the Phalaborwa AQMS were in exceedance between 2018 and 2019. There is a decrease in annual $PM_{2.5}$ concentrations taking place between 2018 and 2019. Annual $PM_{2.5}$ concentrations at the Phalaborwa AQMS have remained below the NAAQS since 2015.

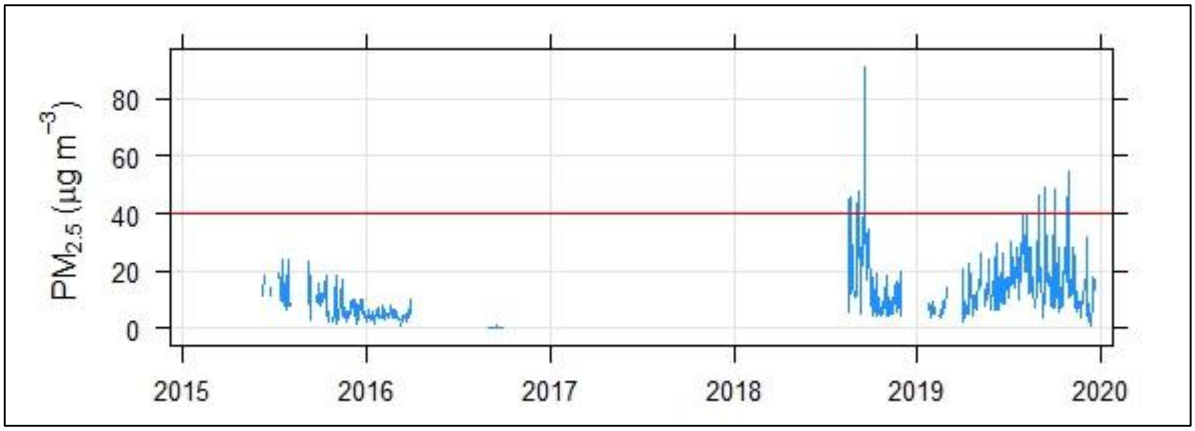


Figure 11: 24-hour average $PM_{2.5}$ concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS [red solid line]:40 $\mu g.m^{-3}$)

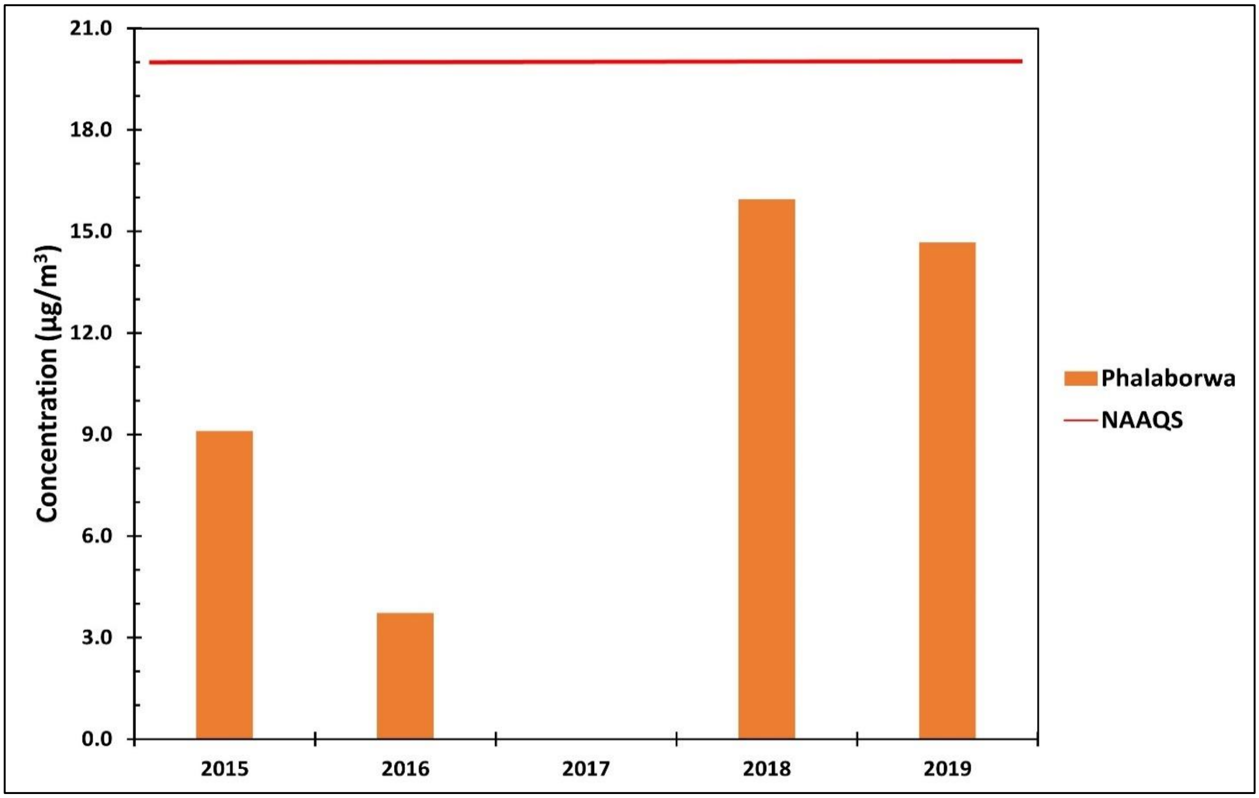


Figure 12: Annual average $PM_{2.5}$ concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS:20 µg.m^{-3})

3.4 Nitrogen Dioxide (NO_2)

Analysis of 1-hour NO_2 averages at the Phalaborwa AQMS generally shows that concentrations are well below the NAAQS. There are only 2 instances, between 2017 and 2018, in which exceedances occur. These are isolated incidences. There are no annual NO_2 exceedances experienced at the Phalaborwa AMQS throughout the 2015-2019 period. The annual NO_2 concentrations are significantly below the NAAQS.

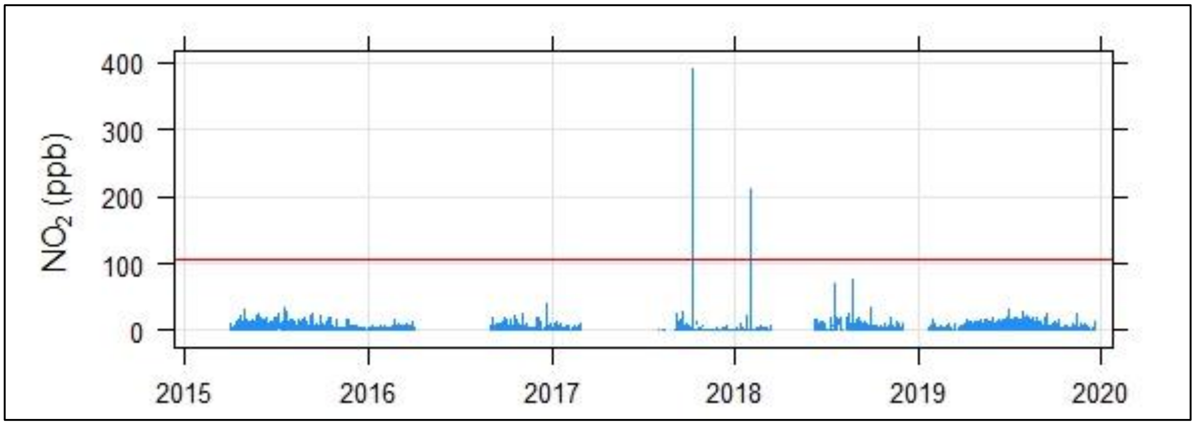


Figure 13: 1-hour average NO_2 concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS [red solid line]:106 ppb)

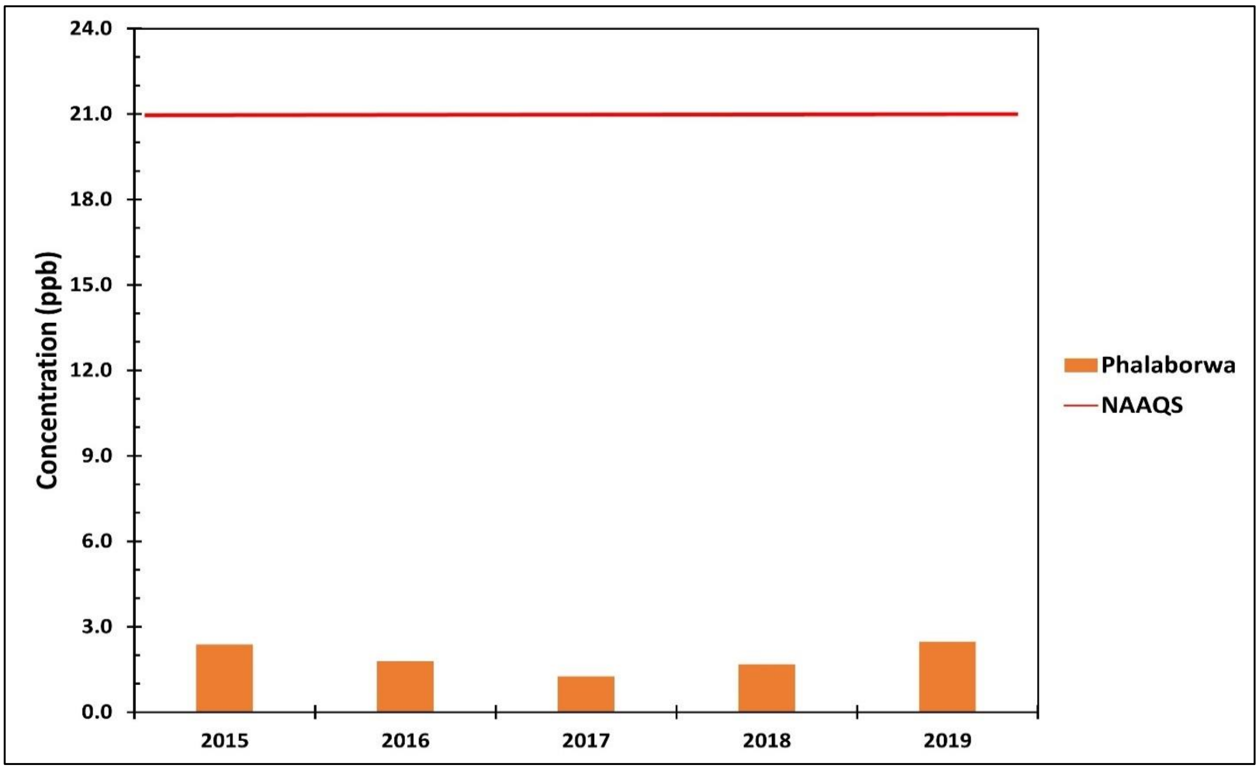


Figure 14: Annual average NO_2 concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS:21 ppb)

3.5 Ozone (O_3)

Long-term trends for O_3 concentrations at the Phalaborwa AQMS showed non-compliance with the 8-hour-running average NAAQS. The highest concentrations of O_3

were mainly observed during spring and summer as the intensity of sunlight needed for the photochemical reactions is highest during this time.

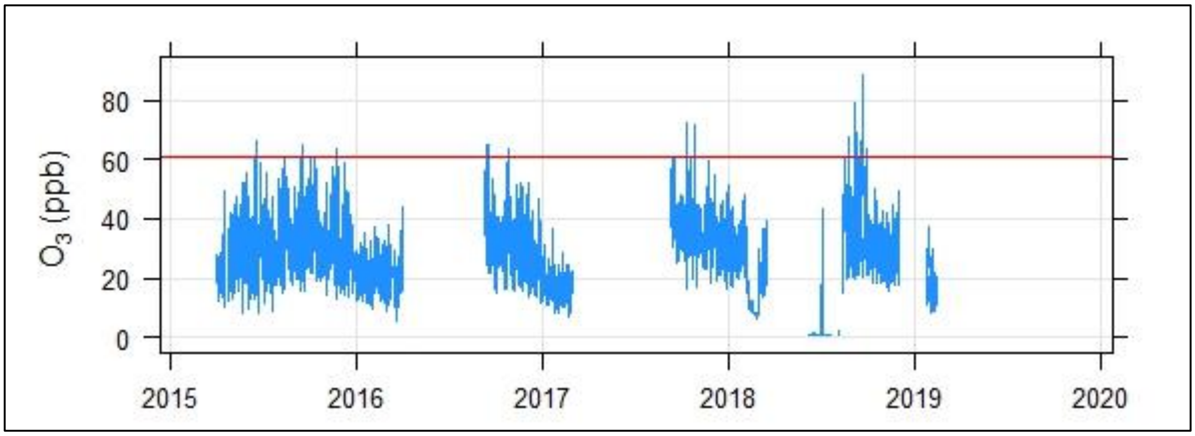


Figure 15: 8-hour average O_3 concentrations at the Phalaborwa air quality monitoring station between 2015 and 2019 (NAAQS [red solid line]:61 ppb)

4 EMISSION INVENTORY

An emission inventory was developed for the 2015 MDM AQMP, and the sources which were considered in the inventory include industrial, mining, and transport (motor vehicles). An assessment of the 2015 MDM AQMP emissions inventory revealed some inadequacies, which include, but are not limited to:

- Emissions were reported for only three sources (industries, mining, and transport) which is not an adequate representation of the total emissions in the MDM;
- Poor and/or no descriptions of methodologies used to quantify emissions;
- Calculation discrepancies in industrial emissions, specifically for smelters, small boilers and chemical fertiliser production.

The AQMP review sought to address these challenges by updating the emission sources previously quantified in the 2015 MDM AQMP, introducing new emission sources that were not previously quantified and providing a better description of the updated methodologies applied in the review.

4.1 Emission Sources that were updated

4.1.1 Industrial emissions

4.1.1.1 Methodology

The industrial emission inventory for the 2015 MDM AQMP was developed through the collection of information (on emission sources) from the MDM and LEDET. Analysis of the 2015 MDM industrial emission inventory revealed some discrepancies in the calculation of the industrial emissions, specifically for smelters, small boilers and chemical fertiliser production.

For the AQMP review, the updated emissions from industrial activities were based on the year 2019 activity data reported through the NAEIS system. The NAEIS platform supports reporting of atmospheric emissions from industrial activities in a coherent and sustainable manner. This approach may be considered to be more robust and transparent as compared to the previous methodologies used to estimate industrial emissions in South Africa. Emissions from small boilers were estimated using data on fuel usage (obtained from small industries in the MDM) and emission factors from the Australian National Pollution Inventory (NPI).

Comparisons between the 2015 industrial emissions and the 2019 industrial emissions were not made due to the calculation discrepancies found in the 2015 industrial emissions.

4.1.1.2 Results

The map below shows the location of industries in the MDM. The updated Industrial emissions inventory for the MDM indicates that there are 16 section 21 and 10 section 23 industrial emission sources that are operating within the Mopani district, with the majority of the facilities located in Ba-Phalaborwa and Greater Tzaneen. These facilities include amongst others those supporting agricultural, bulk fuel storage, smelters, and wood processing.

Table 4 presents a breakdown, according to industry type, of the 2019 annual emissions for PM_{10}, $PM_{2.5}$, SO_2, NO_x, VOC and CO in the Mopani region.

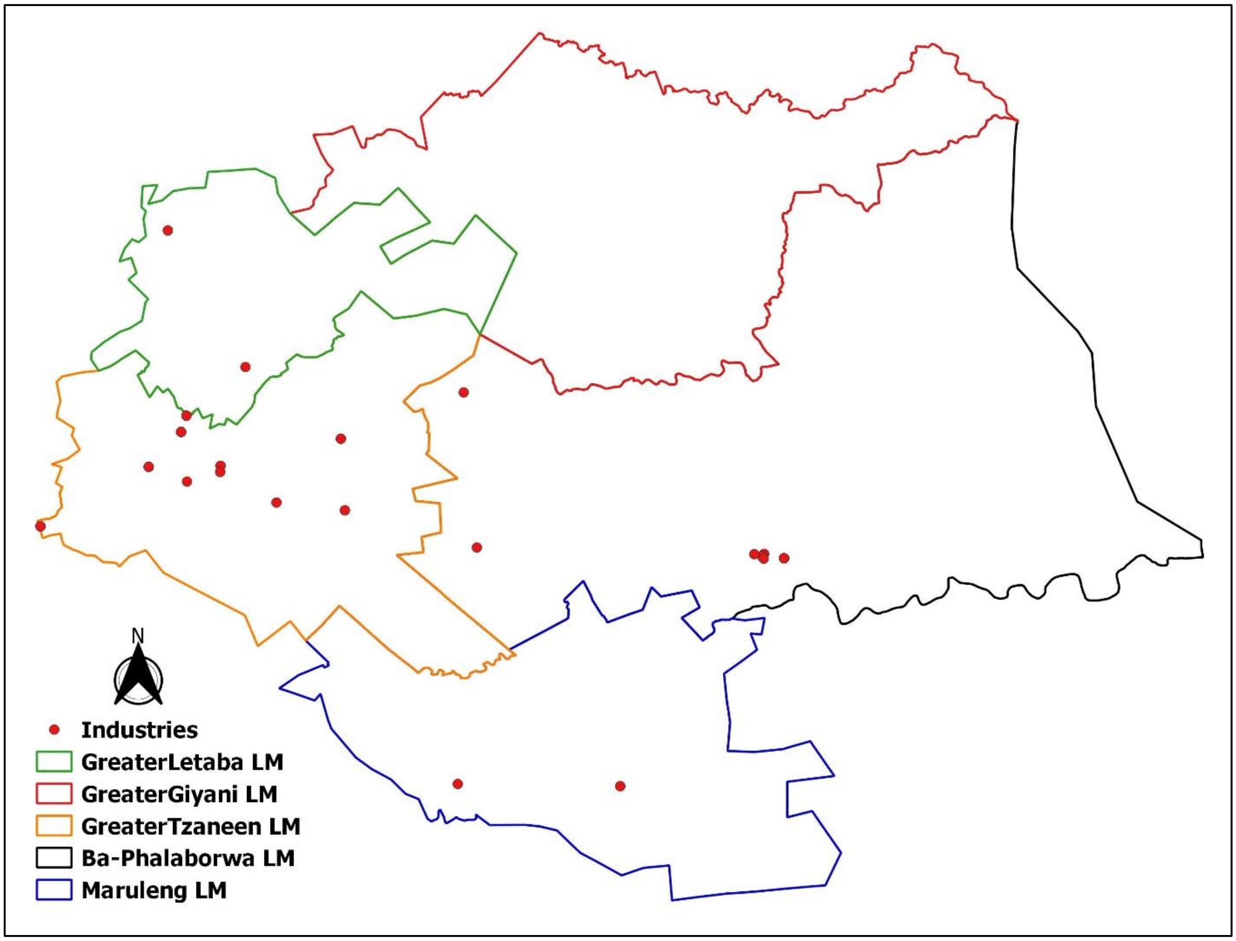


Figure 16: Location of industries in the MDM

Table 4: Updated industrial-related emissions profile (tonnes/annum) for the MDM.

Category	No. of facilities	PM_{10} (tpa)	SO_2 (tpa)	NO_x (tpa)	$PM_{2.5}$ (tpa)	VOC (tpa)	CO (tpa)
Chemical fertiliser production	1	794	37	673	422	1 309	–
Smelter	1	47	144	81	9	0	27
Wood processing	7	88	13	100	22	526	195
Petrochemical	1	–	–	–	–	8	–
Non-ferrous metal production	1	1 350	–	113	995	169	282
Mineral beneficiation	4	457	9	20	152	24	9
Food processing	1	5	98	–	3	–	12
Small-Scale Char/Charcoal	1	–	–	–	0.006	–	–
Small boilers	9	178	409	157	62	–	68
Total	**26**	**2 919**	**713**	**1 143**	**1 664**	**2 036**	**593**

4.1.2 Mining emissions

4.1.2.1 Methodology

Mining emissions were quantified for the 2015 MDM AQMP, however, there is no clear description of the methodology applied in estimating emissions from mining activities.

For the AQMP review, the updated emissions from mining activities were based on the year 2019 activity data reported through the NAEIS system. Additionally, mines and quarries not reporting their emissions to the NAEIS system were identified using the DMR online database (https://www.dmr.gov.za/mineral-policy-promotion/operating-mines/Limpopo). Two sand mines were identified from the DMR database. Emissions for these mines were estimated using emission factors derived from a study done by Van Basten & Van Nierop (2018).

4.1.2.2 Results

The assessment of mining emissions showed that since the publication of the 2015 MDM AQMP, there has been an increase in the number of mines in the MDM (Table 5). Updated TSP emissions (for 2019) in the MDM are less than the emissions estimated in 2015. However, this comparison has to be taken with caution as the methodologies applied for the two inventories are different.

Table 5: Changes in the mining-related emissions profile (tonnes/annum) in the MDM.

Year	Facilities	PM_{10}	$PM_{2.5}$	TSP
2015	3	Not quantified	Not quantified	1 731
2019	6	758	125	1 539

4.1.3 Motor vehicles emissions

4.1.3.1 Methodology

The 2015 MDM AQMP emission inventory quantified emissions from motor vehicles using a “bottom-up” approach in which the Roads Agency Limpopo data for 2011 and 2012 based on traffic counts from their traffic counting stations were used as input data in estimating motor vehicle emissions. The traffic count data set includes descriptions of the road type, road length, and average daily traffic. A split is provided between the percentage of heavy-duty vehicles, very heavy-duty vehicles, light-duty vehicles, buses, taxis, and passenger cars. The inventory also utilised the emission rate factors developed by the European Environment Agency (COPERT III and COPERT IV).

For the AQMP review, updated motor vehicle emissions for the MDM were estimated using a “top-down” approach where district-level fuel sale data is utilised as input data. The “top-down” approach was used instead of the “bottom-up” approach as updated traffic count data for the MDM was not available. The “top-down” approach is discussed in greater detail below.

Top-down

The top-down approach uses provincial fuel sales and fuel efficiency data from COPERT; to estimate vehicle kilometres travelled (VKT). A key assumption is that fuel sales equate to fuel consumption. This is true for total national volume, however, if one tries to look at sales spatially, the possibility of fuel sales being consumed elsewhere is likely. Therefore, Magisterial District sales are used rather than provincial sales (also available from DoE) to minimize this effect. Table 6 details the district-level fuel sales within the MDM for 2018 (DOE, 2018). These fuel sales were apportioned according to the rate of travel across the five local municipalities in line with the Stats SA Community Travel Survey for the Limpopo province (Stats SA, 2013).

Table 6: District-level fuel sales within the MDM for 2019.

Area	Total Fuel Sales	Diesel (Million L)	Petrol (Million L)
Greater Giyani	25 267 810.80	11 662 066.52	13 605 744.28
Greater Letaba	23 464 811.48	10 829 912.99	12 634 898.49
Greater Tzaneen	43 469 191.43	20 062 703.74	23 406 487.69
Ba-Phalaborwa	17 646 582.67	8 144 576.62	9 502 006.05
Maruleng	10 141 731.95	4 680 799.36	5 460 932.59
Total	**119 990 128.33**	**55 380 059.23**	**64 610 069.10**

There is an inherent difficulty in assigning the fuel/VKT to specific road links. National household survey data are used to further disaggregate provincial fuel sales based on travel activity. However, for this assessment fuel sales are allocated to each Local Municipality (LM) to further disaggregate fuel down to the road level. This is accomplished by using data from the South African Road Classification and Access Manual (SARCAM) (SANRAL, 2012). Tables B and C of the manual provide the typical average annual daily traffic (AADT) for different road classes. These typical road AADTs were used to proportionally distribute fuel to different World Bank data CatLog for South African road classes. The result is unique road classes, to which typical AADT from the SARCAM can be assigned. Fuel within each LM is then distributed by the typical AADT proportion amongst classes. The final level of disaggregation is achieved by then allocating fuel proportionally within classes based on link length. The result is a fuel consumption estimate on each of the remaining (after removals from the bottom-up processing once updated data is obtained) CDSM roads. This fuel consumption is converted to VKT using the COPERT-derived fuel efficiency data i.e., fuel consumption per vehicle type and AADT. Since there is no indication of vehicle age or technology within the activity data used (both counts for the bottom-up and fuel sales for the top-down) it is necessary to aggregate the emission factors by the EURO stage. Simply taking an average would not be accurate since that would assume all vehicle ages exist at an equal proportion in the vehicle parc. This is not true as newer vehicles enter the parc, older ones leave, resulting in a shift towards newer vehicles. Table 7 details approximate manufacture years for each EURO stage.

Table 7: Vehicle EURO stage and corresponding manufacture years.

EURO Stage	Vehicle Model Year
EURO 1	1992 – 1995
EURO 2	1996 – 1999
EURO 3	2000 – 2004
EURO 4	2005 – 2009
EURO 5	2010 – 2014
EURO 6	2015 – current

4.1.3.2 Results

The emission factors were then applied to the VKT per vehicle class and road type to derive an annual emission estimate per road link for all pollutants of concern. For verification, the VKT and fuel consumption estimates derived from the COPERT model are adjusted to ensure a +/- 10% agreement with petrol and diesel fuel sales determined for each LM ensuring an accurate estimation of emissions in each area. Estimated vehicle emissions for the MDM are detailed in Table 8 below.

Table 8: Estimated vehicle emissions for the MDM (tonnes/annum) for the year 2019.

Area	CO	NO_x	NMVOCs	$PM_{2.5}$	SO_2
Greater Giyani	51	171	3	4	3
Greater Letaba	47	159	3	3	2
Greater Tzaneen	87	295	5	6	4
Ba-Phalaborwa	35	120	2	2	2
Maruleng	20	69	1	1	1
MDM	**240**	**814**	**14**	**16**	**12**

Table 9 compares the vehicle emissions for the 2015 MDM AQMP against the emissions developed for the AQMP review. There is a substantial increase in vehicle emissions of CO and NO_x in the MDM. This could be due to the different methodologies and emission factors applied to each inventory.

Table 9: Changes in the vehicle-related emissions profile (tonnes/annum) in the MDM.

Pollutant	Previous emission inventory (2015)	Updated emission inventory (2019)
CO	14	240
NO_x	10	814
NMVOCs	ND	14
$PM_{2.5}$	ND	16
SO_2	ND	12

4.2 New Emissions Sources added to the Mopani District Municipality Emissions Inventory

4.2.1 Domestic fuel burning emissions

There is growing evidence that domestic fuel burning is potentially one of the greatest sources of air pollution within townships, informal settlements, and rural areas. Coal, wood, and paraffin are widely used for space heating and cooking purposes. Although access to electricity has increased in South Africa, many households are still reliant on fossil fuels for their domestic energy needs. This is due to high electricity tariffs and persistent power outages. Incomplete combustion of fossil fuels such as wood and coal within households can result in the release of particulates and gaseous pollutants that are harmful to human health.

4.2.1.1 Methodology

A top-down approach was used in the estimation of domestic fuel burning (DFB) emissions for the year 2019. This involved the use of national residential fuel consumption volumes and population statistics. The national residential fuel consumption data was obtained from the annual published Department of Mineral Resource and Energy (DMRE) energy balance data which is based on the International Energy Agency (IEA) best practice methodology. The data represented the year 2018, as statistics for 2019 have not yet been collated because of the Covid-19 global pandemic. The DMRE energy balance data for the fuels of interest (gas, paraffin, and coal) is selected based on National

Commodity Flows because of commerce purchases and public services ensuring that industrial consumption of fuels is omitted from the assessment while publicly used fuels are included in the assessment.

Population data used in this assessment included that obtained from the StatSA General Household Survey (2019) which detailed a percentage distribution of main energy sources used for residential fuel burning at the provincial level. This data was used to allocate the national publicly consumed fossil fuels to the provincial level (Limpopo province). Using the StatSA 2016 Community Survey, the provincial proportion of fossil fuel consumption was disaggregated further into fossil fuel consumption per household at the local municipality level. Prior to using the StatSA 2016 Community Survey for fossil fuel disaggregation, an intercensal growth rate was applied to this dataset so as estimate the population in the MDM for the year 2019.

While residential wood combustion is a component of residential fuel burning, this data is not detailed in the DMRE National Commodity Flows Commerce and Public Services (2018). In order to overcome this, literature values are utilised as a substitute with the value of 3 tonnes of wood being assumed to be burned at the household (HH) level. Similarly, the national total of 380 955 (t) for residential bituminous coal combustion is noted to significantly underestimate residential coal combustion at the HH level. Once again, literature values are utilised as a substitute with the value of 2.4 tonnes of coal being assumed to be burned at the household (HH) level.

A comparison of emission factors was done, considering those from the FRIDGE study (Scorgie et al., 2004), the USEPA AP-42 dataset, the GAINS United States and Australia model (Amann et al., 2011), Ballard-Treemer (1997), Britton (1998), Scorgie (2012) and Makonese et al. (2015). Many of the South African studies focused on coal. A hybrid selection from the studies mentioned is considered in this household fuel combustion emissions methodology and is presented in Table 10.

Table 10: Emission factors used for domestic fuel combustion.

Pollutant	LPG		Paraffin		Coal		Wood	
	Factor (g/Kg)	Source	Factor (g/Kg)	Source	Factor (g/Kg)	Source	Factor (g/Kg)	Source
SO_2	0.01	FRIDGE	0.8510	FRIDGE	11.6	Scorgie, 2012	0.123	Ballard-Tremeer, 1997
PM_{10} (a)	0	NA	0	NA	0	Makonese et al., 2015	1.035	AP-42
$PM_{2.5}$	0.068	AP-42	0.359	AP-42	16.146	Makonese et al., 2015	13.745	AP-42
NOx	1.4	FRIDGE	1.5	FRIDGE	3.95	Makonese et al., 2015	1.224	AP-42
VOC	0.018	AP-42	0.085	AP-42	5	FRIDGE	19.867	AP-42
NH_3	0	NA	0	NA	0.0003	AP-42	0	N/A
CO	13.6	FRIDGE	44.9	FRIDGE	94.38	Makonese et al., 2015	114.577	FRIDGE
CH_4	0.012	AP-42	0.213	AP-42	3.6	AP-42	2.177	AP-42

Note: (a) PM_{10} represents only the coarse fraction (i.e., PM with a diameter of 2.5 µm to 10 µm).

4.2.1.2 Results

It is important to understand the type of fossil fuel being burned for which purpose and in which area so as to ensure the development of appropriate air pollution interventions. To this end, household fuel consumption estimates are presented per household to account for the fact that some areas will have higher consumption due purely to a higher number of households. Figure 17 indicates that the Greater Tzaneen local municipality (LM) has the highest residential coal and wood consumption rates. The lowest coal and wood consumption rates occur in the Maruleng LM. Coal is the highest consumed fuel in all municipalities.

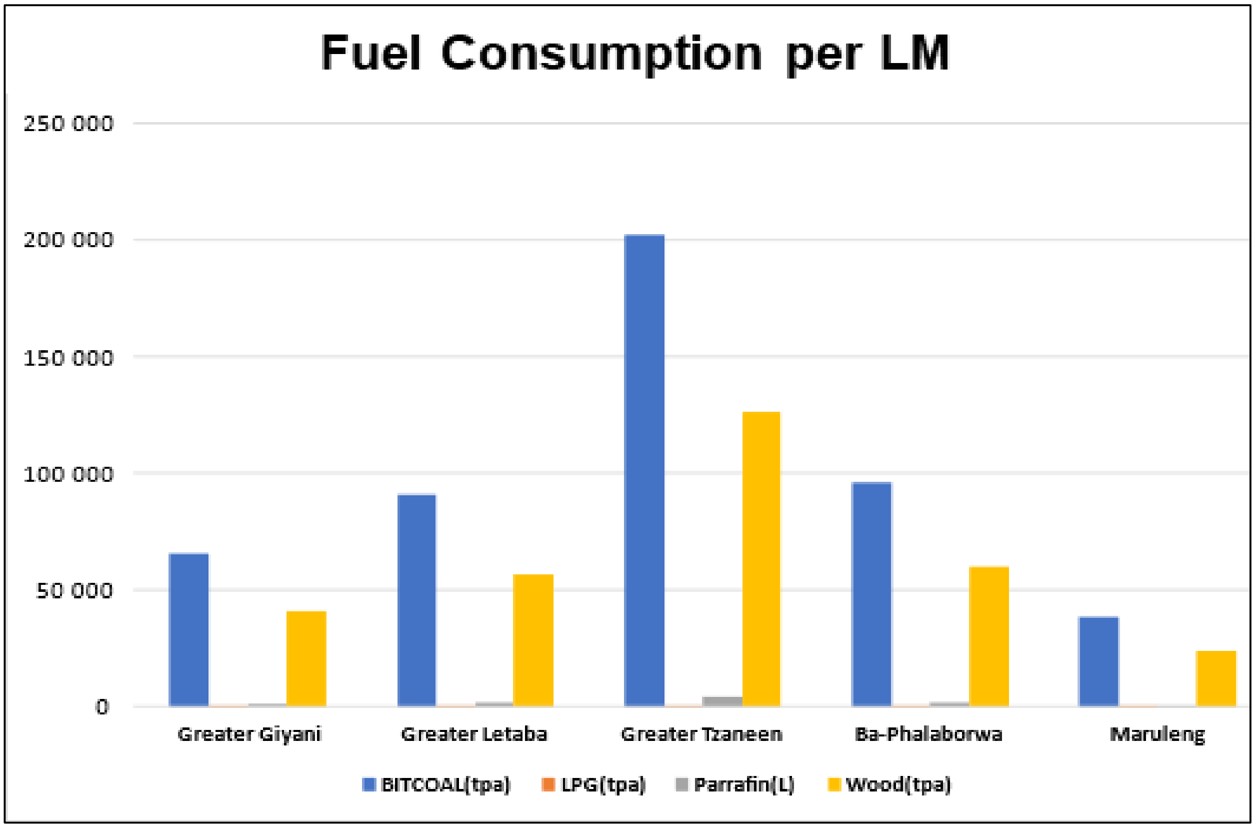


Figure 17: Annual estimated fuel consumption for different fuels used for domestic combustion in the MDM.

Table 11 below provides a breakdown of DFB emissions for the MDM.

Table 11: MDM domestic fuel burning emissions (tonnes/annum) for the year 2019.

Area	SO_2	$PM_{2.5}$	PM_{10}*	NOx	VOC	CO	CH4
Greater Giyani	772	1 634	1 677	313	1 150	11 020	328
Greater Letaba	1 065	2 253	2 312	432	1 586	15 194	452
Greater Tzaneen	2 368	5 012	5 143	961	3 528	33 802	1 006
Ba-Phalaborwa	1 121	2 371	2 433	455	1 669	15 992	476
Maruleng	449	949	974	182	668	6 402	191
Mopani	**5 774**	**12 218**	**12 537**	**2 343**	**8 601**	**82 410**	**2 452**

Note: * Emissions are estimated as the sum of PM_{10} and $PM_{2.5}$

4.2.2 Domestic waste burning emissions

In the absence of municipal waste collection, residents are forced to find means of disposal other than through formal landfills. Disposal can be done either through open burning or the burial of waste. Open burning of waste can impact air quality through the emissions of a range of pollutants. In South Africa, open burning of waste typically occurs in low-income settlements where municipal collection of waste is infrequent and waste generation is high due to the high population density in these areas.

4.2.2.1 Methodology

The approach used to estimate domestic waste burning (DWB) emissions is based on Wiedinmyer et al. (2014), which follows the IPCC methods (IPCC, 2006). Based on Equation 1, the emissions of pollutant i (Ei) are estimated as the product of the emission factor of the waste (EFi) and the amount of waste burned (WB).

$$E_{i} = W_{B} \times EF_{i} \quad \text{Equation 1}$$

where:

Ei	The emissions of pollutant *i (Ei)*
W_B	The amount of waste burned
EF_i	The emission factor of the waste

The generalized equation to estimate waste burned is shown in Equation 4-2.

$$W_{B} = P \; x \; P_{frac} \; x \; MSW_{P} \; x \; B_{frac} \quad \text{Equation 2}$$

where:

P	Population
P frac	The fraction of the population accounts whose waste is not collected i.e. assumed to burn their waste
MSW P	The mass of annual per capita waste production
B frac	The fraction that is available to be burned that is actually burned

For this methodology, local data on waste per person and composition are used i.e., waste generated per person per capita. This information is taken from the 2018 Sasol Waste Collection Interventions (WCI) study (Mamadi & Co., 2018) noted in which waste generated per capita is estimated to be 0.612 tonne/person/annum, and this waste generated per capita is then assumed to be representative of the whole MDM. According to Equation 2, not all waste is combustible. For example, glass and metals will not readily burn thus a burn fraction is required. The IPCC recommended fraction of 0.6 is used i.e., 60% of the waste generated by people that do not receive removal services is burned. Population is another variable required to estimate the amount of waste burned. The StatSA 2016 Community Survey data was used and an intercensal growth rate was applied to estimate the population in the MDM for the year 2019. The StatSA 2016 Community Survey data was also used to determine the number of people not receiving waste services. By multiplying the waste generated per capita by the number of people not receiving waste services, an estimate of the amount of waste generated (that may likely be burned) is calculated.

Equation 1 also requires the use of emission factors. The most recent compilation of waste emission factors in a South African context is detailed in the Sasol South Africa Emission Factors for Criteria Pollutants from Solid Waste Material Combustion Report (Mamadi & Co., 2018). The report identifies several categories of materials that are common in waste burned in South African townships. Figure 18 below illustrates a weight distribution for the composition of waste materials collected by SASOL's WCI program. The major waste components of the program were: paper, leather/rubber, textile, plastic bottles and bags, ceramic, metal, and glass.

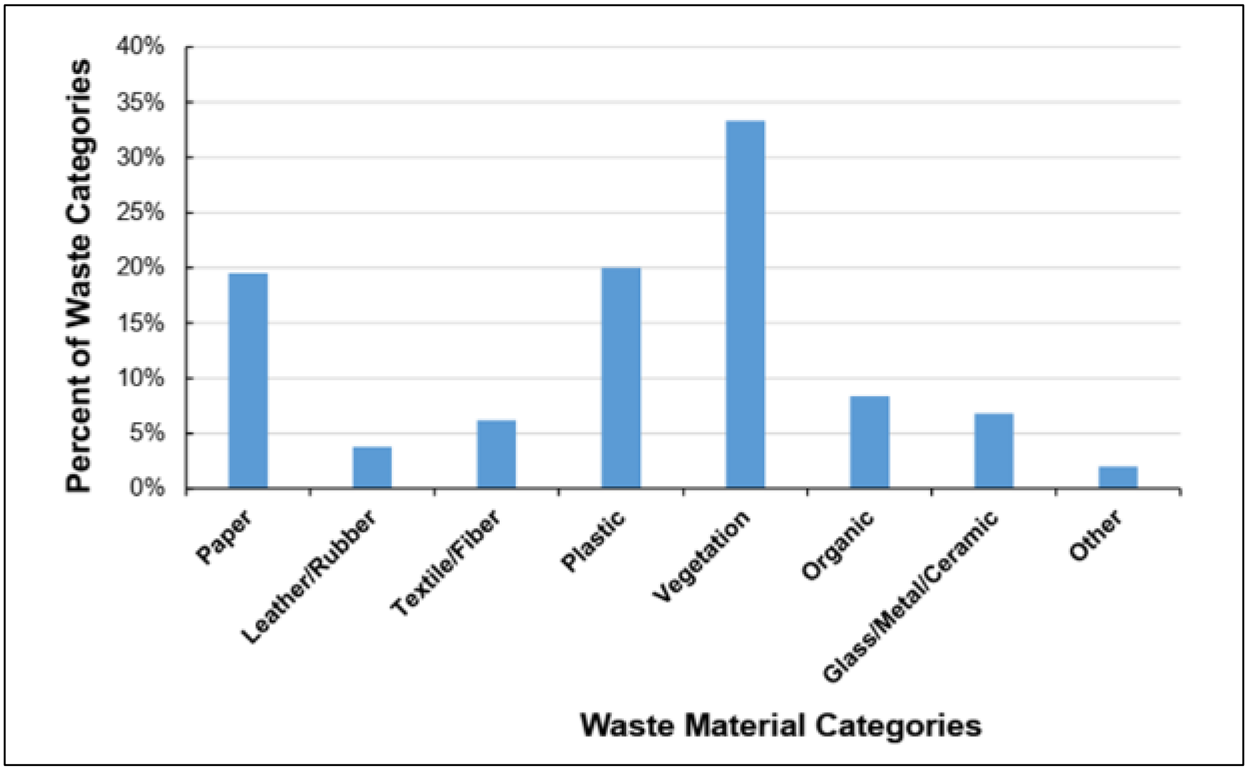


Figure 18: Weight fraction of municipal solid waste categories collected by SASOL. (Data provided by Mr. Warren Carter, Sasol Technology).

Table 12 summarizes the emission factors used for estimating waste burning emissions for different pollutants.

Table 12: South Africa-specific waste burning emission factors.

Pollutant Emission Factors (g/kg fuel)				
CO	NO_x (as NO_2)	SO_2	$PM_{2.5}$	PM_{10}
31.6	2.41	0.95	6.86	7.26

4.2.2.2 Results

Figure 19 below provides a breakdown of domestic waste burning emissions at the local municipality level in the MDM. The highest levels of domestic waste burning emissions occur in the Greater Tzaneen LM with Ba-Phalaborwa LM experiencing the lowest emissions.

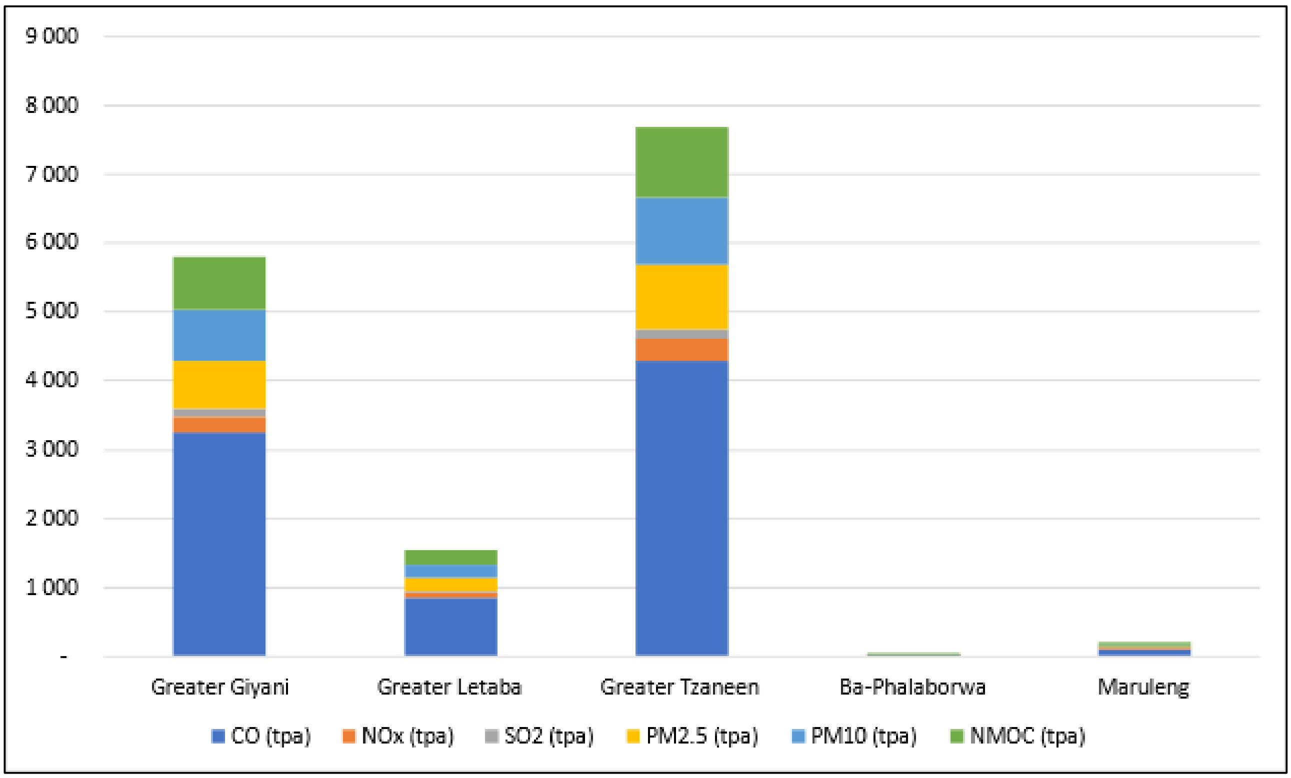


Figure 19: MDM domestic waste burning emissions at the local municipality level.

Table 13 below shows the pollutant emissions due to domestic waste burning for the MDM as a whole.

Table 13: MDM Residential Waste Burning Emissions (tonnes/annum) for the year 2019.

Area	CO_2	CO	NO_x (as NO_2)	SO_2	$PM_{2.5}$	PM_{10}
Greater Giyani	145 331	3 241	247	97	704	745
Greater Letaba	38 415	857	65	26	186	197
Greater Tzaneen	192 302	4 288	327	129	931	985
Ba-Phalaborwa	607	14	1	0	3	3
Maruleng	4 968	111	8	3	24	25
MDM	**381 622**	**8 510**	**649**	**256**	**1 848**	**1 955**

4.2.3 Windblown particulate emissions

The prevailing dry climatic conditions in the urban and peri-urban areas of South Africa make windblown dust a potential nuisance. Windblown dust can be a road traffic safety concern as these particles obscure visibility for vehicles. The high particulate concentrations emanating from dust emissions can have substantial effects on the quality of air breathed and in turn human health. The sources of windblown particulates include exposed topsoil areas. activities on construction sites, vehicle entrainment on unpaved roads, mining and quarry activities especially haul roads and wind entrainment from mine tailings storage facilities (TSF).

4.2.3.1 Methodology

A global gridded dust emissions dataset (http://rain.ucis.dal.ca/ctm/HEMCO/OFFLINE_DUST/v2021-08/0.25x0.3125/) developed at the Atmospheric Composition Analysis Group, Washington University in St. Louis, USA was used to provide dust emission estimates, for the year 2019, for the Mopani region. Dust emissions were generated in the GEOS-Chem model using the dust entrainment and deposition (DEAD) scheme. This dust scheme employs a source function together with information on soil moisture, vegetation, and land use to calculate hourly emissions using the offline Harmonized Emissions Component (HEMCO) module. These emissions were simulated in four PM size bins (0.1–1.0, 1.0–1.8, 1.8–3.0, and 3.0–6.0 µm).

The dust emissions dataset (0.25° x 0.3125° grid resolution) was downloaded for the year 2019. The 0.1–1.0, 1.0–1.8, and 1.8–3.0 µm size bins were selected for this dataset and combined together as they are a closer representation of fine ($PM_{2.5}$) dust emissions. This dataset was then spatially disaggregated onto a 0.05° x 0.0625° grid using a non-interpolating technique that involves assigning a fractional value (based on a fraction of the area) within each domain's grid cell. This form of spatial disaggregation is mass-consistent between the original dust dataset (0.25° x 0.3125°) and the resulting downscaled estimated emissions (0.05° x 0.0625°).

4.2.3.2 Results

Figure 20 shows the estimated total annual fine PM emissions for windblown dust in the MDM. Accordingly, Table 14 shows the total tonnage for fine PM dust emitted in the MDM region.

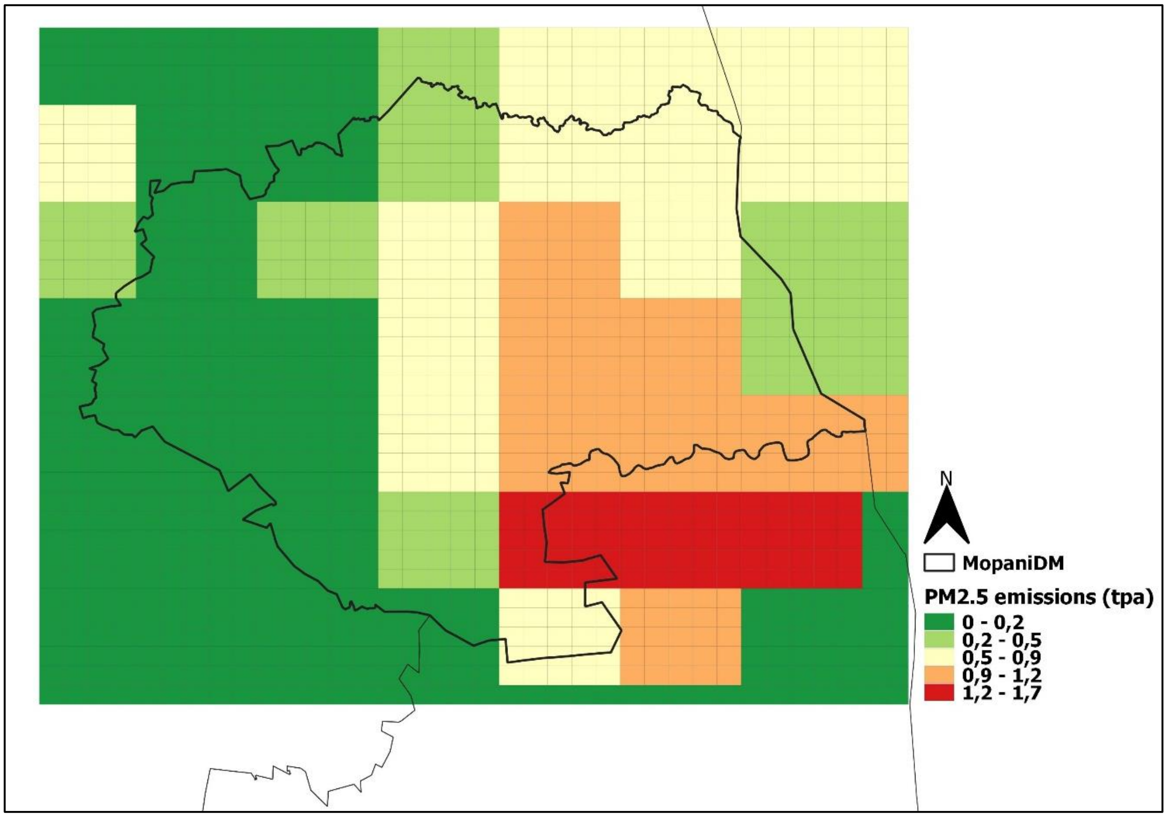


Figure 20: Total annual $PM_{2.5}$ windblown dust emissions over the MDM region for the year 2019.

Table 14: Estimated $PM_{2.5}$ dust annual tonnage emitted in the MDM for the year 2019.

Area	$PM_{2.5}$[b] emissions (tpa)
Ba-Phalaborwa	185
Greater Giyani	77
Greater Letaba	10
Greater Tzaneen	6
Maruleng	48
MDM	**326**

Note: [(b)] $PM_{2.5}$ is represented by PM with a diameter of 0.1 µm to 3 µm

4.2.4 Biogenic VOC emissions

Non-methane volatile organic compounds (VOCs) can be released through anthropogenic activities as well as naturally through biochemical processes in soils, oceans, and vegetation. On a global scale, up to 90% of total VOC emissions are derived from biogenic sources. Isoprene is the most abundant species among the biogenic VOCs. These species react chemically with NOx to form tropospheric ozone (photochemical smog) (Sindelarova et al., 2014). Biogenic VOCs are also a major source of secondary organic aerosols.

4.2.4.1 Methodology

The Copernicus Atmosphere Monitoring Service (CAMS) global emissions dataset (https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-global-emission-inventories?tab=form) was used to provide biogenic VOC emission estimates, for the year 2019, for the MDM. These emissions were simulated using the Model of Emissions of Gases and Aerosols from Nature (MEGAN). The inputs for MEGAN include the leaf area index (LAI), plant functional type (PFT), emission factors, and meteorological data. The PFT type and LAI were obtained from remote sensing databases. The meteorological variables were obtained from observations, reanalysis data, and weather forecasting models.

The CAMS dataset (0.25° x 0.25° grid resolution) was downloaded for the year 2019. This dataset was then spatially disaggregated onto a 0.05° x 0.05° grid using a non-interpolating technique that involves assigning a fractional value (based on a fraction of the area) within each domain’s grid cell. This form of spatial disaggregation is mass-consistent between the original CAMS dataset (0.25° x 0.25°) and the resulting downscaled estimated emissions (0.05° x 0.05°).

4.2.4.2 Results

Figure 21 shows the CAMS estimated total annual isoprene emissions for the MDM. Accordingly, Table 15 shows the total tonnage for the biogenic VOC species within the MDM region.

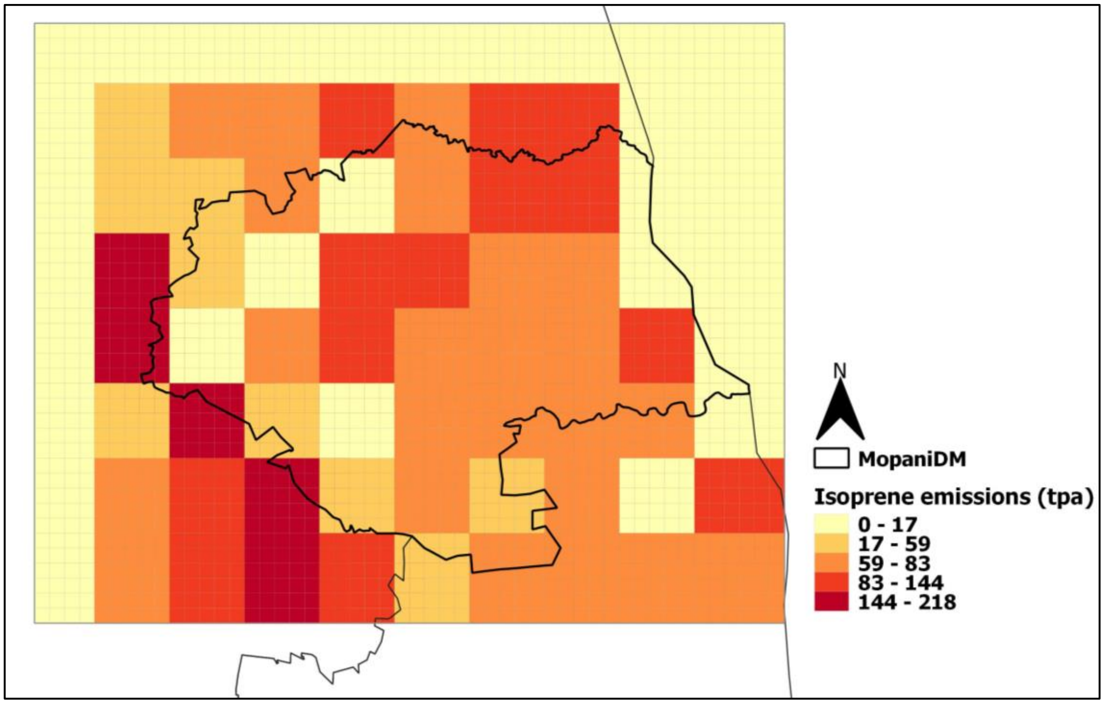


Figure 21: Total annual CAMS biogenic VOC (isoprene) emissions over the MDM region for the year 2019.

Table 15: CAMS estimated biogenic VOC annual tonnage in the MDM for the year 2019.

Species	VOC emissions (tpa)
Alpha-pinene	10 620
Beta-pinene	4 394
Ethane	109
Ethene	8 925
Isoprene	58 071
Total	82 119

4.2.5 Biomass burning emissions

Biomass burning over southern Africa is a significant source of gaseous and particulate emissions. Annually, biomass burning is estimated to contribute about 62% of the global particulate organic carbon (OC) and 27% of black carbon (BC) emissions. These PM emissions can reduce visibility and cause health problems. Biomass burning emissions can alter air quality locally, regionally, and globally i.e. NMVOC and NO_x emissions in fire plumes can react downwind of the fire location and contribute to Ozone formation. Biomass burning also has significant impacts on the climate system by modifying solar radiation and cloud properties (Pan et al., 2020). Large-scale agricultural burning and natural fires are major sources of biomass burning in southern Africa.

Due to the spatiotemporal dynamics of landscape fires, remote sensing techniques are used to estimate biomass burning emissions over large spatial scales (Nguyen, 2020). Remotely observed active fire counts, fire radiative power, and burned area are multiplied with landcover-specific emissions to develop global biomass burning emissions datasets.

4.2.5.1 Methodology

Biomass burning emissions from large-scale agricultural burning and natural fires for the year 2019 were obtained from the Fire Inventory from NCAR version 1.5 (FINN) emission dataset (https://www.acom.ucar.edu/Data/fire/). This dataset utilises active fire count observations, landcover cover from MODIS sensors, and estimated fuel consumption to quantify biomass burning emissions. Active fire counts are carried out at 0.75 km^2 pixels for grasslands and savannas and 1 km^2 pixels for other landcover types. Fuel consumption at each active fire pixel is estimated according to the global wildland fire emission model in which a specific value is assigned according to the landcover type at each fire pixel. The daily global open biomass burning emissions at each active fire pixel are then calculated at a 1 km spatial resolution by multiplying the estimated fuel consumed with the burned area and emission factor of each species.

Corrections were made to the FINN data by first identifying fires that were apportioned incorrectly to surface coal mines and large hot/reflective rooftops and removing these fires through a masking procedure.

4.2.5.2 Results

FINN data was obtained for the year 2019 and processed following the described methodology. Table 16 depicts the annual tonnage emissions from biomass burning within the MDM. Figure 22 shows the annual FINN PM_{10} estimates gridded into the 1 km model grid (gridded for display purposes).

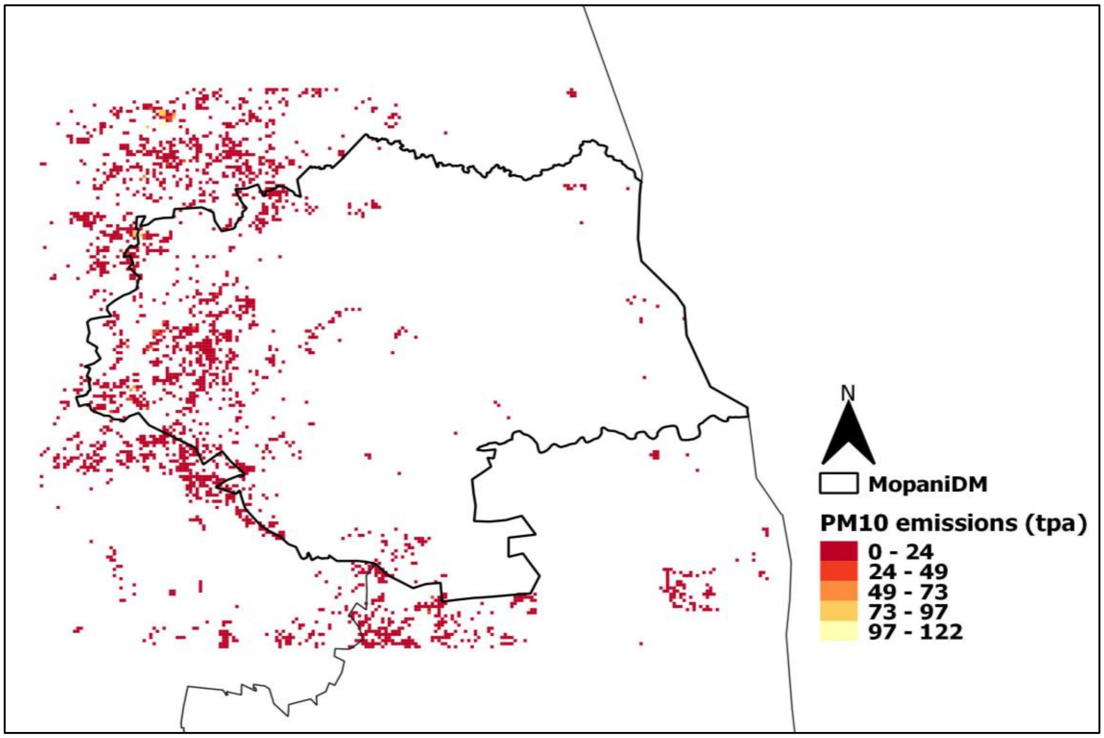


Figure 22: Map showing gridded (to 1km resolution) FINN estimated PM_{10} emissions from biomass burning (total tonnes per annum per cell) for the year 2019.

When considering Figure 22 it is evident that a large majority of the biomass burning events occur in the eastern region of the MDM with a significant number of burning events noted in the Greater Tzaneen and Greater Letaba Local Municipalities.

Table 16: FINN estimated annual emissions from biomass burning (tonnes/annum) in the MDM for the year 2019.

Area	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NH_3
Ba-Phalaborwa	78	74	141	40	2 366	391
Greater Giyani	284	261	485	134	8 239	1 451
Greater Letaba	2 996	2 304	2 517	365	69 949	20 234
Greater Tzaneen	3 067	2 722	3 591	497	81 153	23 824
Maruleng	206	190	344	99	6 346	1 260
MDM	**6 630**	**5 552**	**7 079**	**1 135**	**168 053**	**47 160**

4.2.6 Agricultural ammonia emissions

Ammonia (NH_3) is a highly reactive nitrogen (N) compound in the atmosphere that has impacts on atmospheric chemistry and the environment (Moran et.al., 2016). By reacting with sulphur and nitrogen oxides to form ammonium salts, ammonia is considered a secondary particulate matter precursor (Hou & Yu, 2020). Agriculture is a major source of ammonia through the rapid hydrolysis of urea excreted from livestock and urea from fertilisers. Ammonia production industries and biogenic (soil) are also important sources. The relative contribution of each source will depend on the area of concern.

4.2.6.1 Methodology

The Copernicus Atmosphere Monitoring Service (CAMS) global emissions dataset (https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-global-emission-inventories?tab=form) was used to provide NH_3 emission estimates from agriculture (livestock (animal excreta), soils (fertiliser application) and agricultural waste burning), for the year 2019, for the MDM. This dataset is based on different existing data sets e.g., nationally reported emissions from EDGAR (0.1° x 0.1°) and CEDS (0.5° x 0.5°). Trends for CEDS are disaggregated to the same grid resolution as EDGAR and the sectors for both datasets are then merged and aligned.

The CAMS dataset (0.1° x 0.1° grid resolution) for 2019 was downloaded, then spatially disaggregated onto a 0.05° x 0.05° grid using a non-interpolating technique that involves assigning a fractional value (based on a fraction of the area) within each domain's grid cell. This form of spatial disaggregation does not use interpolation and is thus mass consistent between the original CAMS dataset and the resulting domain emissions estimated here.

4.2.6.2 Results

Figure 23 below shows the CAMS estimated total annual NH_3 emissions from agriculture for the MDM while Table 17 details the total tonnage in the MDM region

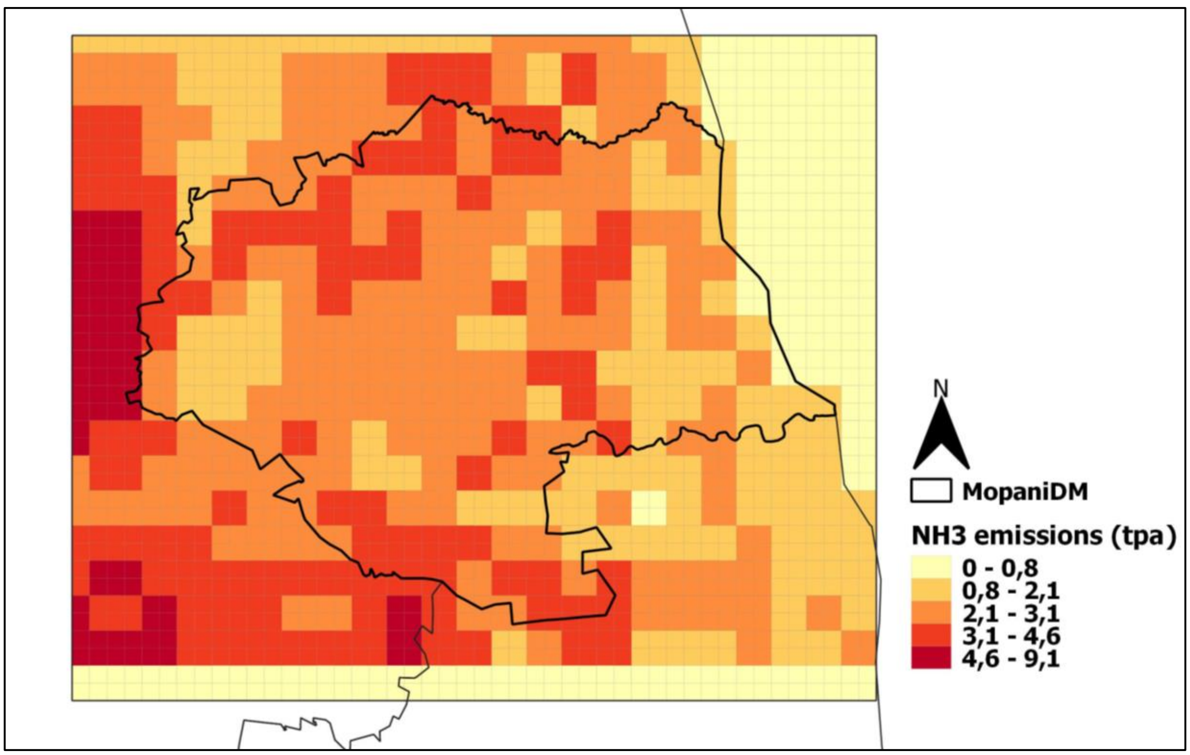


Figure 23: Total annual CAMS NH_3 emissions from agriculture over the MDM for the year 2019.

Table 17: CAMS estimated NH_3 annual emissions from agriculture (tonnes/annum) in the MDM for the year 2019.

Area	NH_3
Ba-Phalaborwa	607
Greater Giyani	403
Greater Letaba	193
Greater Tzaneen	277
Maruleng	334
MDM	**1814**

4.2.7 Wastewater treatment emissions

Wastewater treatment facilities are most commonly associated with odour emissions, which can result in annoyance and consequently have a detrimental effect on the local population. These emissions are highly dependent on the type of treatment units, the temperature of wastewater, liquid density, and concentrations of the various compounds in the liquid waste. Typical species associated with wastewater treatment emissions include methane (CH_4), non-methane VOCs; and odorous compounds such as hydrogen sulphide (H_2S), mercaptans, ammonia, and various fatty acids (butyric, propionic, valeric and acetic). Eleven wastewater treatment facilities are operating in the MDM.

4.2.7.1 Methodology

The Emissions Database for Global Atmospheric Research (EDGAR v7.0) global GHG emissions dataset jointly developed by the Joint Research Centre (JRC) and International Energy Agency (IEA), (Olivier *et al.*, 2021) was used to provide emission estimates from wastewater water treatment facilities. This dataset provides wastewater treatment emissions for CH_4 which is generated using activity data obtained from international statistics and default emission factors adopted from the IPCC Guidelines for National Greenhouse Gas Inventories.

The EDGAR version 7.0 dataset (0.1° x 0.1° grid resolution) for 2019 was downloaded (https://edgar.jrc.ec.europa.eu/dataset_ghg70), then spatially disaggregated onto a 0.001° x 0.001° grid using a non-interpolating technique that involves assigning a fractional value (based on a fraction of the area) within each domain's grid cell. This form of spatial disaggregation does not use interpolation and is thus mass consistent between the original EDGAR dataset and the resulting domain emissions estimated here. The location and shape of the wastewater treatment facilities were obtained using google earth satellite imagery and the HydroWASTE database (https://www.hydrosheds.org/products/hydrowaste#downloads) for wastewater treatment facilities that was developed by Macedo et al. (2022). This GIS shapefile data was then used to extract the emissions from each wastewater treatment facility.

4.2.7.2 Results

Table 18 below provides the annual tonnage emissions from wastewater treatment facilities within the MDM.

Table 18: CAMS estimated annual emissions from wastewater treatment facilities (tonnes/annum) in the MDM for the year 2019.

Area	No. of facilities	CH_4
Ba-Phalaborwa	4	893
Greater Giyani	1	2 011
Greater Letaba	1	1 431
Greater Tzaneen	3	2 329
Maruleng	2	753
MDM	**11**	**7 417**

4.2.8 Landfill emissions

The disposing of waste at landfill sites can have potentially negative effects on the environment in various ways, including emissions into the atmosphere. These emissions can cause odour nuisance and have potential health impacts. Landfill emissions are primarily greenhouse gases consisting of CO_2 and CH_4 and small amounts of odorous compounds that include H_2S. These gases are emitted as a result of waste decomposition. The concentrations of gases emitted from landfills depend on the composition, storage and handling of the waste as well as mitigation measures implemented by the landfill to manage these emissions. Currently, there are four municipal landfill sites in operation in the MDM

4.2.8.1 Methodology

The Emissions Database for Global Atmospheric Research (EDGAR v7.0) global GHG emissions dataset jointly developed by the Joint Research Centre (JRC) and International Energy Agency (IEA), (Olivier et al., 2021) was used to provide emission estimates from landfills. This dataset provides landfill emissions for CH_4 which is generated using activity data obtained from international statistics and default emission factors obtained adopted from the IPCC Guidelines for National Greenhouse Gas Inventories.

The EDGAR version 7.0 dataset (0.1° x 0.1° grid resolution) for 2019 was downloaded (https://edgar.jrc.ec.europa.eu/dataset_ghg70), then spatially disaggregated onto a 0.001° x 0.001° grid using a non-interpolating technique that involves assigning a fractional value (based on a fraction of the area) within each domain's grid cell. This form of spatial disaggregation does not use interpolation and is thus mass consistent between the original EDGAR dataset and the resulting domain emissions estimated here. The location and shape of the landfill sites were obtained using google earth satellite imagery. This GIS shapefile data was then used to extract the emissions from each landfill site.

4.2.8.2 Results

Table 19 below provides the annual tonnage emissions from wastewater treatment facilities within the MDM.

Table 19: CAMS estimated annual emissions from the landfill sites (tonnes/annum) in the MDM for the year 2019.

Area	No. of sites	CH_4
Ba-Phalaborwa	1	1 443
Greater Giyani	1	2 330
Greater Letaba	-	-
Greater Tzaneen	1	3 265
Maruleng	1	892
MDM	**4**	**7 930**

4.3 Synopsis of the updated emissions inventory for the Mopani District Municipality

Table 20 below provides a summary of the updated emissions for industry, mining and transport as well as the newly quantified emissions in the MDM for the year 2019.

Table 20: Emission Inventory summary for all sources within the MDM (tonnes/annum) for the year 2019

Emission Source	CO	NO_x	NMVOC	SO_2	$PM_{2.5}$	PM_{10}	NH_3	CH_4
On Road Vehicles	240	814	14	12	16	-	-	-
Domestic Waste Burning	8 510	649	-	256	1 848	1 955	-	-
Domestic Fuel Burning	83 238	2 367	8 687	5 832	-	12 663[a]	-	-
Wind Blown Dust	-	-	-	-	326[b]	-	-	-
Biomass Burning	168 053	1 135	-	7 079	5 552	6 630	47 160	-
Industry	593	1 143	2 036	713	1 664	2 919	-	-
Mining	-	-	-	-	125	758	-	-
Biogenic VOC	-	-	82 119	-	-	-	-	-
Agricultural Ammonia	-	-	-	-	-	-	1 814	-
Wastewater treatment	-	-	-	-	-	-	-	7 417
Landfills	-	-	-	-	-	-	-	7 930
Total	**260 634**	**6 108**	**92 856**	**13 892**	**9 184**	**12 262**	**48 974**	**15 347**

Note: (a) Emissions are estimated as the sum of PM_{10} and $PM_{2.5}$

: (b) Emissions are estimated as $PM_{1.8\text{–}3}$

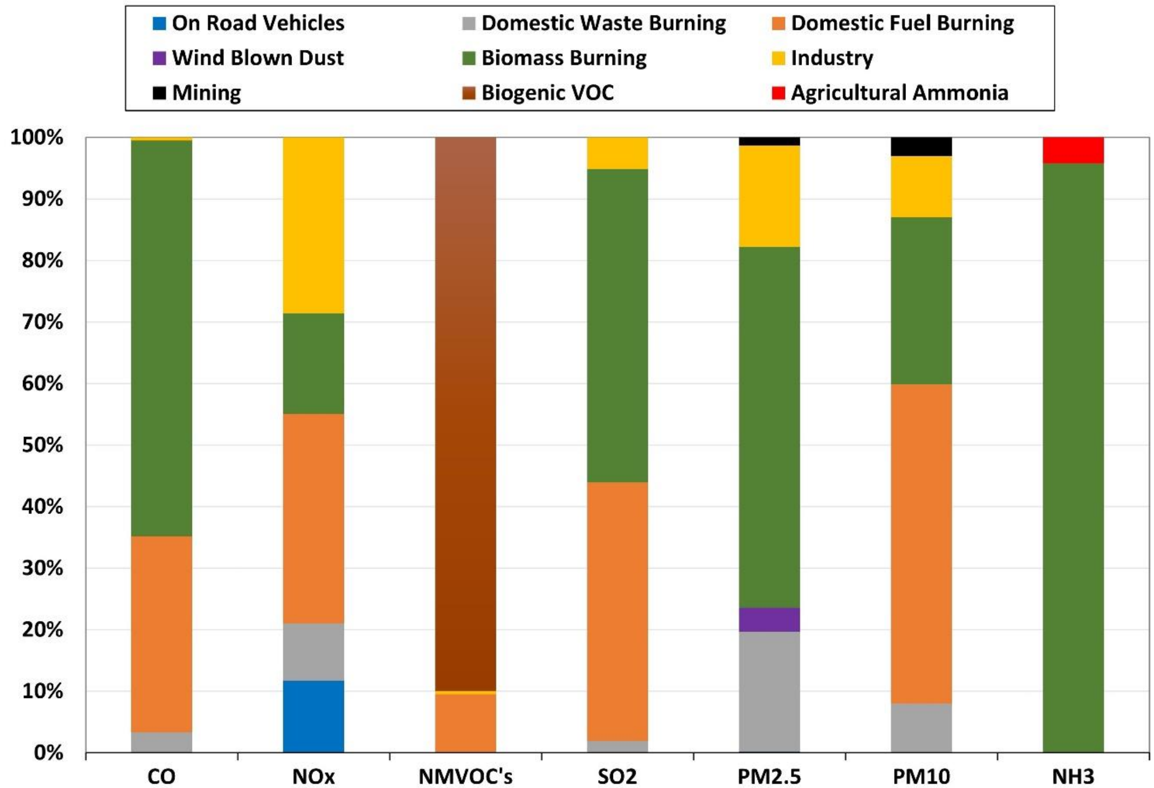


Figure 24: Emission Inventory summary for all sources within the MDM.

Figure 24 graphically summarises Table 20. It is evident that biomass burning is the largest contributor of CO, SO_2, PM_{10}, $PM_{2.5}$ and NH_3 in the MDM, accounting for approximately, 64% of CO, 32% of SO_2, 35% of $PM_{2.5}$ and 96% of NH_3. Biomass burning is also an important contributor to PM_{10} emissions in the MDM. Residential fuel burning activities are the largest contributors to NOx and PM_{10} emissions in the MDM, accounting for 36% of NOx and 33% of $PM_{2.5}$. Residential burning activities are also an important source of CO and SO_2 emissions in the MDM. Residential waste burning activities and industries are important contributors to $PM_{2.5}$ emissions. Industries are also an important source of NOx emissions in the MDM. Overall, industries, residential fuel burning, and biomass burning are the key contributing sources to air pollutant emissions in the MDM.

5 DISPERSION MODELLING

Atmospheric dispersion modelling is an important process in air quality management as it is used to assess compliance to NAAQS on a larger spatial scale than what can be provided with monitoring stations. Areas of elevated concentrations in relation to sensitive receptors can be identified for expanded monitoring and health impact assessments. No atmospheric dispersion modelling was performed during the development of the 2015 MDM AQMP. For this review, atmospheric dispersion modelling was carried out for the MDM The goal of atmospheric dispersion modelling within the context of the AQMP review was to model the dispersion of emission sources (that were quantified for the year 2019) in the MDM to the extent that the interventions for the 2015 MDM AQMP can be realigned.

5.1 Approach

CALPUFF was utilised for the atmospheric dispersion modelling. CALPUFF is a non-steady state Lagrangian puff dispersion model. CALPUFF is a US-EPA recommended dispersion model and is recommended as a Level 3 assessment model in terms of the South African Modelling regulations. CALPUFF can simulate emissions at downwind distances ranging from tens of meters to 300km for multiple emission sources.

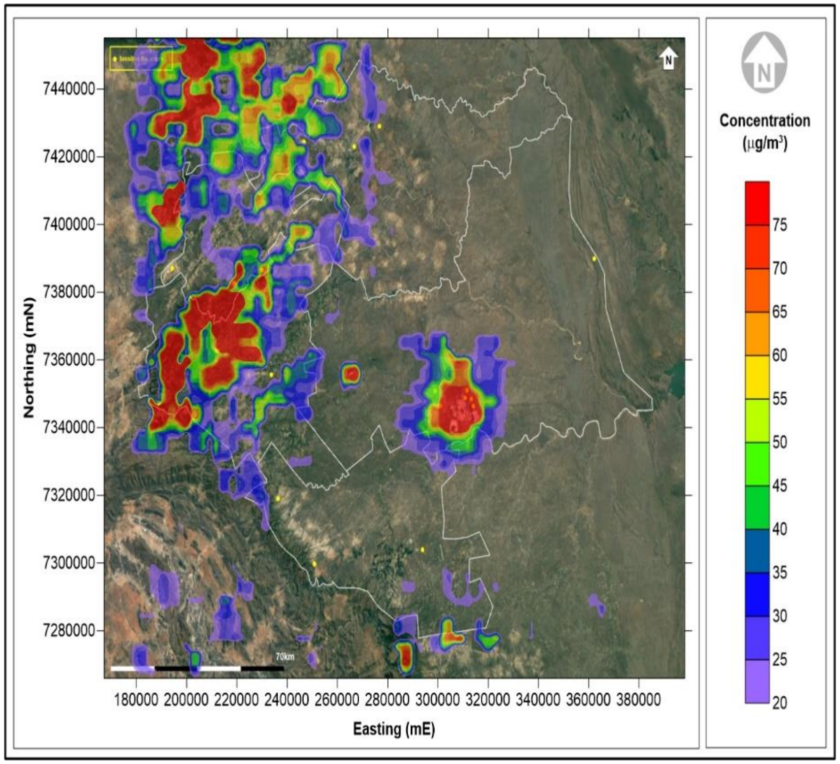
CALPUFF requires detailed and comprehensive 3D meteorological input data. The 3D meteorological data for utilisation in CALMET (a meteorological pre-processor for CALPUFF) was generated with a meteorological prognostic model TAPM. TAPM output was utilised in CALMET to generate the detailed meteorological input data required by CALPUFF.

5.2 Simulated outputs

Dispersion modelling simulations of PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO were undertaken for industries, mining, domestic fuel burning, domestic waste burning, vehicle exhaust, windblown dust and biomass burning emission sources. A simulation of the cumulative impacts of all the emissions sources combined within the MDM airshed was also conducted.

Dispersion maps have been generated for the MDM and are presented in Figures 25 to 30. These maps are indicative of the cumulative impacts of all the emissions sources combined within the MDM airshed. Exceedances were simulated for PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO as indicated by the red isopleths in the figures below. Dispersion maps for individual emission sectors are presented in Appendix A.

PM$_{10}$ (µg/m³) - 24-hour averaging period – 99th percentile



PM$_{10}$ (µg/m³) - annual averaging period

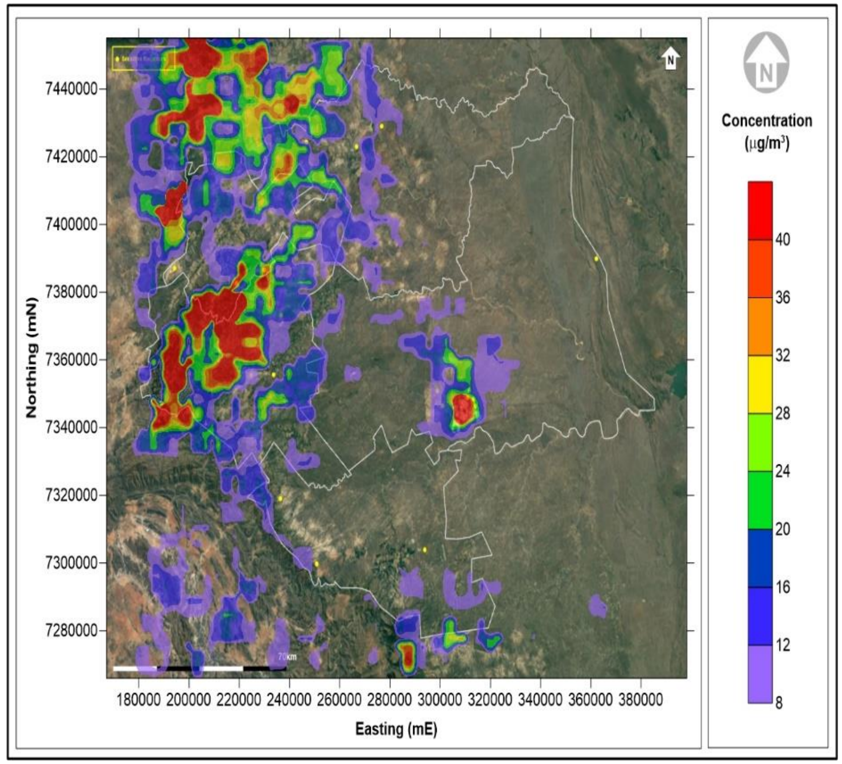
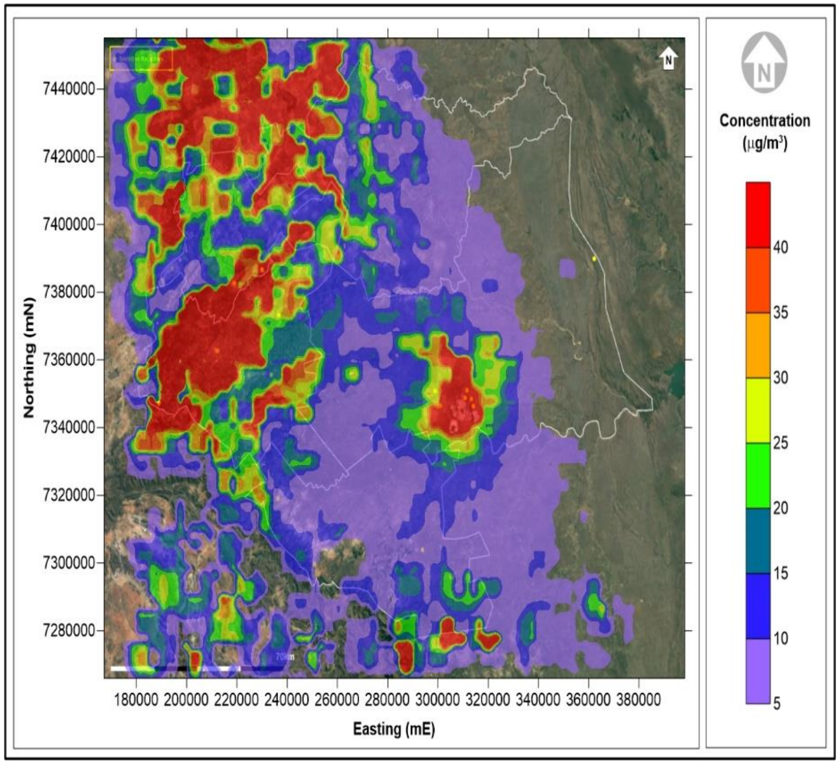


Figure 25: Simulated results for the cumulative emission sources within the MDM (PM$_{10}$ - µg/m³). The red isopleths indicate exceedance regions of the NAAQS.

$PM_{2.5}$ (µg/m³) - 24-hour averaging period – 99th percentile



$PM_{2.5}$ (µg/m³) - annual averaging period

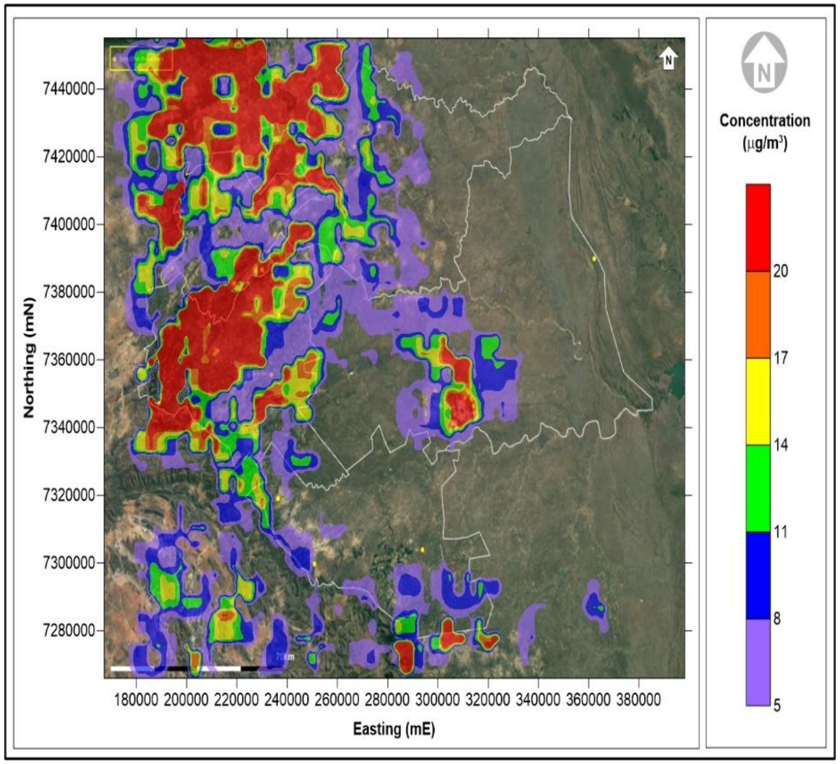
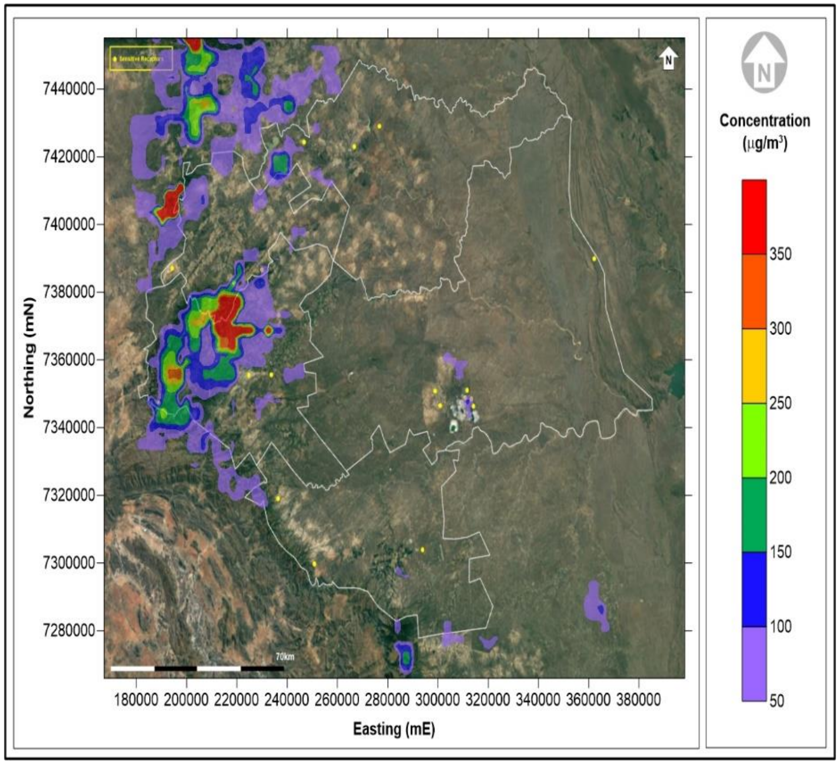


Figure 26: Simulated results for the cumulative emission sources within the MDM ($PM_{2.5}$ - µg/m³). The red isopleths indicate exceedance regions of the NAAQS.

SO_2 (µg/m³) - 1-hour averaging period – 99th percentile



SO_2 (µg/m³) - 24-hour averaging period – 99th percentile

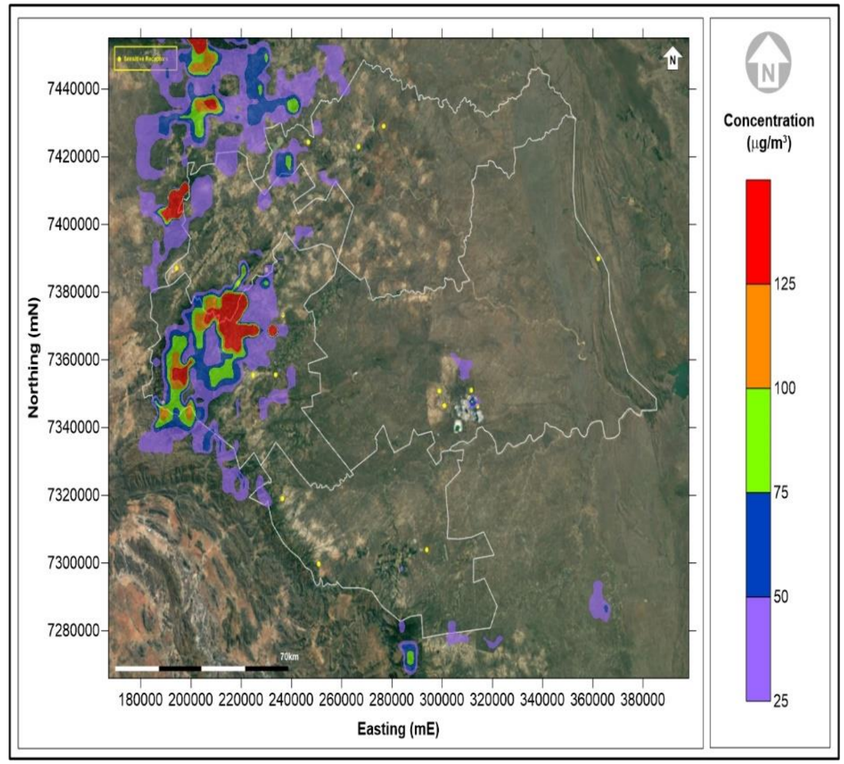


Figure 27: Simulated results for the cumulative emission sources within the MDM (SO_2 - µg/m³). The red isopleths indicate exceedance regions of the NAAQS.

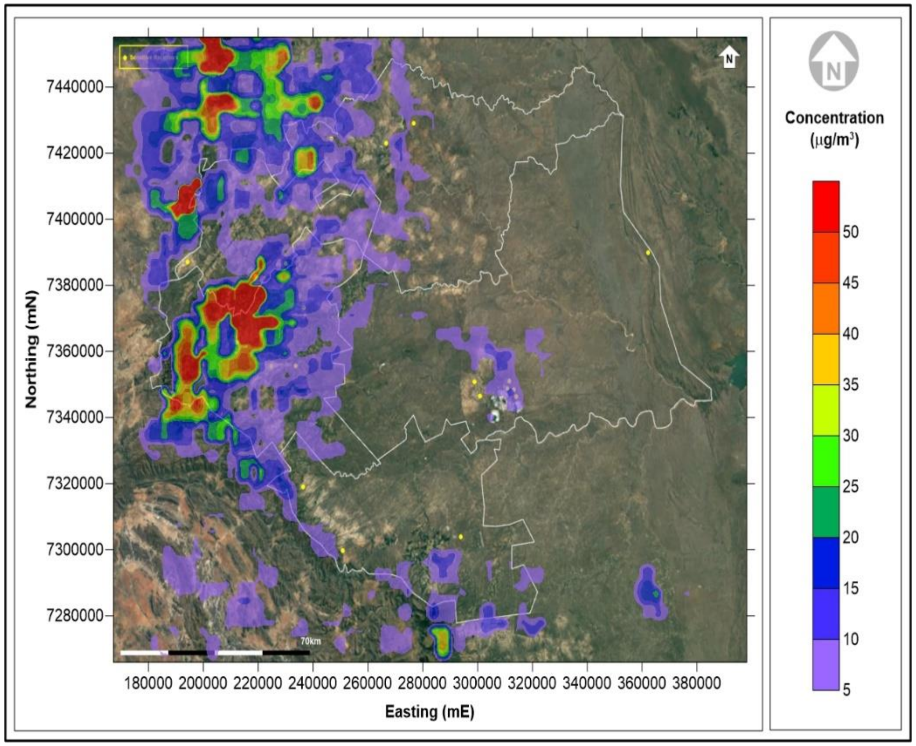
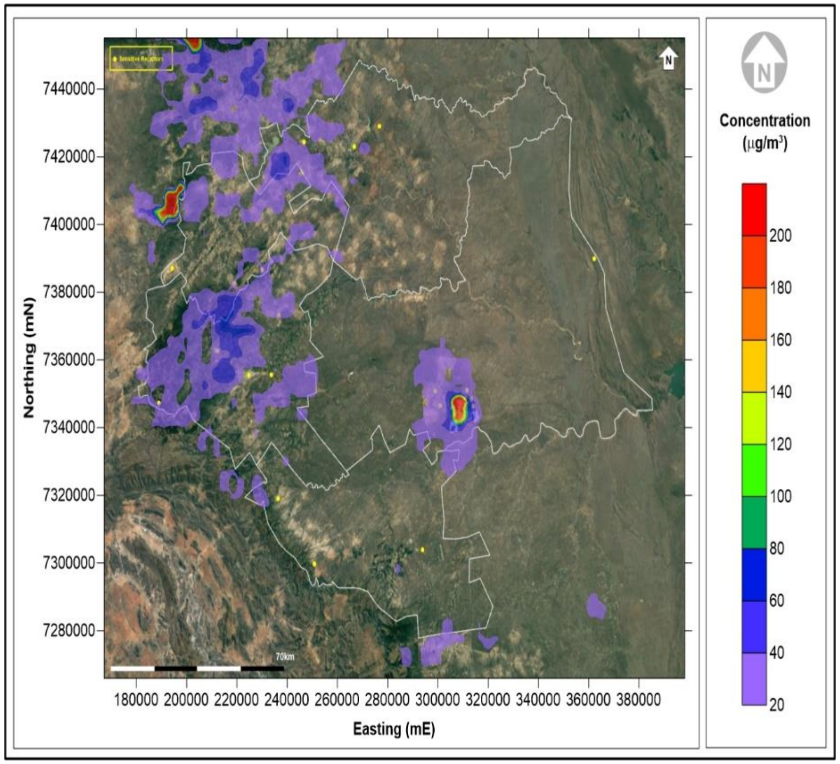
SO$_2$ (µg/m³) - annual averaging period	
	

Figure 28: Simulated results for the cumulative emission sources within the MDM (SO$_2$ - µg/m³). The red isopleths indicate exceedance regions of the NAAQS.

NO_2 (µg/m³) - 1-hour averaging period – 99th percentile



NO_2 (µg/m³) - annual averaging period

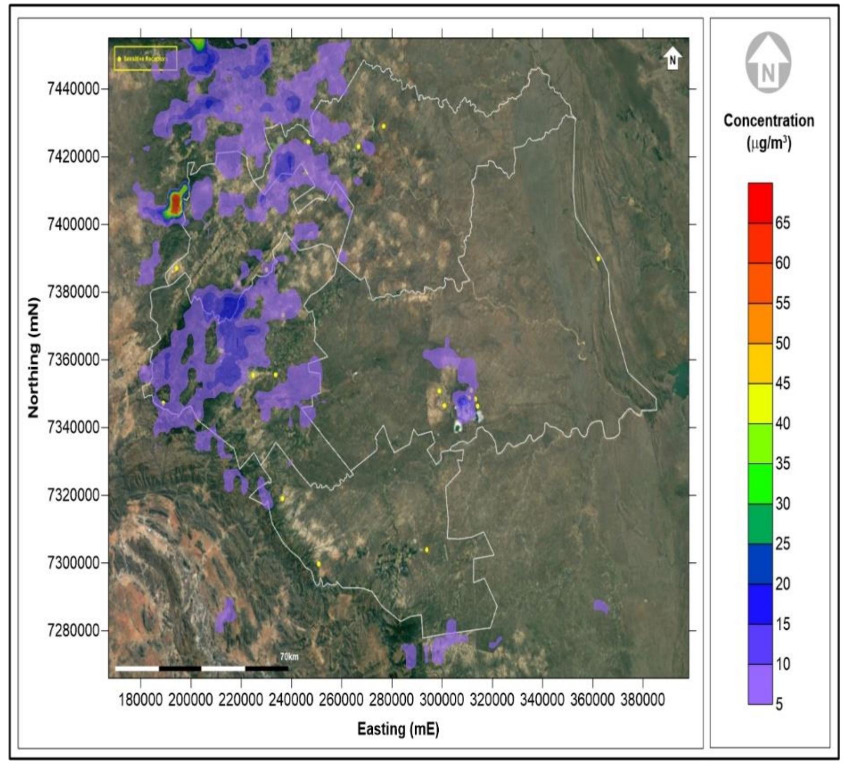


Figure 29: Simulated results for the cumulative emission sources within the MDM (NO_2 - µg/m³). The red isopleths indicate exceedance regions of the NAAQS.

CO (µg/m³) - 1-hour averaging period – 99th percentile | **CO (µg/m³) - 8-hour averaging period – 99th percentile**

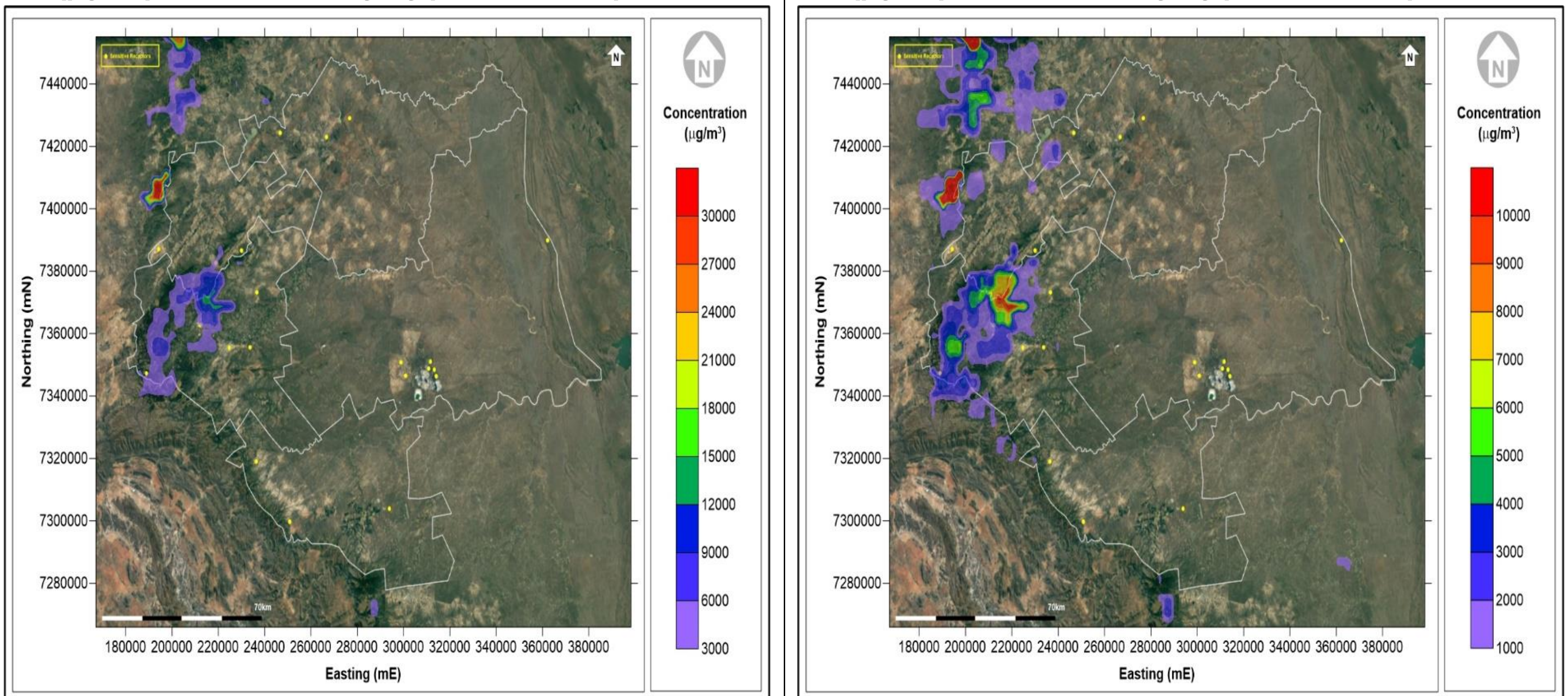


Figure 30: Simulated results for the cumulative emission sources within the MDM (CO - µg/m³). The red isopleths indicate exceedance regions of the NAAQS.

5.3 Summary of findings

The main findings from the dispersion modelling exercise were:

- Annual SO_2, PM_{10}, and $PM_{2.5}$ exceedances occur in the western section of the Greater Tzaneen LM and the northern corner of the Greater Letaba LM. The exceedances are mainly from biomass burning activities. Predicted NO_2 concentrations from biomass burning emissions were well within the NAAQS.
- Domestic fuel burning activities are also an important source in the MDM as they contribute significantly to annual $PM_{2.5}$ exceedances taking place in the western section of the MDM (Greater Tzaneen, Greater Letaba and Greater Giyani), in the Phalaborwa region and a small section in the southwestern corner of Maruleng LM.
- 24-hr and annual PM_{10} and $PM_{2.5}$ exceedances occur in the Phalaborwa area and are due to industrial and mining emissions.
- 1-hr SO_2 and NO_2 exceedances are experienced in the Phalaborwa region but are below the tolerated frequency of exceedances of ambient air standards. These exceedances are mainly from industrial emissions.
- There are no CO exceedances experienced in the MDM.
- No exceedances of the ambient air quality concentrations were simulated for residential waste burning.
- No exceedances of the ambient air quality concentrations were simulated for motor vehicle emissions within the MDM region.
- Model validation (verification) indicated that modelled annual SO_2 concentrations are lower in magnitude compared to the observed (measured) values. The model is consistently underpredicting the annual SO_2 concentrations at all AQMS. This indicates that other sources have an influence and contribute to the ambient concentrations at the AQMS.
- With regards to modelled annual average NO_2 concentration, the modelled annual NO_2 concentrations are also generally lower in magnitude compared to the observed (measured) values at the Phalaborwa AQMS.

- For PM_{10} and $PM_{2.5}$, the modelled annual average PM_{10} and $PM_{2.5}$ concentrations are generally lower in magnitude compared to the observed (measured) values, however, the shorter time averages (1-Hr 99 Percentile) indicate a slight overprediction of the modelled results for $PM_{2.5}$ compared to the measured values.
- The model is underpredicting the 8-hr (99 Percentile) CO concentrations at the Phalaborwa AQMS, this underprediction is the same for the shorter time average (1-Hr 99 Percentile). Again, this could be indicative of unquantified sources in the airshed having an influence and contributing to the ambient concentrations at the AQMS.

Given the simulated results from this study, intervention strategies should be realigned to focus on reducing the impacts associated with industries, domestic fuel burning and biomass burning emissions within the MDM airshed.

6 OPERATIONAL CAPACITIY

Capacity development is a cross-cutting issue that underpins every element of environmental governance. The scarcity of skills in South Africa is a key constraint to service delivery in general, however, within the field of air quality management, this shortage is critical. Capacity development is often seen as simply the provision of extra financial or staff resources or the provision of extra skills through training and education. Capacity development, however, must be seen as an attempt to build an organisation's capacity to fulfil its role efficiently and effectively through a diverse range of strategies at all levels of governance. As defined by the National framework, strategies for capacity development are categorised as follows:

- Applying additional financial and physical resources;
- Improving organisational and technical capabilities;
- Definition of a clear strategic direction;
- Protecting innovation and providing the opportunity for learning;
- Strengthening the organisational system;
- Shape an enabling environment; and
- Creating performance incentives and pressures.

In line with the National Environmental Management: Air Quality Act, 39 of 2004 (NEM: AQA) and the stipulated roles and responsibilities of different spheres of government in relation to air quality management, district and local municipalities are required to conduct the following:

- Designate an Air Quality Officer (AQO) within the municipal administration;
- Develop an AQMP as part of their Integrated Development Plan (IDP);

District municipalities are also responsible for implementing the atmospheric emission licensing system and performing functions of the licensing authority (in-line with Chapter 5 of NEM: AQA) including the registration of controlled emitters.

An Institutional Capacity assessment across all spheres of government within the MDM was conducted in order to determine capacity issues and gaps that may need interventions for the district and local municipalities to effectively implement air quality management functions in the district. The major findings from the air quality management capacity assessment are summarised below:

- Apart from the MDM, there is no clear and defined plan for managing air quality in the local municipalities.
- There are no dedicated municipal departments for air quality management in the local municipalities and this inhibits AQM functions from being carried out efficiently.
- MDM has appointed an Air Quality Officer (AQO) and two personnel from the Greater Giyani local municipality are responsible for managing air quality issues.
- The skill base for AQM at the local municipal level is lacking and this prevents important activities such as emissions inventory compilation, atmospheric dispersion modelling and ambient air quality monitoring from being performed.
- There is a lack of financial support to perform AQM functions at the local municipal level.

7 EMISSION REDUCTION PLAN

7.1 Emission Reduction Strategies

The findings from the updated emission inventory and the atmospheric dispersion modelling exercise form the basis for the formulation of intervention strategies targeting specific emission source categories, and the development of a comprehensive emission reduction plan.

An emission reduction plan was developed for the MDM, providing strategies and intervention descriptions, with their associated time frames, targeting specific emission source categories. The intervention strategies were formulated in line with national strategies (e.g., National Green Transport Strategy) and regulations and were designed to target the main problem complexes contributing to the current air quality situation in the MDM. These complexes are:

I. Industry
II. Mining
III. Residential Fuel Burning
IV. Biomass burning

An emission reduction plan has been developed with the aim of reducing emissions emanating from each of the problem complexes. This is detailed in Tables 21 to 25 below:

7.1.1 Industry

Goal 1: *All Listed Activities will be compliant with MES by 2025, and fugitive emissions would have been reduced such as to ensure compliance with NAAQS.*

Table 21: Emission Reduction Plan for Industries

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce emissions from industries	Compliance with the existing MES.	Industries	By 2030	Submission of monitoring reports (compliance monitoring activities).
	Processing of AEL applications within legislated timeframes.	District Municipalities	By 2030	AEL applications processed. Compliance with AEL requirements.
	Establish incentive schemes for energy efficiency improvements and fuel switching that directly reduce air emissions.	DTIC	By 2030	Fuel switched. Improved energy efficiency.
	Foster closer working relationships between DTIC and small industries on improving standards in industrial processes.	DFFE	By 2030	Partnerships formed. Adherence to emission standards.
Reduce emissions from Category 2 industries	Identify energy-saving opportunities and improve overall operational energy efficiency.	Industries (Category 2)	By 2030	Opportunities identified and implemented. Improved energy efficiency.

Objectives	Activities	Responsibility	Timeframes	Indicators
	Install energy-efficient boiler systems and kilns, including the replacement of old boilers with new ones.	Industries (Category 2)	By 2030	% installation of energy-efficient boiler systems and kilns.
Reduce emissions from Category 4 industries	Use biocarbon reductants (e.g., charcoal and wood) instead of coal/coke.	Industries (Category 4)	By 2030	Reduced coal/coke use.
Reduce emissions from Category 7 Industries	Replace coal-fired partial oxidation processes with natural gas-fired steam reforming production.	Industries (Category 7)	By 2030	Coal-fired partial oxidation processes replaced.
Reduce emissions from Category 9 Industries	Fuel switch: convert fuel from coal to biomass/ residual wood waste so as to reduce emissions from fossil fuels in pulp and paper production.	Industries (Category 9)	By 2030	Reduced coal use.

Notes: DTIC – Department of Trade, Industry and Competition, DFFE – Department of Forestry, Fisheries and the Environment

7.1.2 Mining

Goal 2: *Mining emissions, specifically for PM_{10} and $PM_{2.5}$, will have been reduced to ensure compliance with NAAQS and National Dust Control Regulations (NDCR).*

Table 22: Emission Reduction Plan for Mines

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce emissions from mines	Timeous review and approval of dust management plans	Regulatory authorities	By 2030	Number of dust management plans approved
	Develop and implement the Dust Management Plan. Under the plan the following measures should be considered: • Keep surfaces of stockpiles damp where windblown dust could potentially be generated. • Have height limits for debris/waste or gravel stockpiles. • Minimise or cease dust generating activity during periods of high wind.	Mines	By 2030	Submission of implementation progress reports.

Objectives	Activities	Responsibility	Timeframes	Indicators
	• Wetting coal products during transport along conveyor belts. • Wetting the coal in the crusher and stage loader area. • Sheeting of all dust load products immediately after vehicle loading. • Enforce low speed limits for vehicular traffic. • Increase the distance between vehicles travelling the haul road so as to allow road dust dissipation.			
	Initiation of dustfall monitoring programmes.	Mines	By 2030	Submission of dustfall monitoring reports
	Conduct yearly inspections of mines for adherence to environmental requirements.	DMRE	By 2030	Mines inspected. Mines adhering to environmental requirements.

Notes: DMRE – Department of Mineral Resources and Energy

7.1.3 Domestic Fuel Burning

Goal 3: *Reduce emissions from domestic fuel burning to ensure compliance with NAAQS.*

Table 23: Emission Reduction Plan for Domestic Fuel Burning

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce domestic fuel burning emissions	Improve public awareness on air pollution and involve communities in developing solutions that suit their socio-economic circumstances.	Local Municipalities, DOH	By 2030	Number of awareness campaigns conducted.
	Promote the use of clean/green fuels.	DMRE	By 2030	% of households have converted to or added clean/green fuels to their energy mix.
	Collaborate and engage with communities to introduce low energy systems for residential heating.	DMRE	By 2030	% of households that are using low energy residential heating systems.
	Strengthen the Intergovernmental Relations (IGR) to ensure environmental health (air pollution) is included in all planning and policies	DOH	By 2030	Partnerships have been formed.
	Train Environmental Health Practitioners (EHPs) on the implementation of the Indoor Air Quality (IAQ) guidelines in provinces and municipalities.	DOH	By 2030	% of EHPs trained and educated.
	Establish Air Quality and Health focus groups in provinces and municipalities.	DOH	By 2030	Number of Air Quality and Health focus groups that have been established.

Objectives	Activities	Responsibility	Timeframes	Indicators
	Foster closer working relationships between municipalities and stakeholders on designing and implementing possible emissions reduction measures.	DFFE	By 2030	Partnerships have been formed.
	Initiate pilot projects that encourage social upliftment with air quality benefits e.g., fitting RDP houses with sufficient insulation.	DHS	By 2030	Number of pilot projects initiated and finalised.
	Create partnerships with industries to retrofit or assist with retrofitting houses with sufficient insulation) in close proximity to industries as part of their cooperate social responsibility.	DFFE, Industries	By 2030	% of households retrofitted.
	Create partnerships with industries to provide clean fuels/green fuels to houses in close proximity to industries as part of their cooperate social responsibility.	DFFE, Industries	By 2030	% of households that have converted to or added clean/green fuels to their energy mix.
	Develop a targeted communications campaign to promote best practices in the use of wood stoves and fireplaces so as to reduce exposure to pollutants.	DFFE	By 2030	Number of awareness campaigns conducted.

Notes: DHS – Department of Human Settlements, DOH – Department of Health, DMRE – Department of Mineral Resources, DFFE – Department of Forestry, Fisheries and the Environment

7.1.4 Biomass Burning

Goal 4: *Reduce emissions from biomass burning through veld management measures and quick response times.*

Table 24: Emission Reduction Plan for Biomass Burning

Objectives	Activities	Responsibility	Timeframes	Indicators
Reduce biomass burning emissions	Establish Fire Protection Associations that will enforce the veldfires act.	Municipal Fire Services, Traditional leaders	By 2030	Number of registered Fire Protection Associations. Fire Protection Associations enforcing the veldfires act.
	Conduct education and awareness campaigns in the communities on the impact and prevention of veld fires.	Fire Protection Associations	By 2030	Number of awareness campaigns conducted.
	Publish outdoor burning best practice guidance so as to reduce the risk of veldfires.	Fire Protection Associations	By 2030	Outdoor burning best practice guidance implemented. Reduced number of uncontrolled veld fires.
	Promote the establishment of strategic firebreaks across the high fire risk areas.	Fire Protection Associations	By 2030	Firebreaks established and maintained.

Objectives	Activities	Responsibility	Timeframes	Indicators
	Ensure there is sufficient resource capacity for quick and sustained response to veld fires.	Municipal Fire Services	By 2030	Quick response to veld fire outbreaks.

7.1.5 Education, awareness and resource mobilisation

Goal 5: *Increase awareness on air quality challenges and mobilise resources to tackle these challenges.*

Table 25: Implementation Plan for education, awareness and resource mobilisation

Objectives	Activities	Responsibility	Timeframes	Indicators
To promote education, awareness and mobilise resources	Follow up on plans/ programmes and reduction commitments to ensure that the emission reduction commitments in the plans of stakeholders are fully implemented.	MDM, Local Municipalities	By 2030	Submission and review of progress reports. Implementation of recommendations from progress reports.
	Mobilisation of private capital for environmentally sustainable investments that support the zero pollution objectives.	NGOs, CBOs	By 2030	Funds availed. Implementation of emission reduction measures.
	Provide updated best practices to make tangible progress in identifying and reducing exposure to environmental risks in vulnerable groups.	NGOs, CBOs	By 2030	Updated best practices updated and implemented
	Support better governance on air pollution by offering new insights into overall pollution levels and impacts and by monitoring whether emission reduction plans implementation is on track to achieve the agreed objectives.	DFFE/DOH	By 2030	Submission and review of progress reports. Implementation of recommendations from progress reports.
	Enable local authorities to share best practices, success stories and experiences to drive improvement.	DFFE	By 2030	Number of air quality forums.

Objectives	Activities	Responsibility	Timeframes	Indicators
				Implementation of recommendations from air quality forums.
	Capacitate authorities and stakeholders.	DFFE	By 2030	% of authorities trained and educated.

Notes: NGO – Non-Government Organisations, CBO – Community Based Organisations, DFFE – Department of Forestry, Fisheries and the Environment

7.2 Air Quality Management Systems

7.2.1 Ambient Air Quality Monitoring Network

Goal 5 promotes the expansion of ambient air quality monitoring in the MDM so as to have wider coverage. Ambient air quality monitoring is an integral part of effective air quality management. Monitoring will enable the municipality to assess the extent of the air pollution situation to develop appropriate air quality goals and evaluate the effectiveness of emissions control strategies.

The monitoring network in the Mopani district is limited in providing sufficient information to support adequate air quality management for the greater Mopani region. Currently, there are only four operational ambient air quality monitoring stations in the MDM, which are concentrated in the Ba-Phalaborwa region. Of the four stations, one is managed by the LEDET, and the remaining three stations are privately owned and managed by the Phalaborwa Mining Company. There is an ambient air quality monitoring station located in Tzaneen managed by the MDM, however, this station is currently not functional due to technical problems. The MDM needs to consider expanding its ambient air quality monitoring network in order for the data collected to be a true representation of the state of air in the district.

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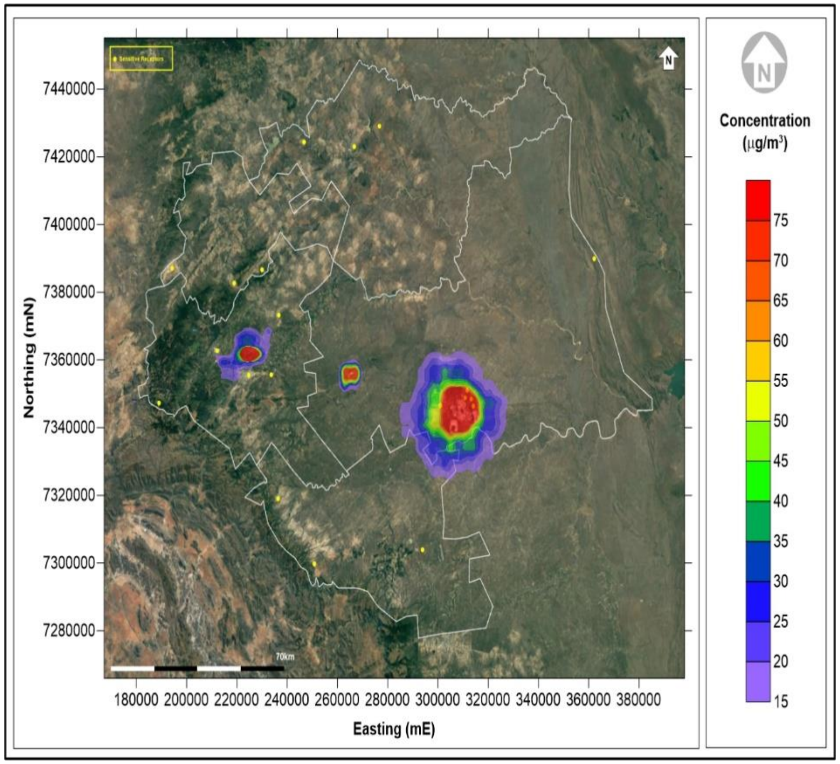
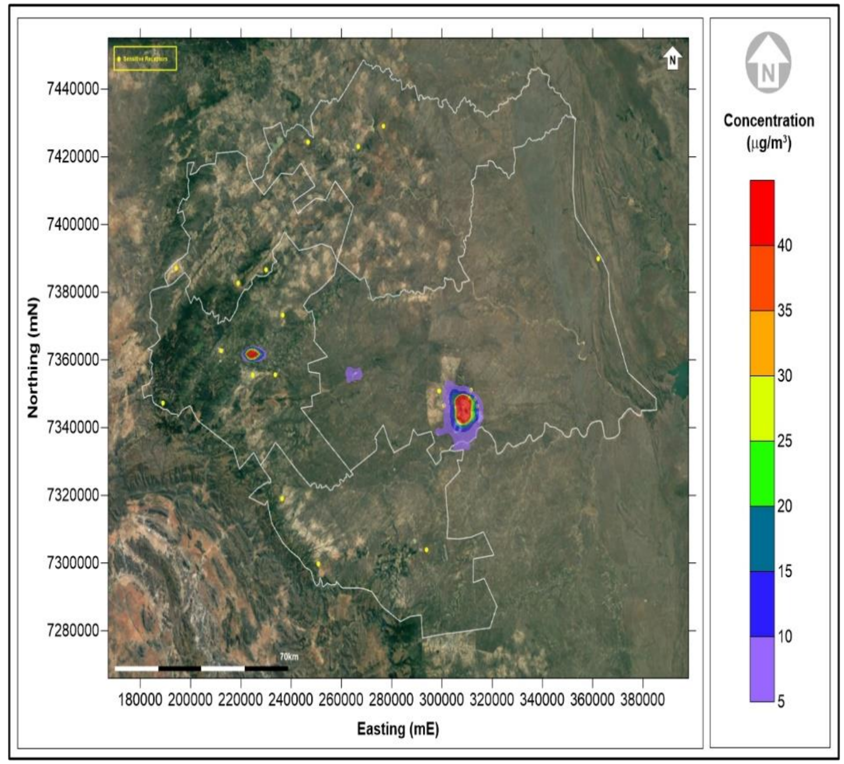
APPENDIX A – SECTOR-SPECIFIC TIME-AVERAGED CONCENTRATION MAPS

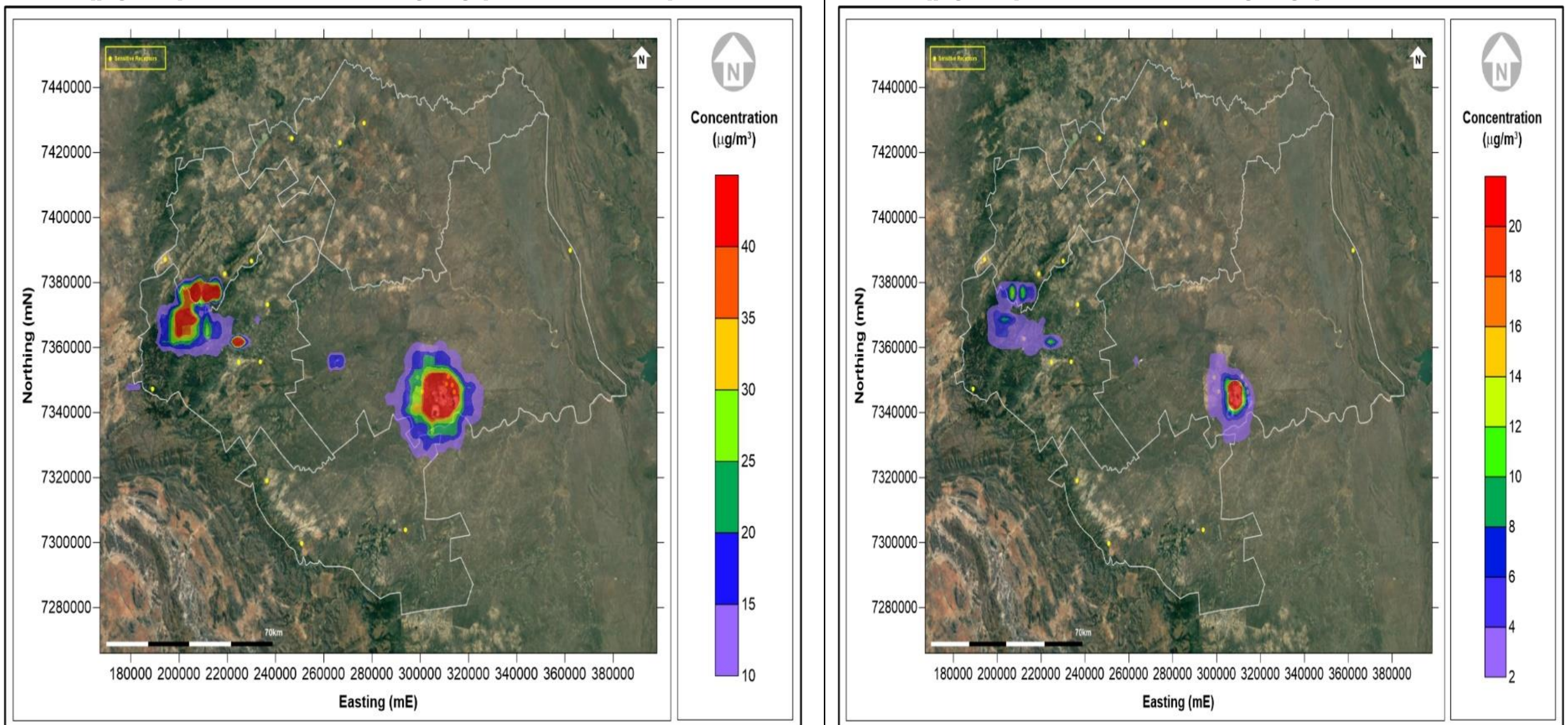
Industrial and Mining Sources

Figures A-1 to A-6 are a graphical representation of the impacts associated with the priority pollutants emanating from the industrial sources. The impact regions are localised close to the industrial facilities, with the highest simulated concentrations in close vicinity of the sources.

PM10 (µg/m³) - 24-hour averaging period – 99th percentile	PM10 (µg/m³) - annual averaging period
	

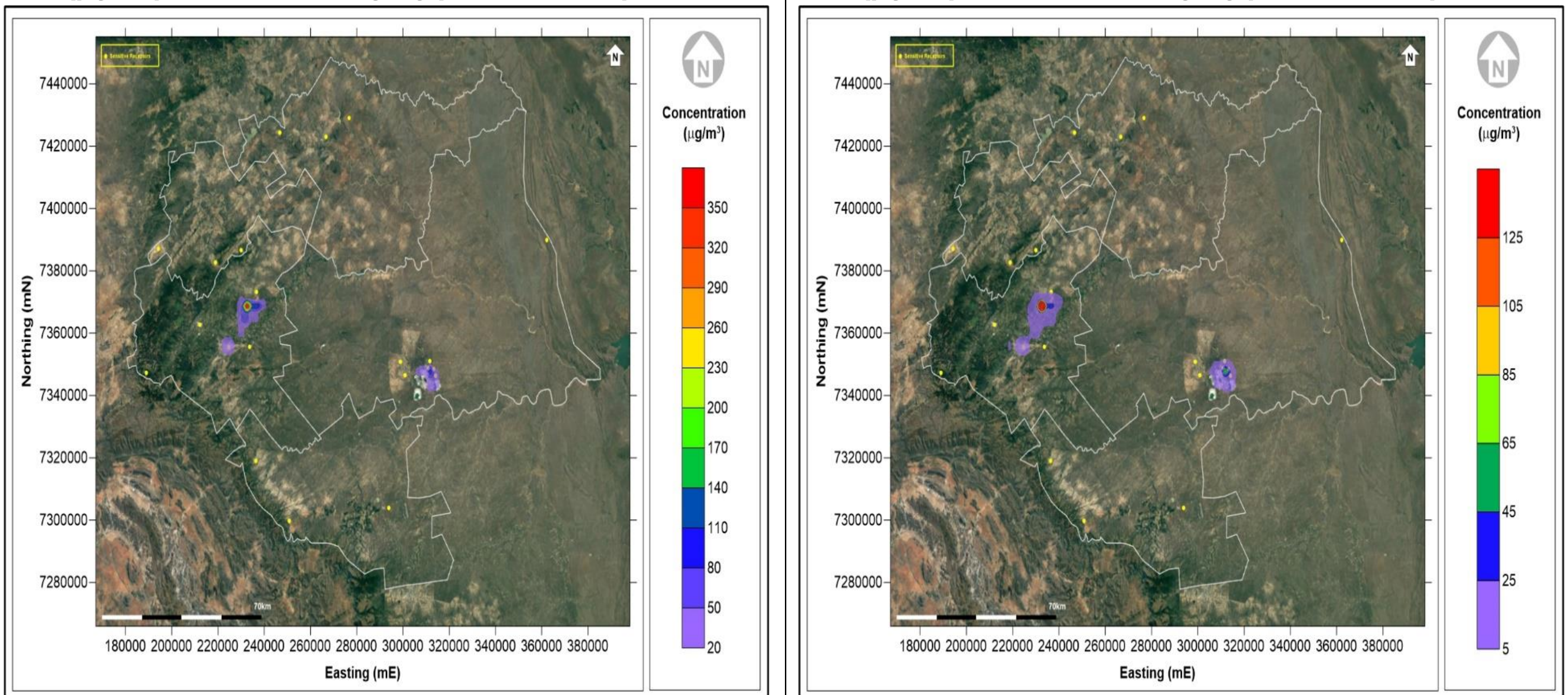
A-1: Simulated results for the Industrial and Mining Sources (PM_{10} - µg/m³). The red isopleths indicate areas exceeding the NAAQS.

PM2.5 (µg/m³) - 24-hour averaging period – 99th percentile | **PM2.5 (µg/m³) - annual averaging period**



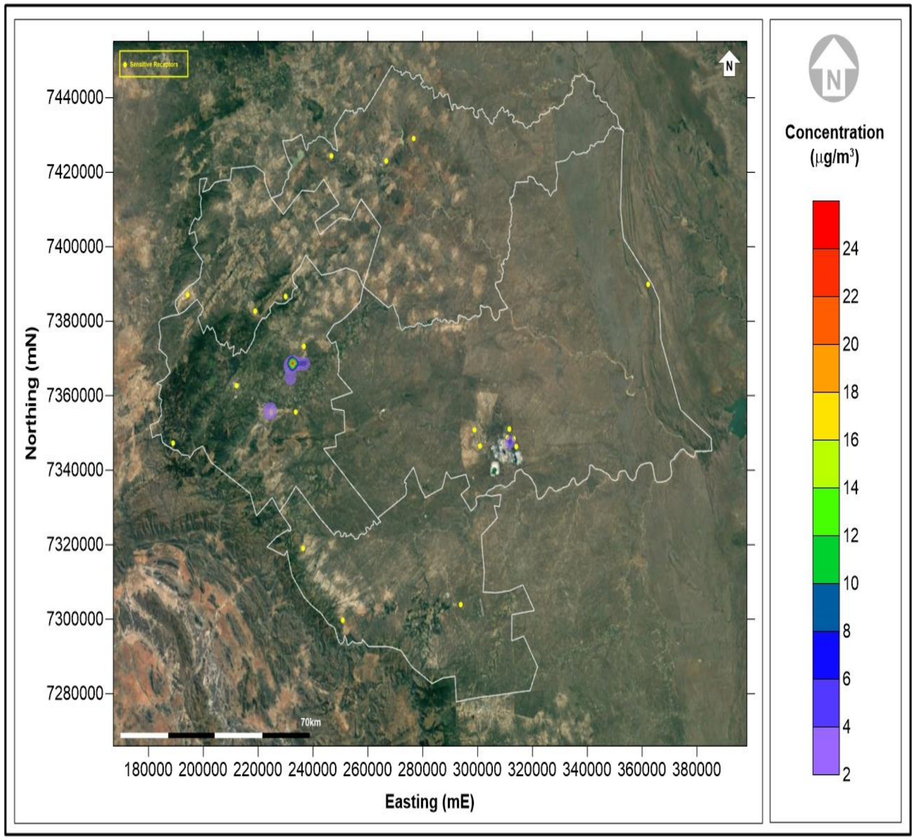
A-2: Simulated results for the Industrial and Mining Sources (PM2.5 - µg/m³). The red isopleths indicate areas exceeding the NAAQS.

SO_2 (µg/m³) - 1-hour averaging period – 99th percentile | **SO_2 (µg/m³) - 24-hour averaging period – 99th percentile**

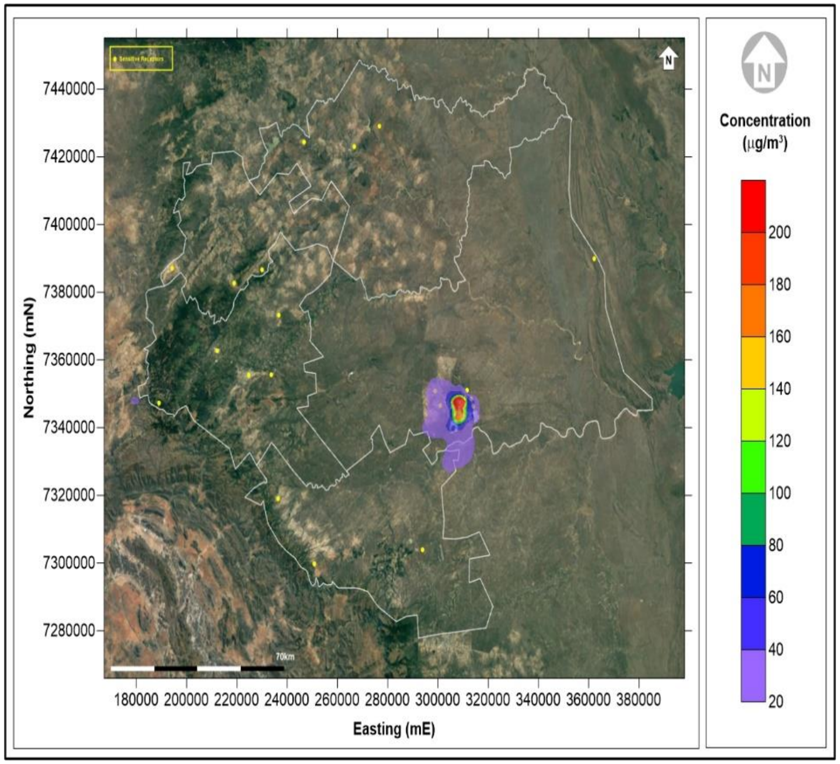
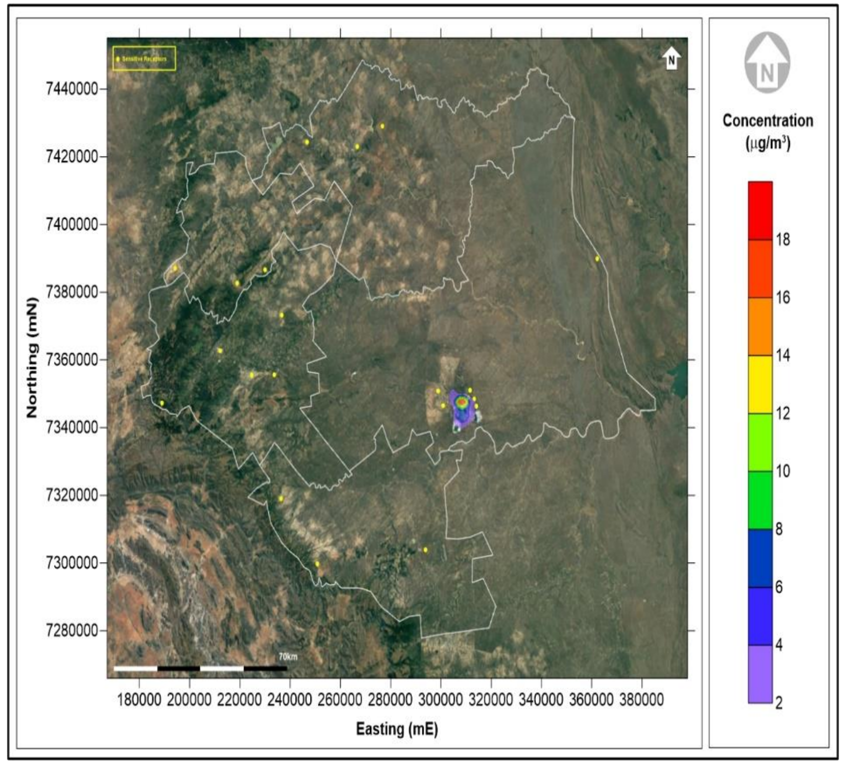


A-3: Simulated results for the Industrial and Mining Sources (SO_2 - µg/m³). The red isopleths indicate areas exceeding the NAAQS.

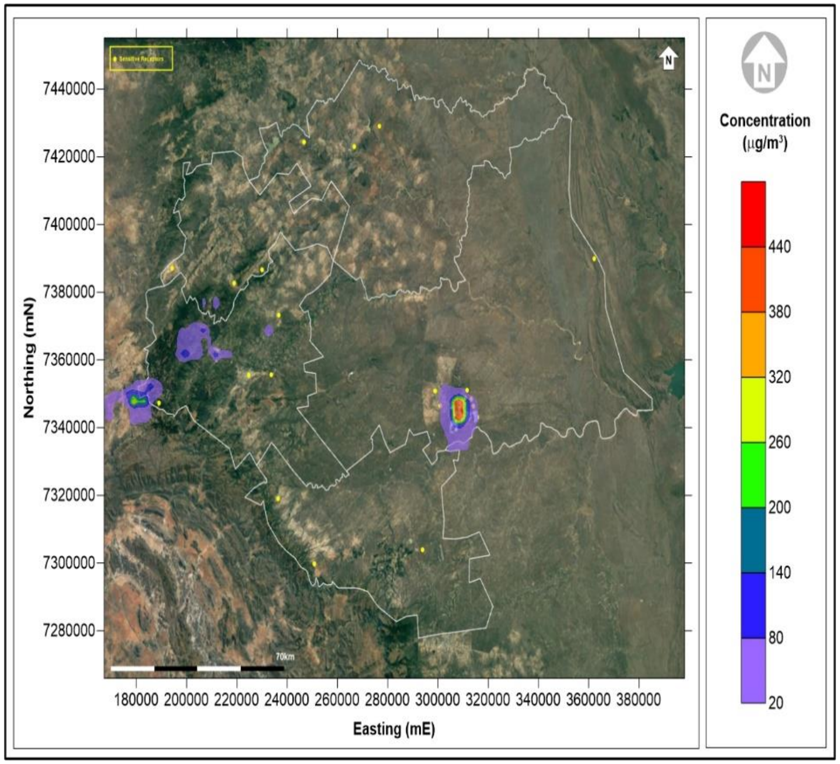
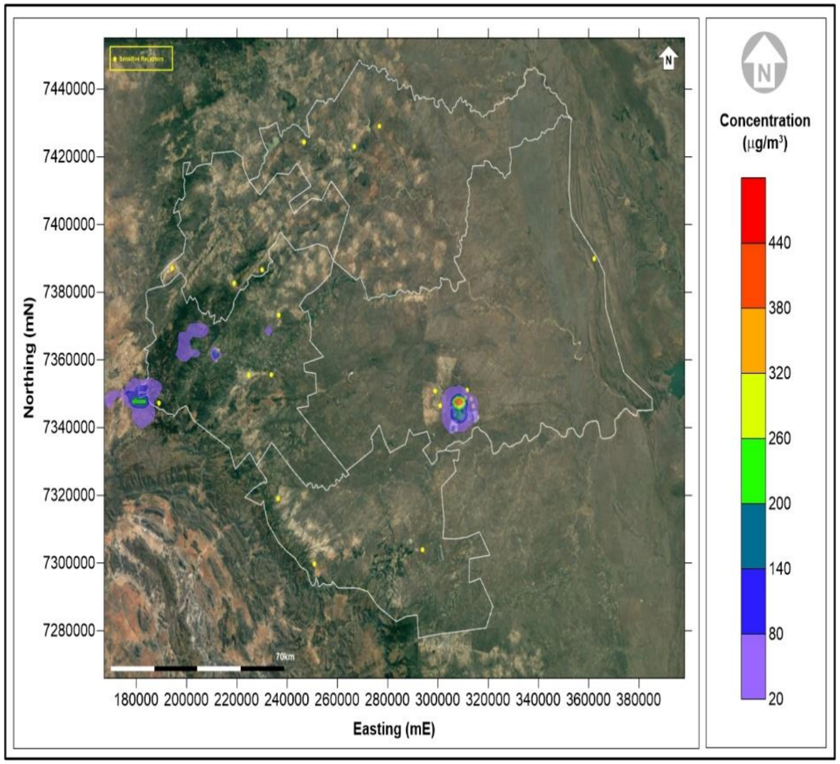
SO_2 (µg/m³) - annual averaging period



A-4: Simulated results for the Industrial and Mining Sources (SO_2 - µg/m³). The red isopleths indicate areas exceeding the NAAQS.

NO2 (µg/m³) - 1-hour averaging period – 99th percentile	NO2 (µg/m³) - annual averaging period
	

A-5: Simulated results for the Industrial and Mining Sources (NO_2 - µg/m³). The red isopleths indicate areas exceeding the NAAQS.

CO (µg/m³) - 1-hour averaging period – 99th percentile	CO (µg/m³) - 8-hour averaging period – 99th percentile
	

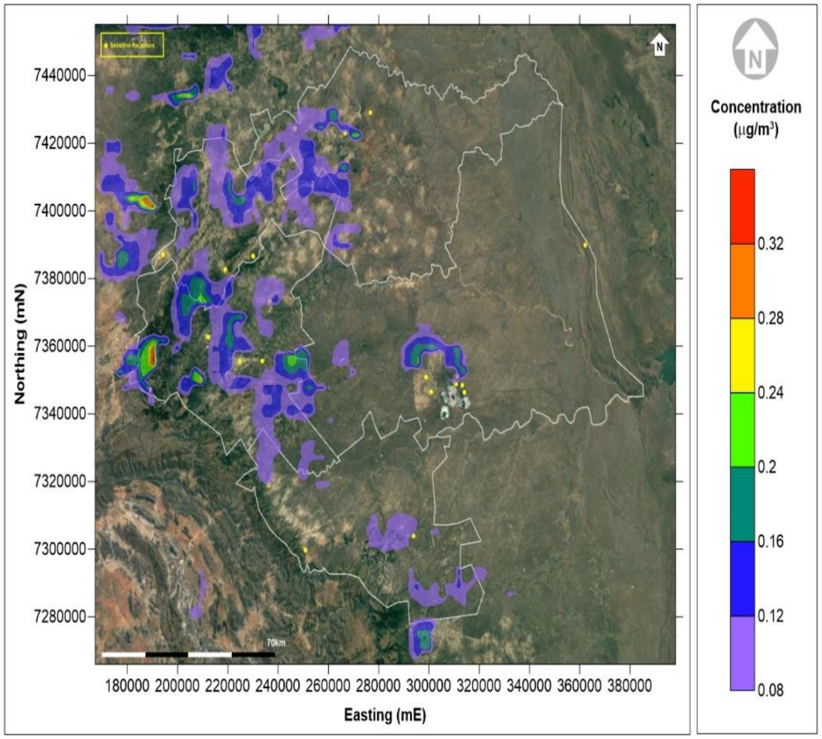
A-6: Simulated results for the Industrial and Mining Sources (CO - µg/m³). The red isopleths indicate areas exceeding the NAAQS.

Vehicle (Mobile) Emissions

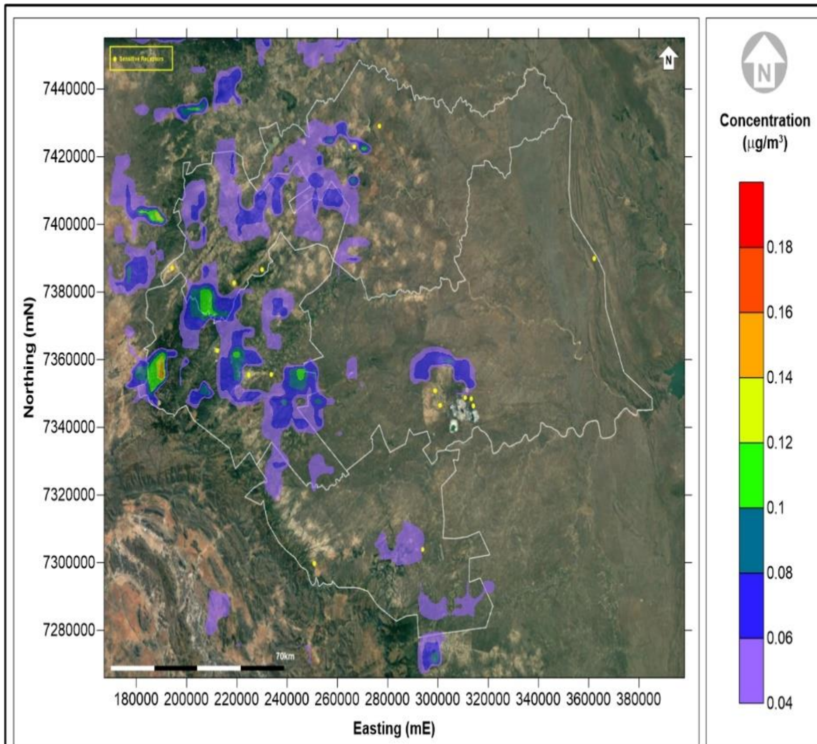
Figures A-7 to A-11 are a graphical representation of the impacts (ground-level concentrations) associated with the priority pollutants emanating from the vehicle tailpipe emissions within the MDM.

In general, isolated exceedances of the AAQ concentrations were predicted based on the mobile emissions within MDM.

$PM_{2.5}$ (µg/m³) - 24-hour averaging period – 99th percentile

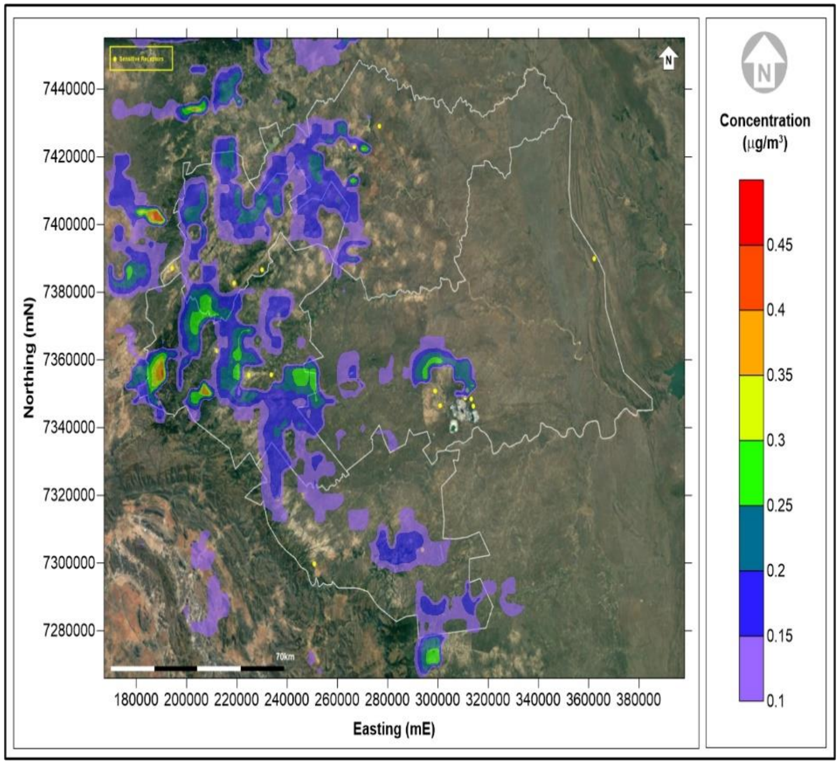


$PM_{2.5}$ (µg/m³) - annual averaging period

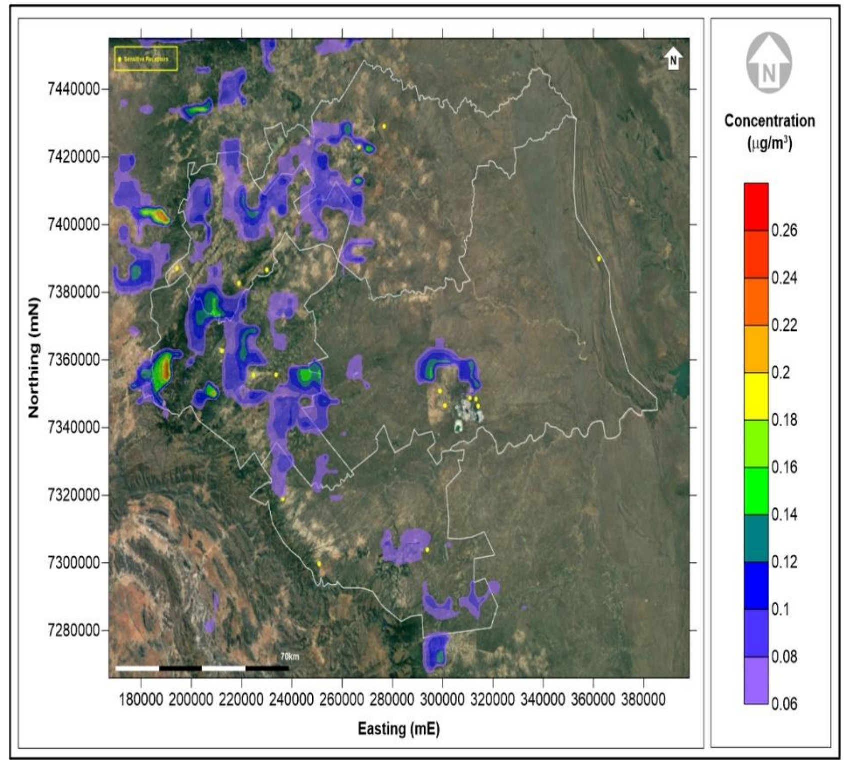


A-7: Simulated results for the Vehicle (Mobile) Sources ($PM_{2.5}$ - µg/m³).

SO_2 (µg/m³) - 1-hour averaging period – 99th percentile

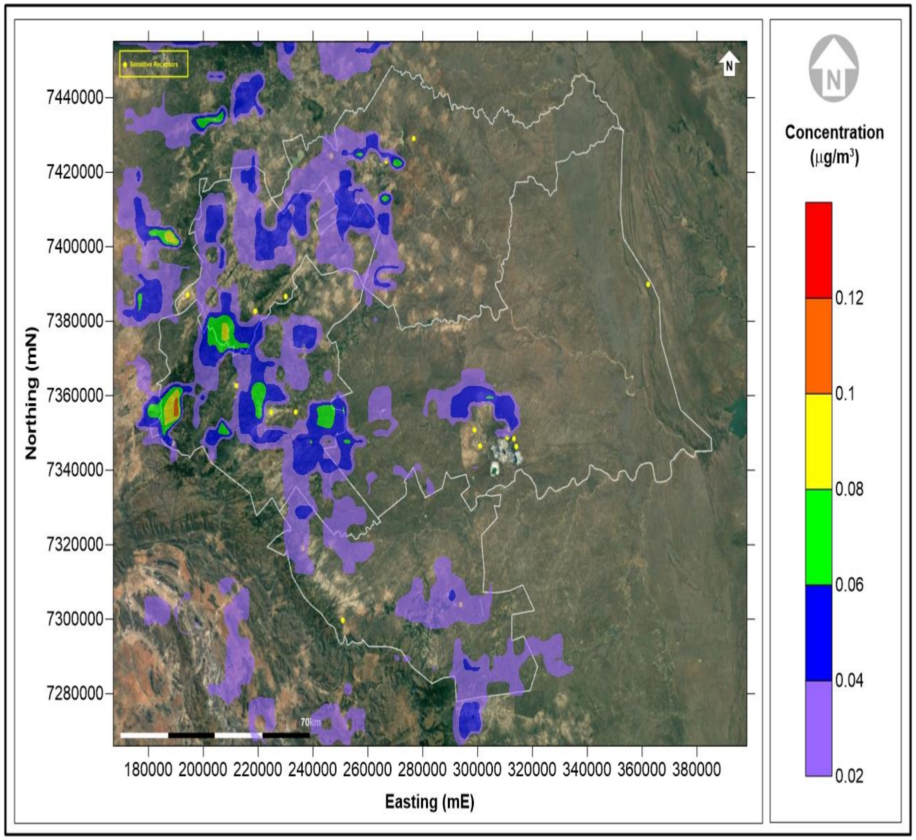


SO_2 (µg/m³) - 24-hour averaging period – 99th percentile

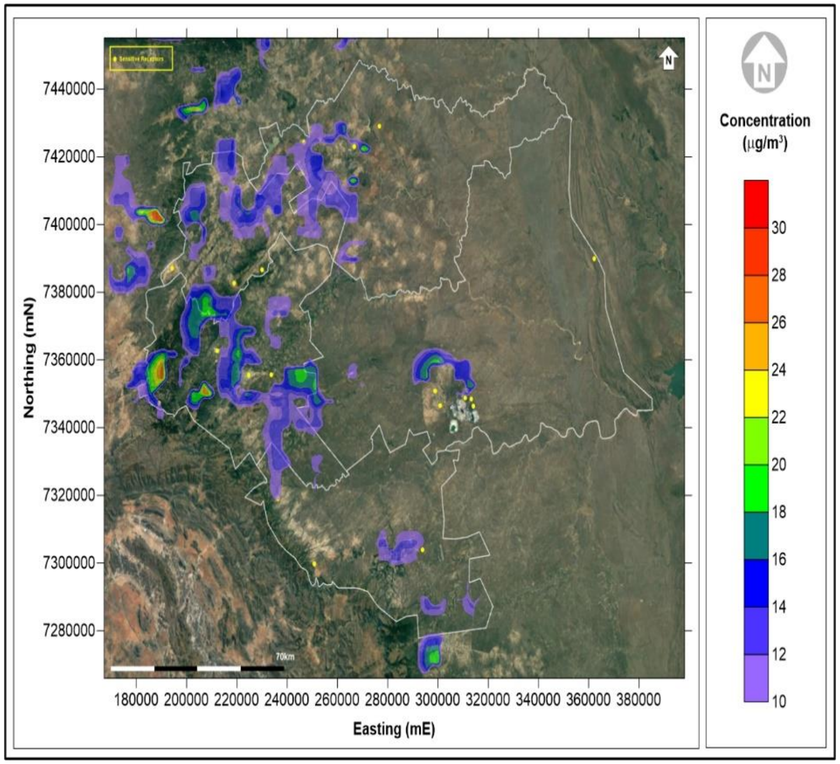
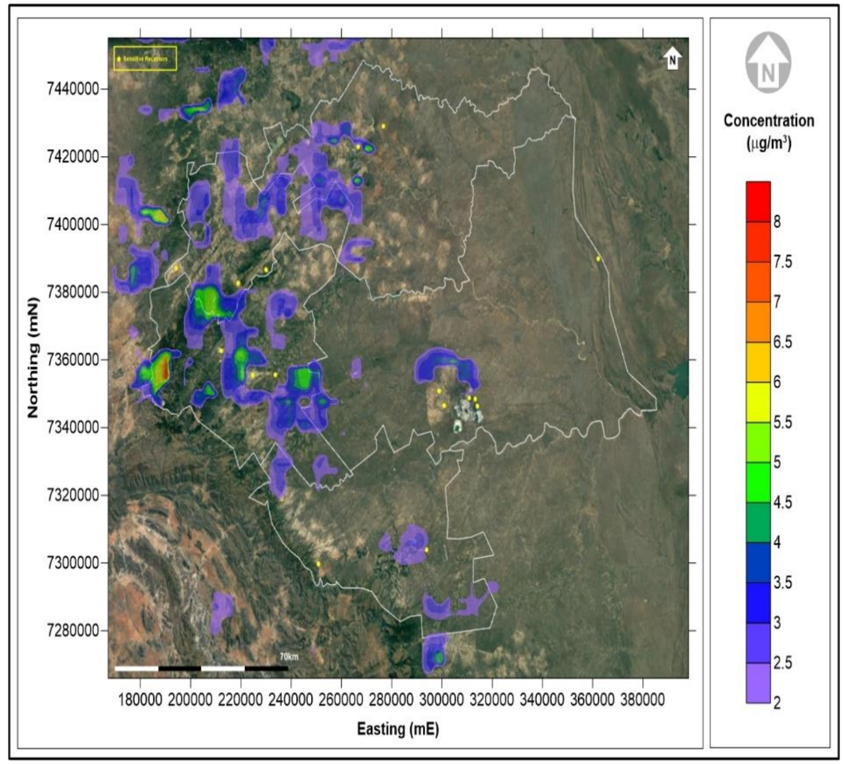


A-8: Simulated results for the Vehicle (Mobile) Sources (SO_2 - µg/m³).

SO_2 (µg/m³) - annual averaging period

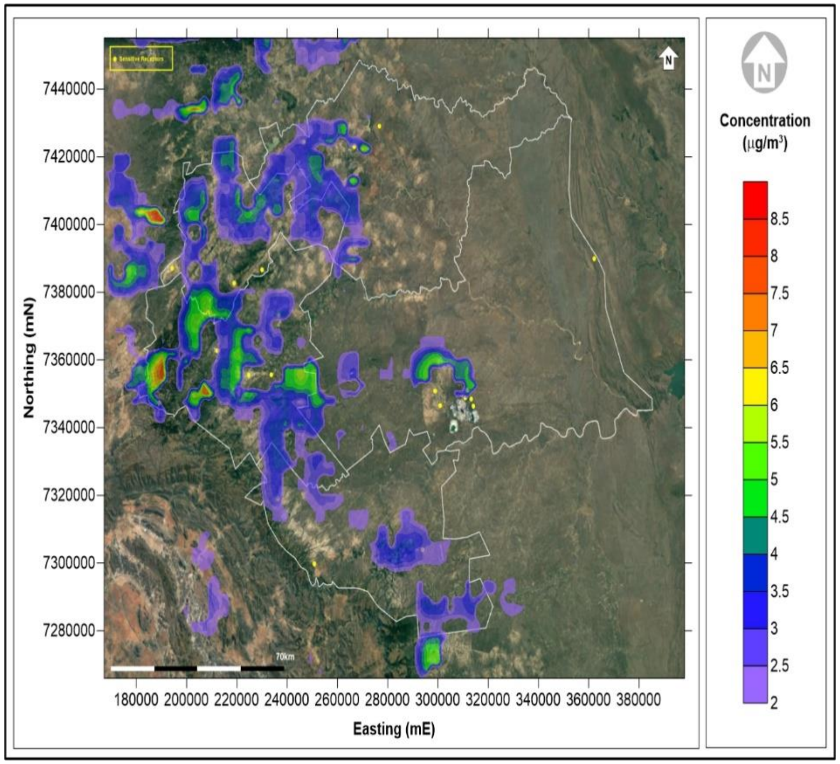


A-9: Simulated results for the Vehicle (Mobile) Sources. (SO_2 - µg/m³).

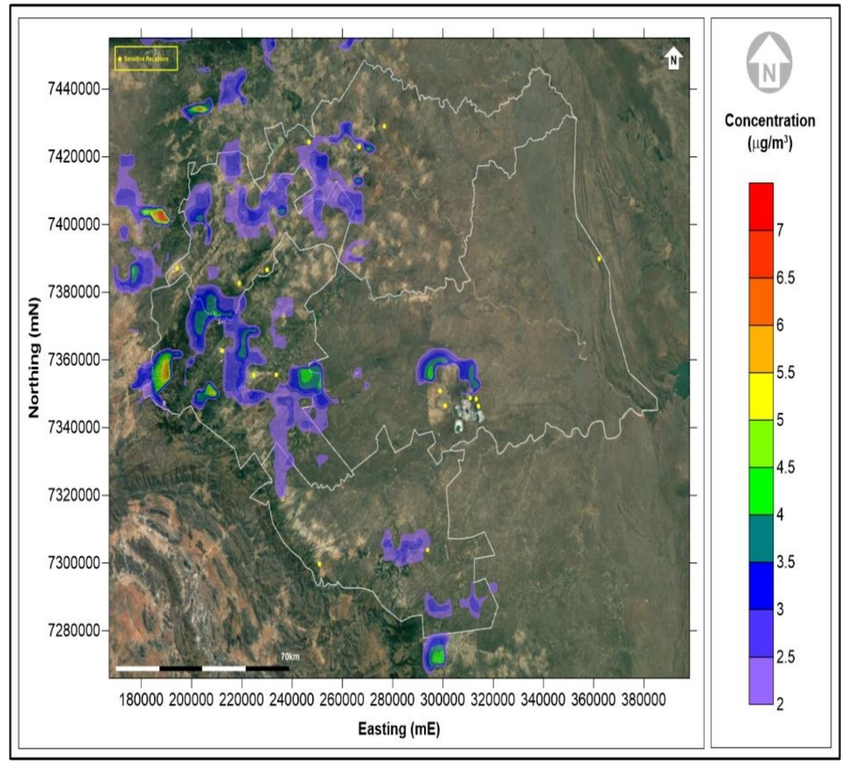
NO$_2$ (µg/m³) - 1-hour averaging period – 99th percentile	NO$_2$ (µg/m³) - annual averaging period
	

A-10: Simulated results for the Vehicle (Mobile) Sources. (NO$_2$ - µg/m³).

CO (µg/m³) - 1-hour averaging period – 99th percentile



CO (µg/m³) - 8-hour averaging period – 99th percentile



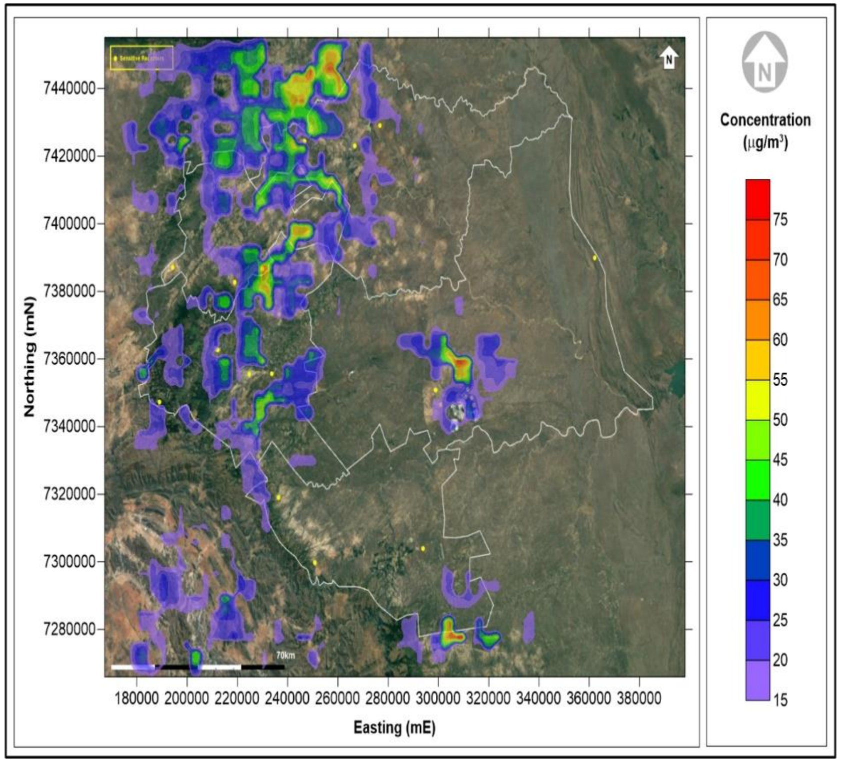
A-11: Simulated results for the Vehicle (Mobile) Sources. (CO - µg/m³).

Domestic Fuel Burning Emissions

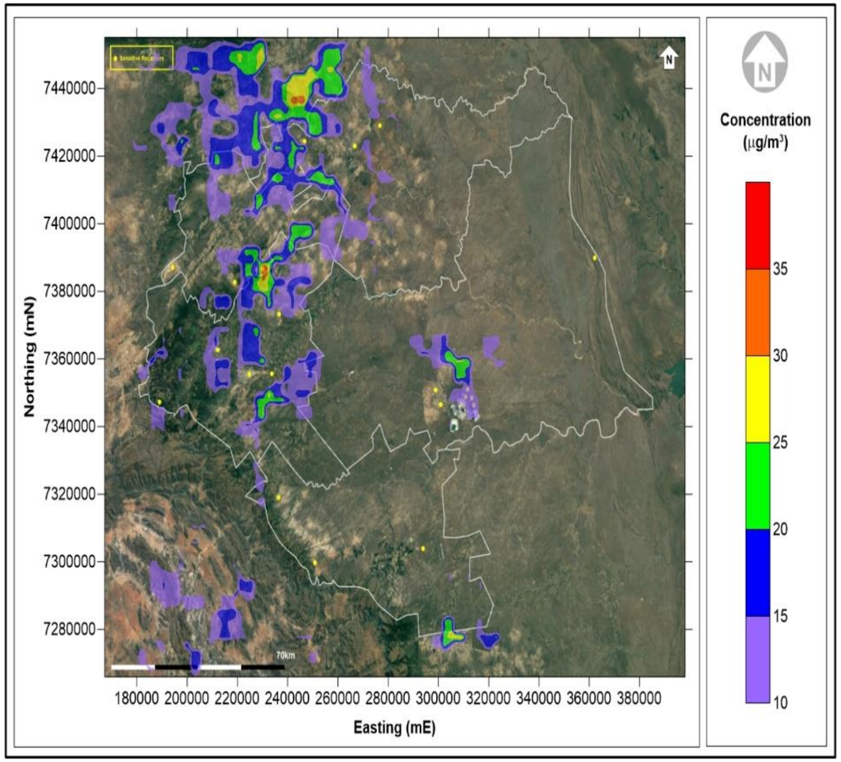
Figures A-12 to A-17 are graphical representations of the impacts (ground level concentrations) associated with the priority pollutants emanating from domestic fuel burning emissions within the MDM airshed.

Elevated $PM_{2.5}$ concentrations and exceedances were predicted based on the DFB emissions within MDM.

PM_{10} (µg/m³) - 24-hour averaging period – 99th percentile

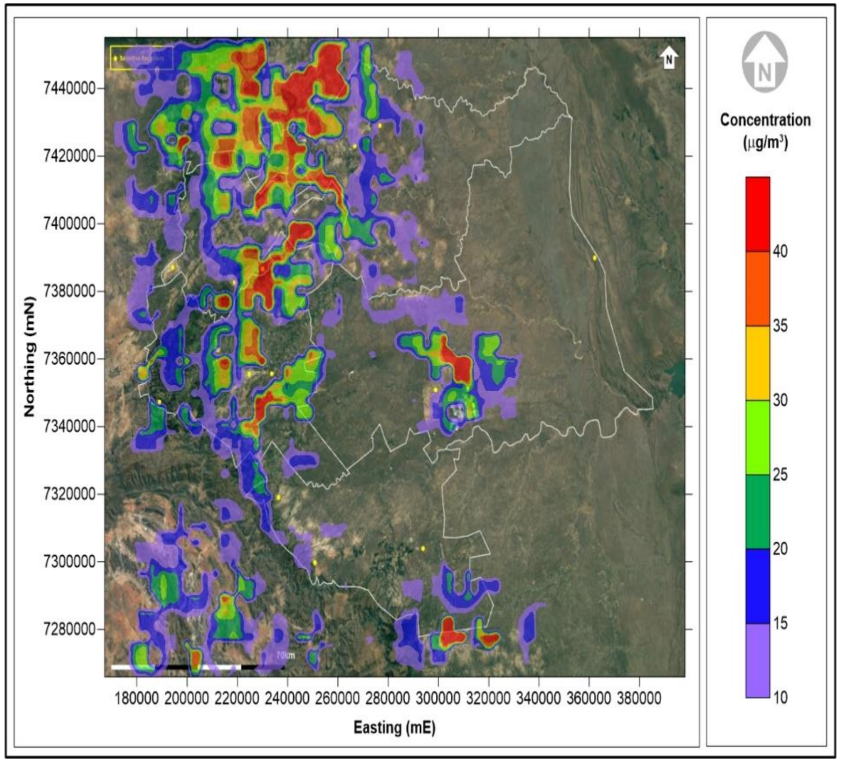


PM_{10} (µg/m³) - annual averaging period

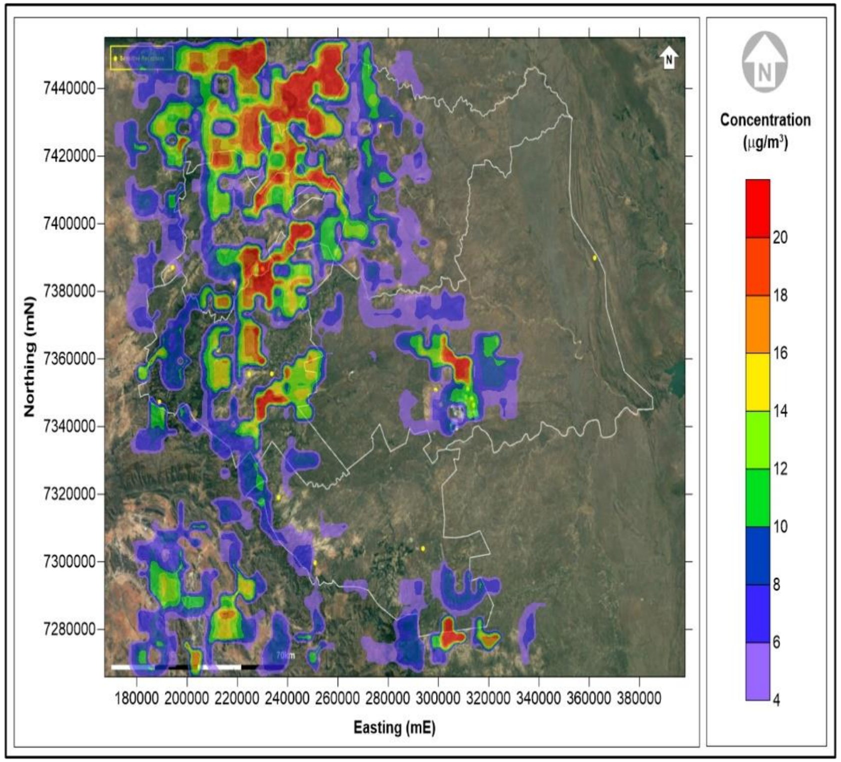


A-12: Simulated results for the DFB emissions (PM_{10} - µg/m³).

PM2.5 (µg/m³) - 24-hour averaging period – 99th percentile

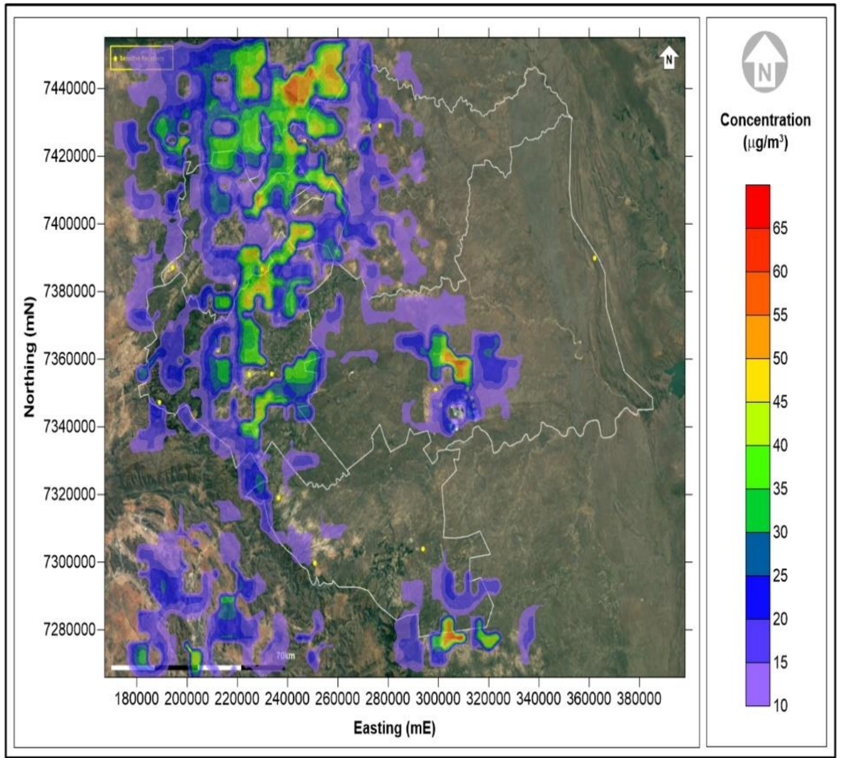


PM2.5 (µg/m³) - annual averaging period

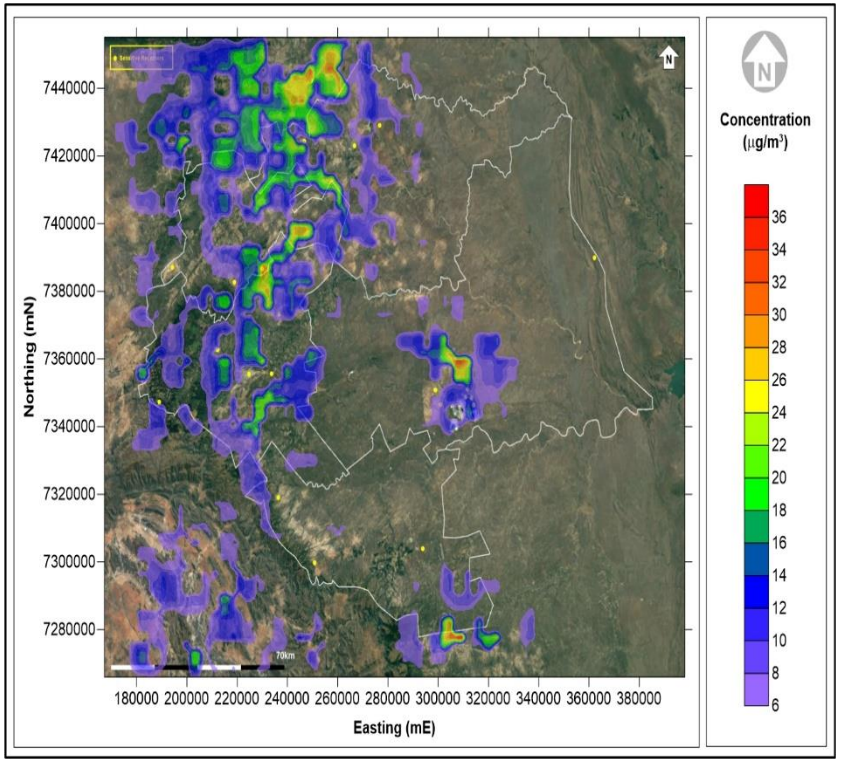


A-13: Simulated results for the DFB emissions ($PM_{2.5}$ - µg/m³).

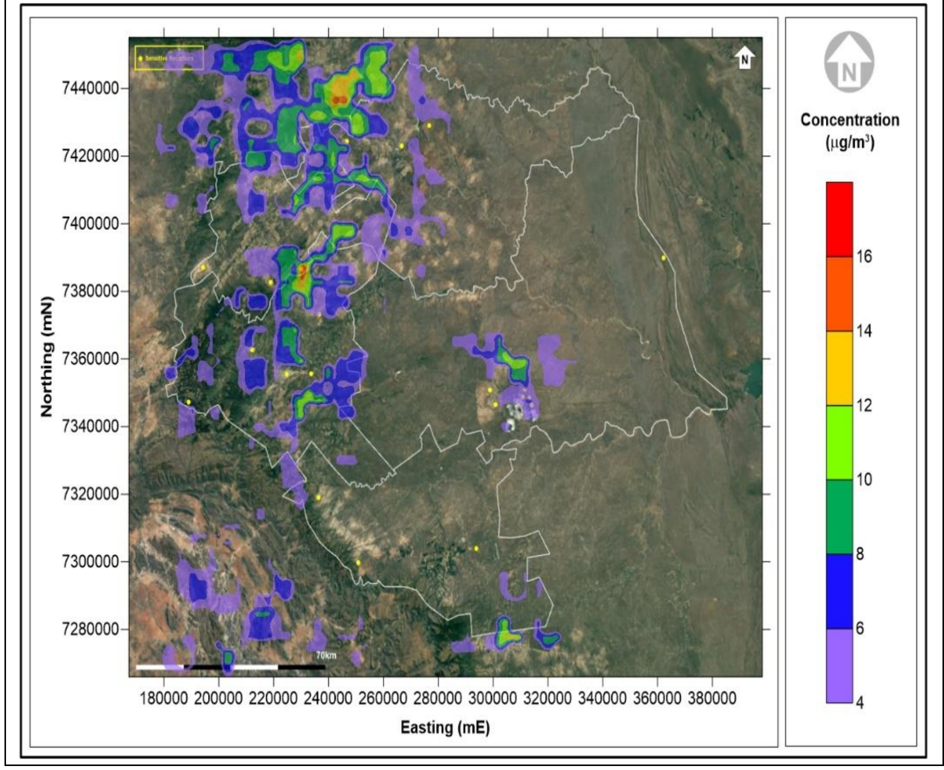
SO_2 (µg/m³) - 1-hour averaging period – 99th percentile



SO_2 (µg/m³) - 24-hour averaging period – 99th percentile

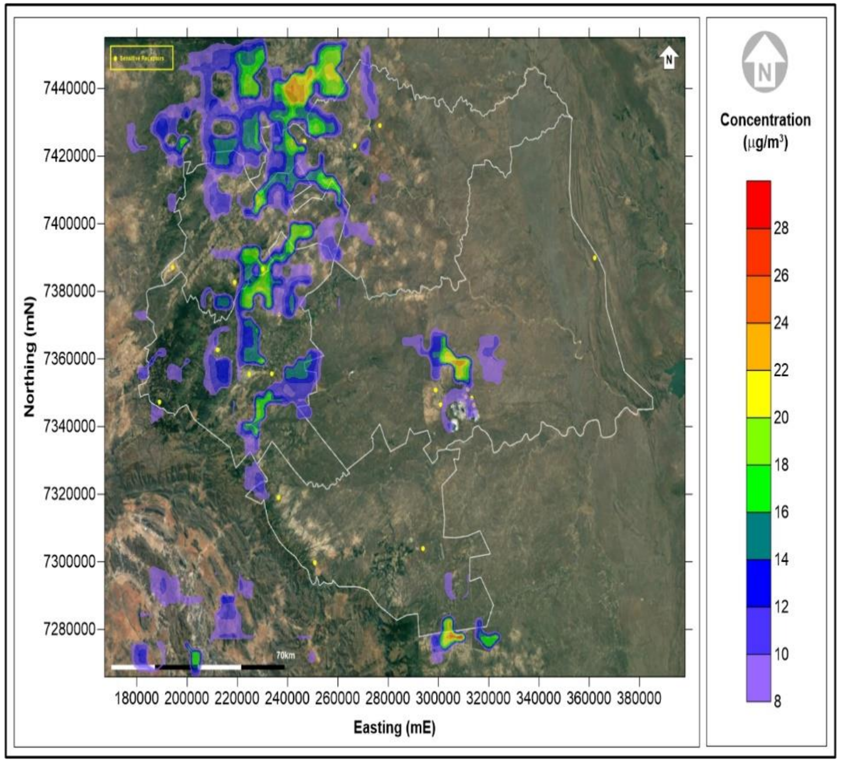


A-14: Simulated results for the DFB emissions (SO_2 - µg/m³).

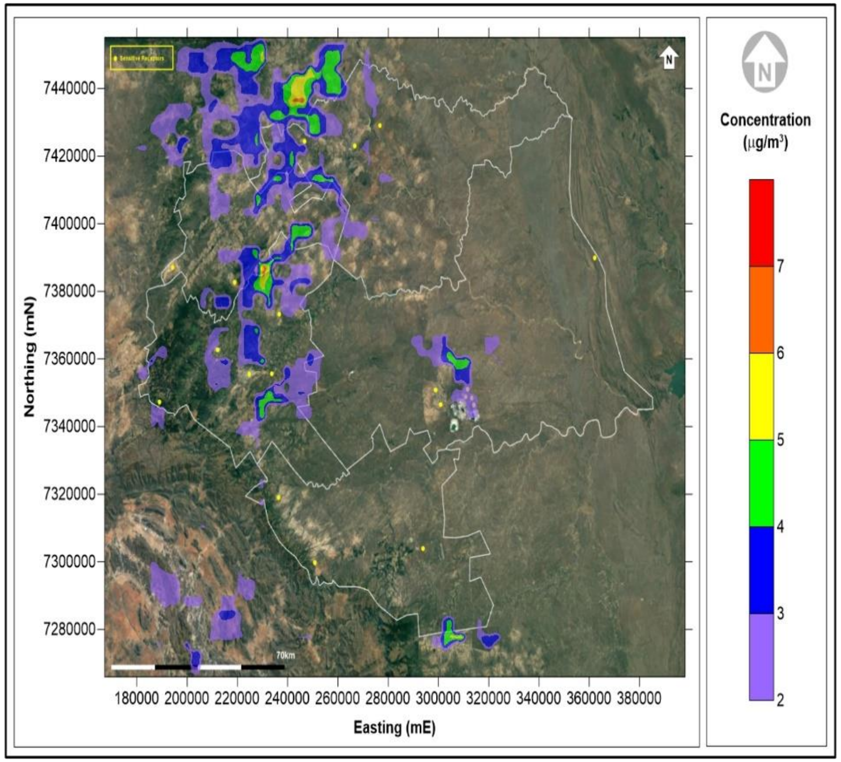
SO2 (µg/m³) - annual averaging period	
	

A-15: Simulated results for the DFB emissions (SO_2 - µg/m³).

NO_2 (µg/m³) - 1-hour averaging period – 99th percentile

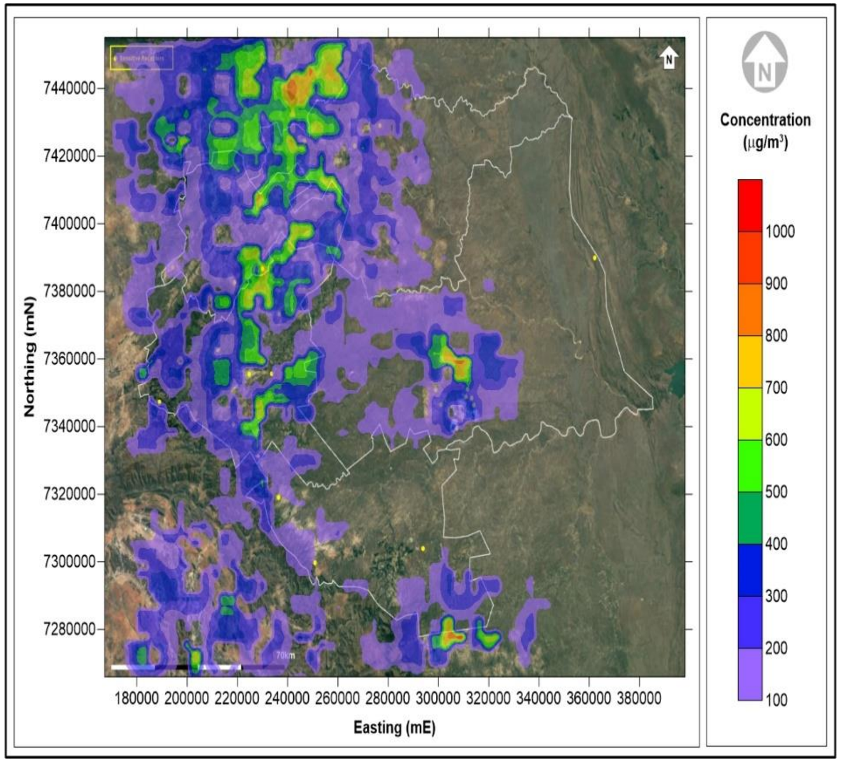


NO_2 (µg/m³) - annual averaging period

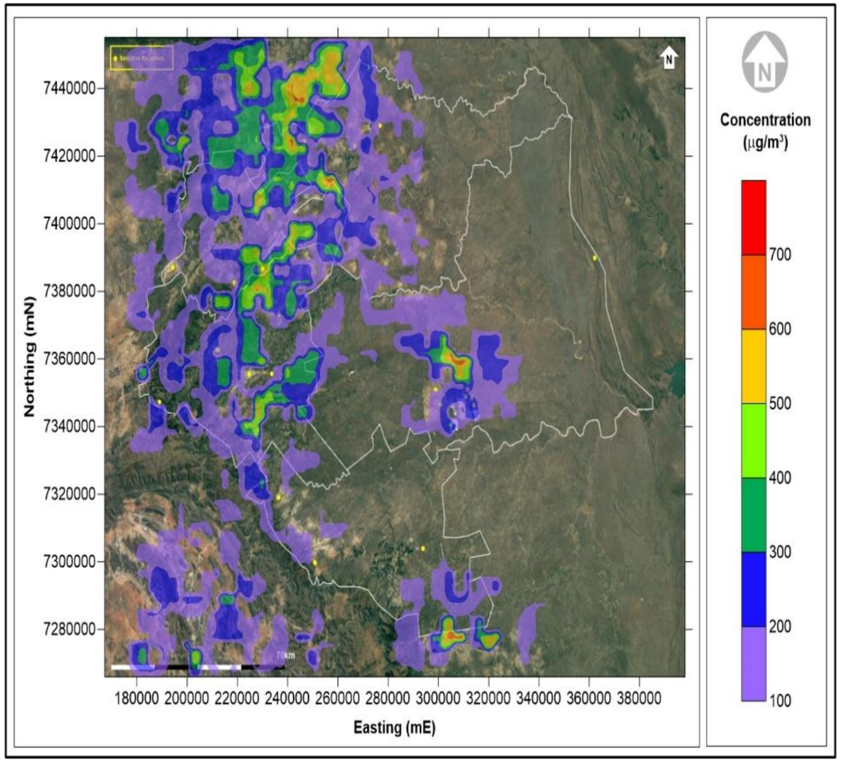


A-16: Simulated results for the DFB emissions (NO_2 - µg/m³).

CO (µg/m³) - 1-hour averaging period – 99th percentile



CO (µg/m³) - 8-hour averaging period – 99th percentile



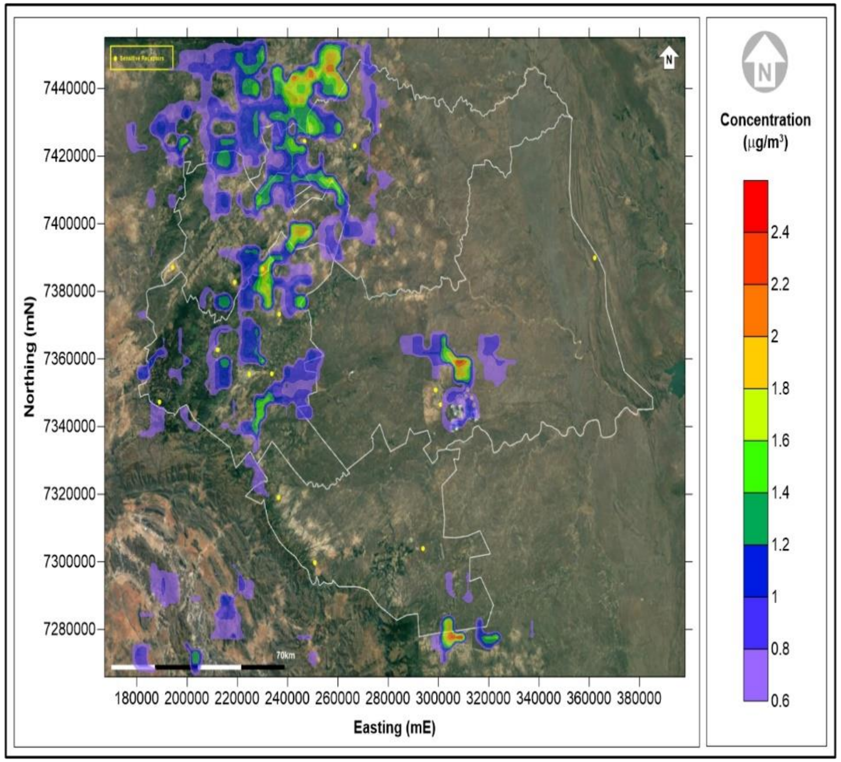
A-17: Simulated results for the DFB emissions (CO - µg/m³).

Domestic Waste Burning Emissions

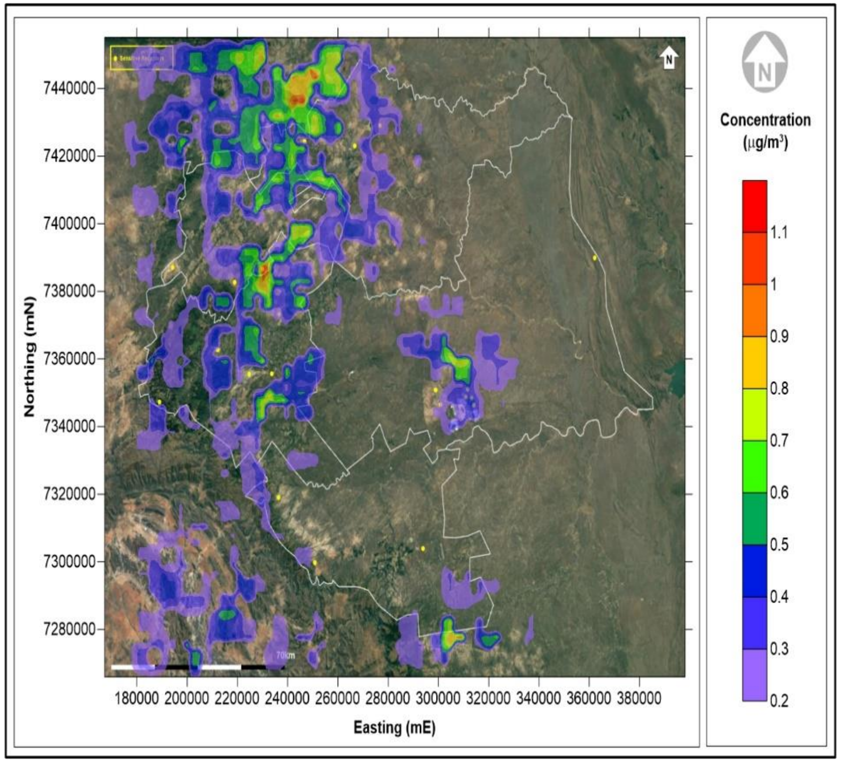
Figures A-18 to A-23 are graphical representations of the impacts (ground level concentrations) associated with the priority pollutants emanating from domestic waste burning emissions within the MDM airshed.

In general, isolated exceedances of the AAQ concentrations were predicted based on the DWB emissions within MDM.

PM_{10} (µg/m³) - 24-hour averaging period – 99th percentile

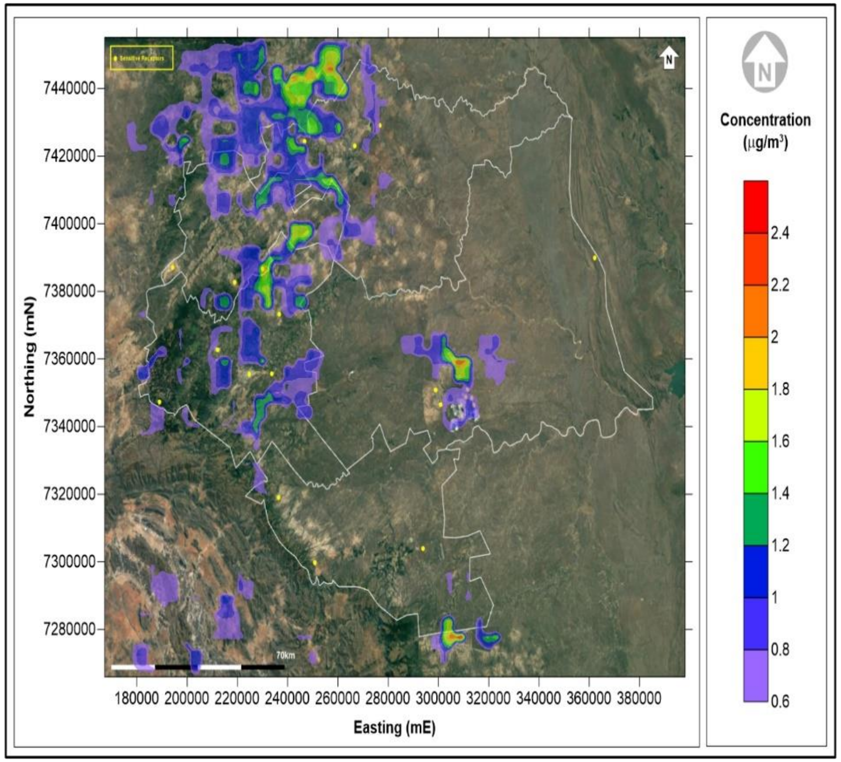


PM_{10} (µg/m³) - annual averaging period

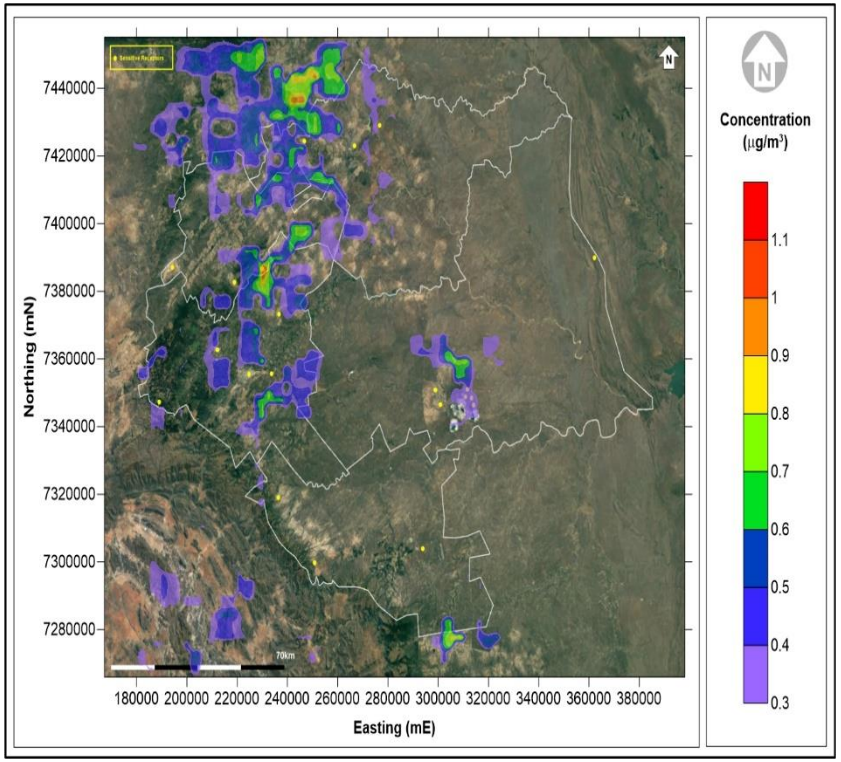


A-18: Simulated results for the DWB emissions (PM_{10} - µg/m³).

PM$_{2.5}$ (µg/m³) - 24-hour averaging period – 99th percentile

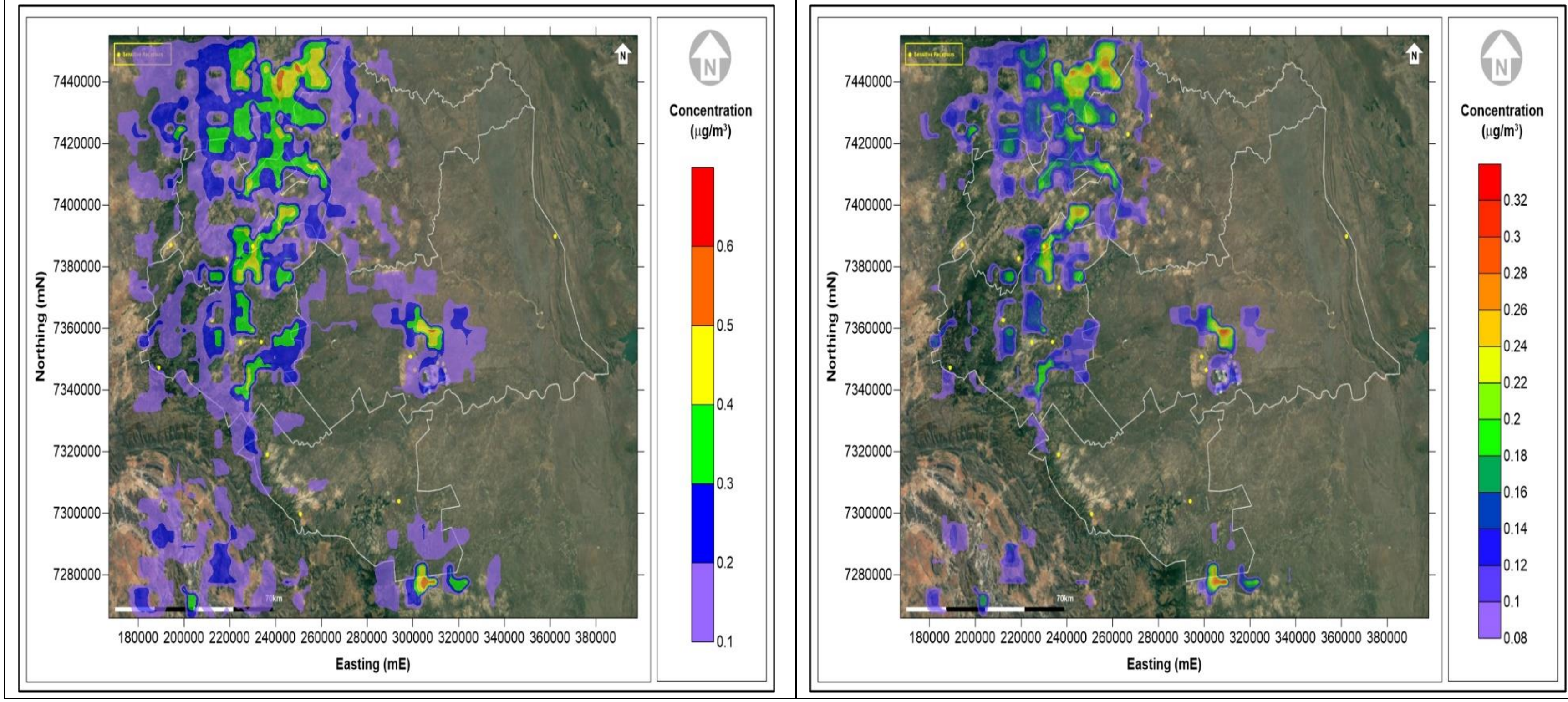


PM$_{2.5}$ (µg/m³) - annual averaging period

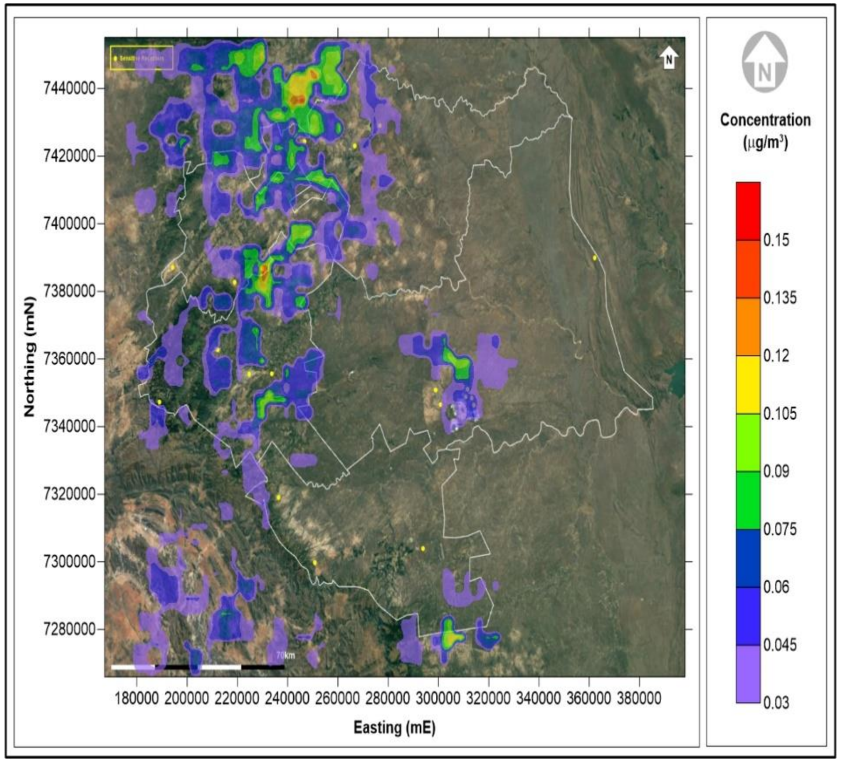


A-19: Simulated results for the DWB emissions (PM$_{2.5}$ - µg/m³).

SO_2 (µg/m³) - 1-hour averaging period – 99th percentile | **SO_2 (µg/m³) - 24-hour averaging period – 99th percentile**

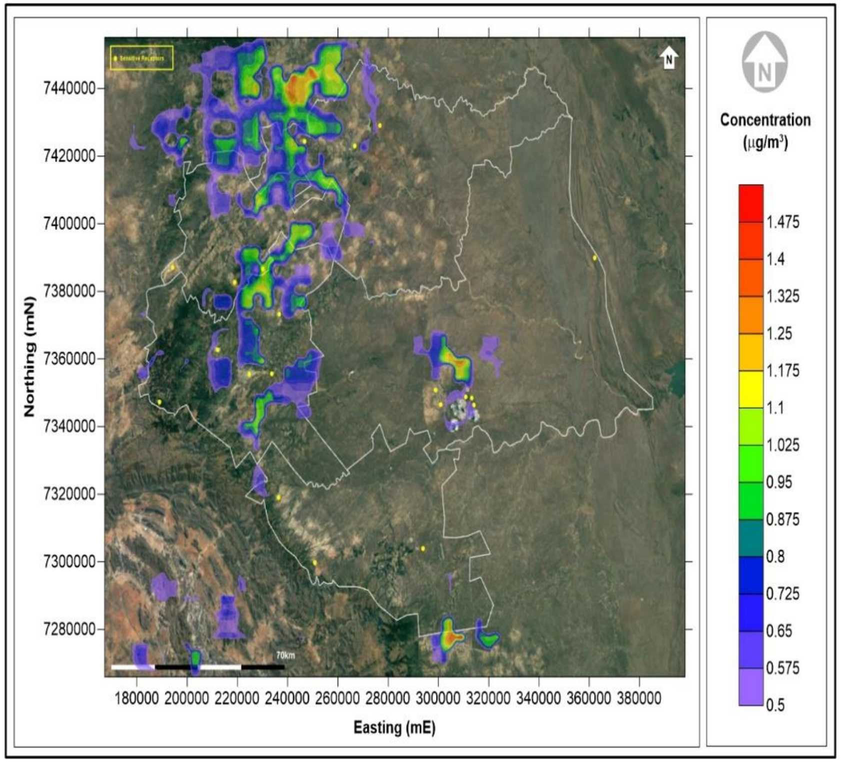


A-20: Simulated results for the DWB emissions (SO_2 - µg/m³).

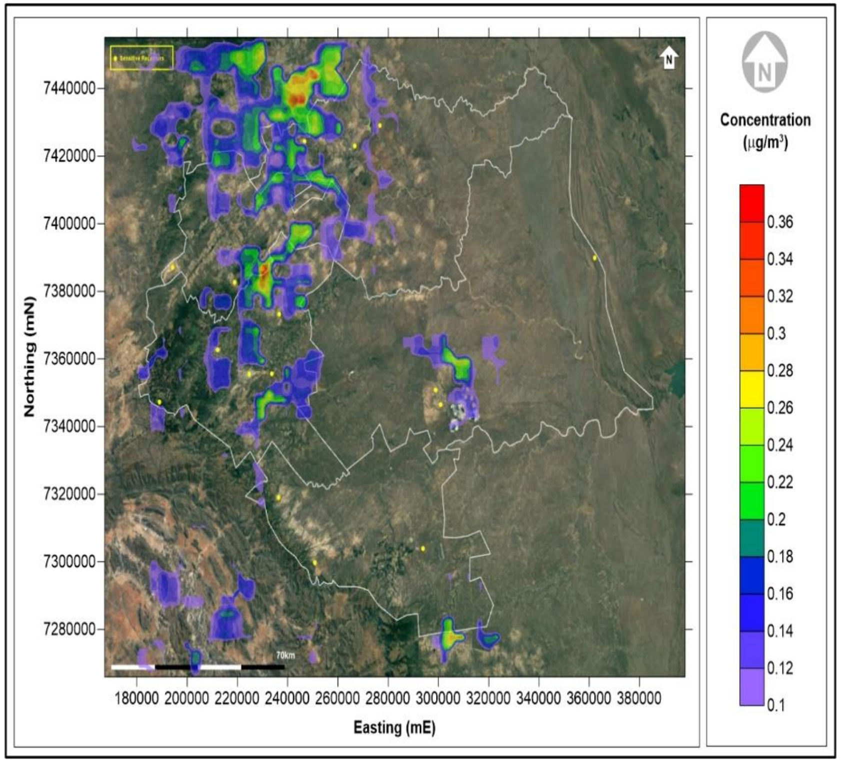
SO$_2$ (µg/m³) - annual averaging period	
 	

A-21: Simulated results for the DWB emissions (SO$_2$ - µg/m³).

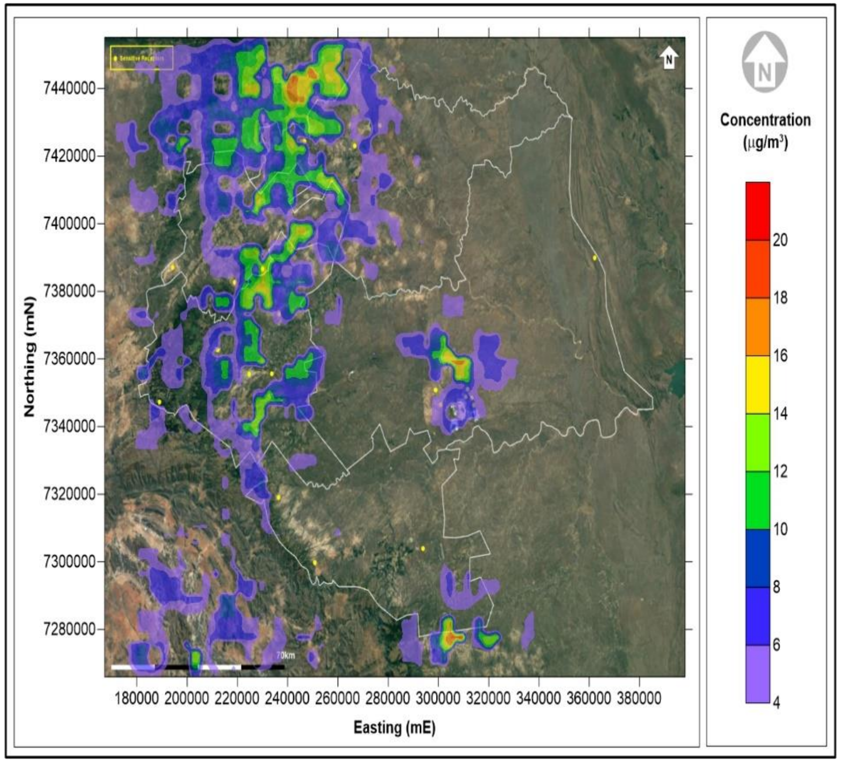
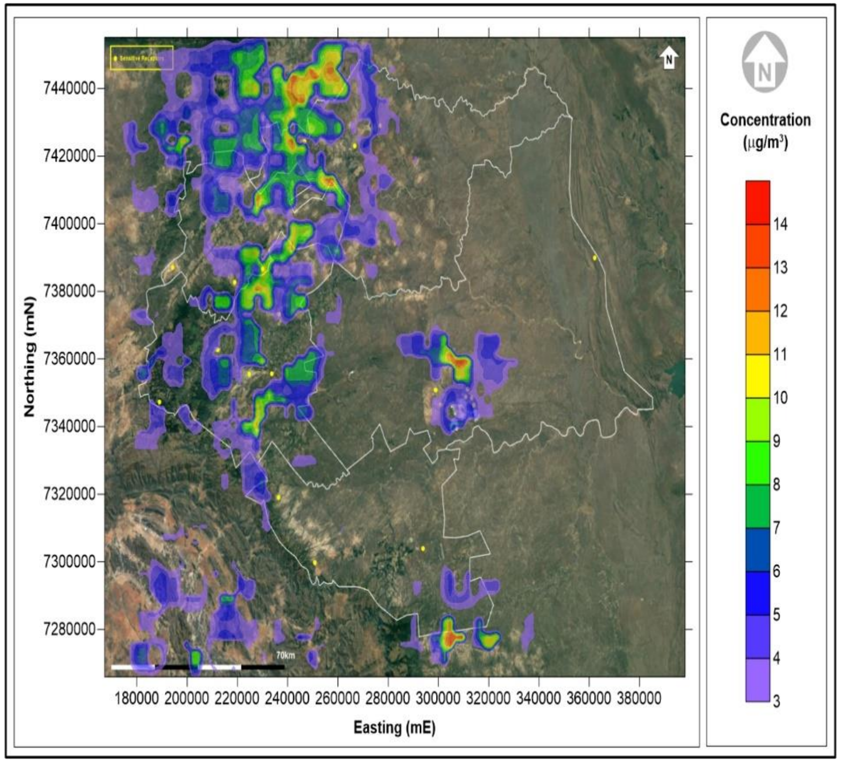
NO_2 (µg/m³) - 1-hour averaging period – 99th percentile



NO_2 (µg/m³) - annual averaging period



A-22: Simulated results for the DWB emissions (NO_2 - µg/m³).

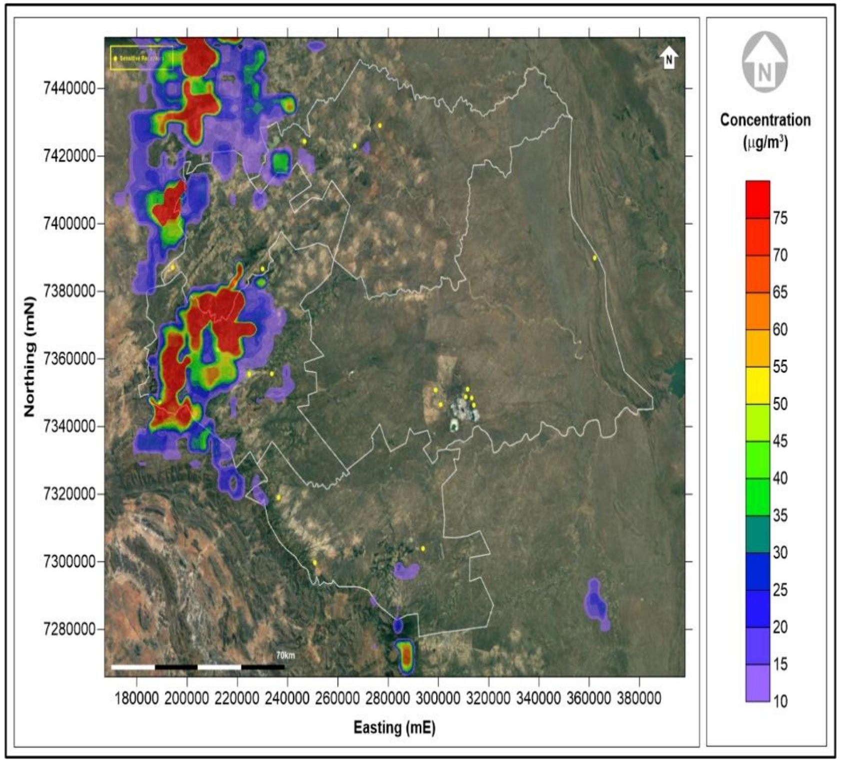
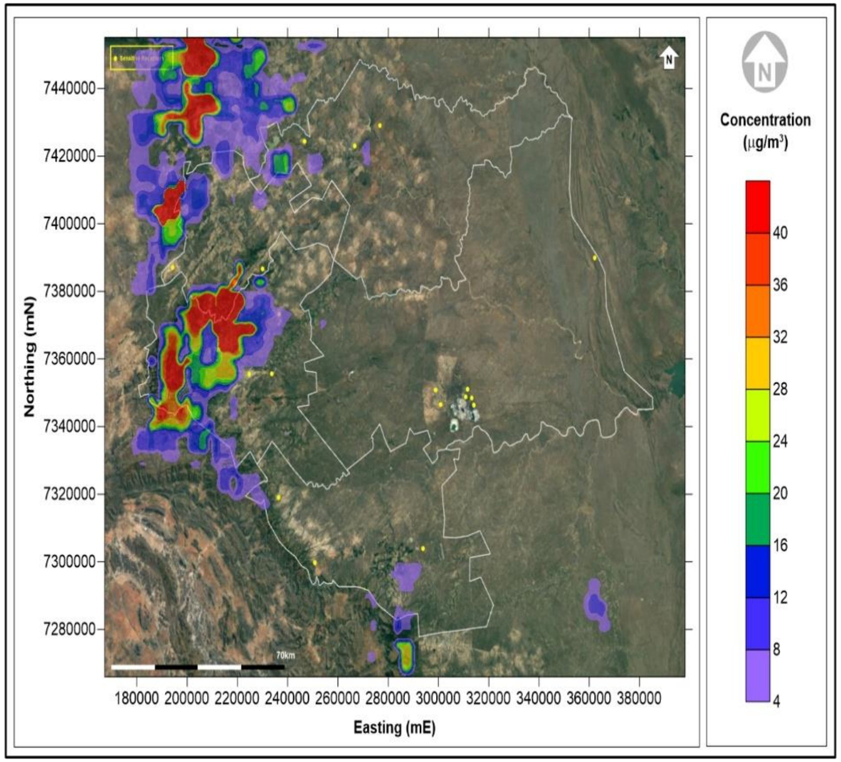
CO (µg/m³) - 1-hour averaging period – 99th percentile	CO (µg/m³) - 8-hour averaging period – 99th percentile
	

A-23: Simulated results for the DWB emissions (CO - µg/m³).

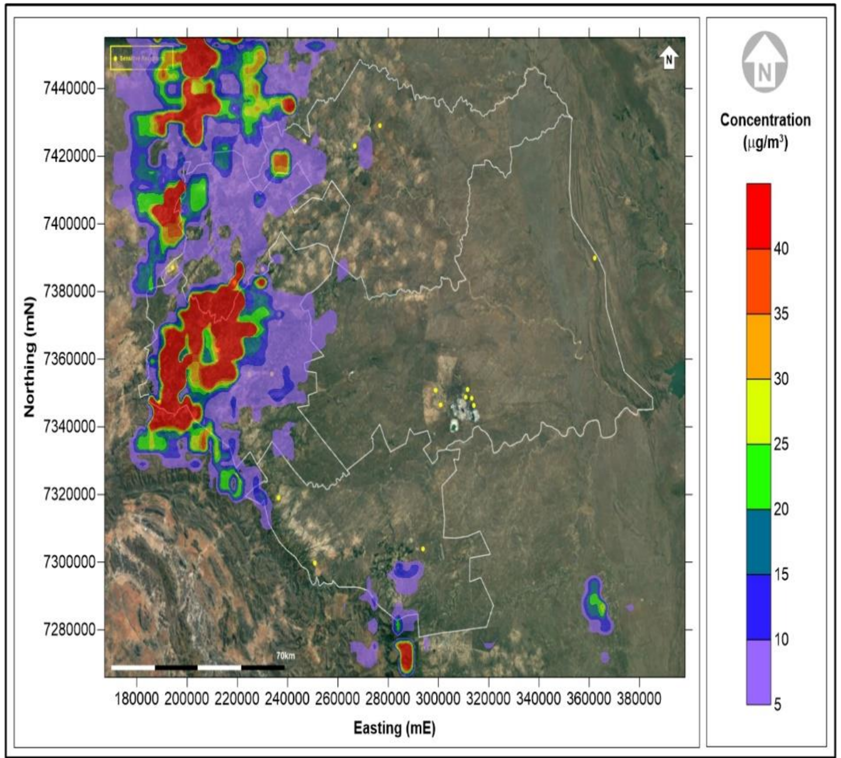
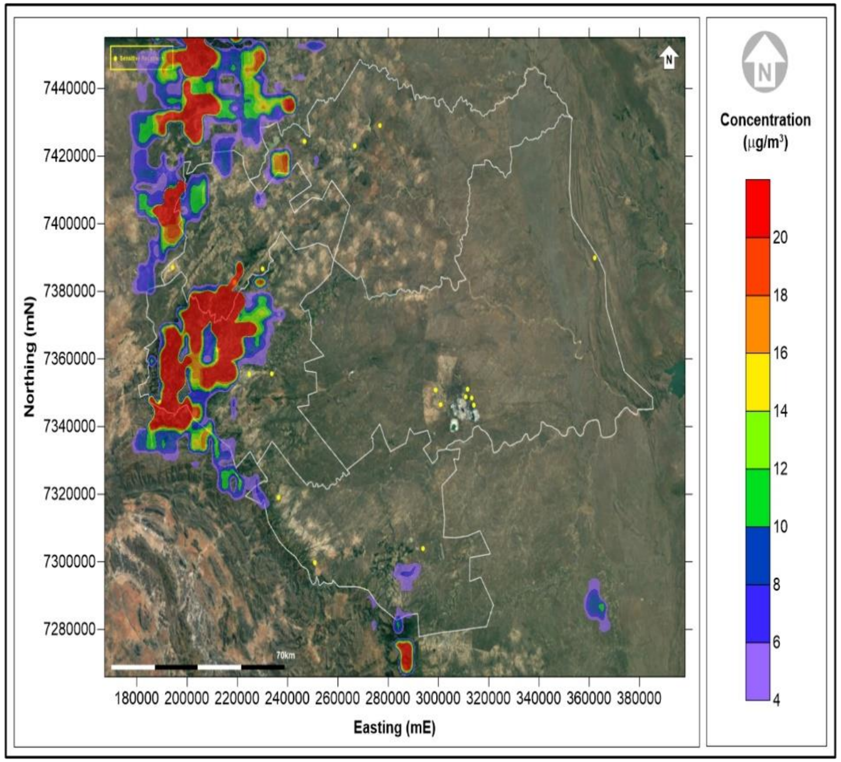
Biomass Burning Emissions

Figures A-24 to A-29 are graphical representations of the impacts (ground level concentrations) associated with the priority pollutants emanating from biomass burning emissions within the MDM airshed.

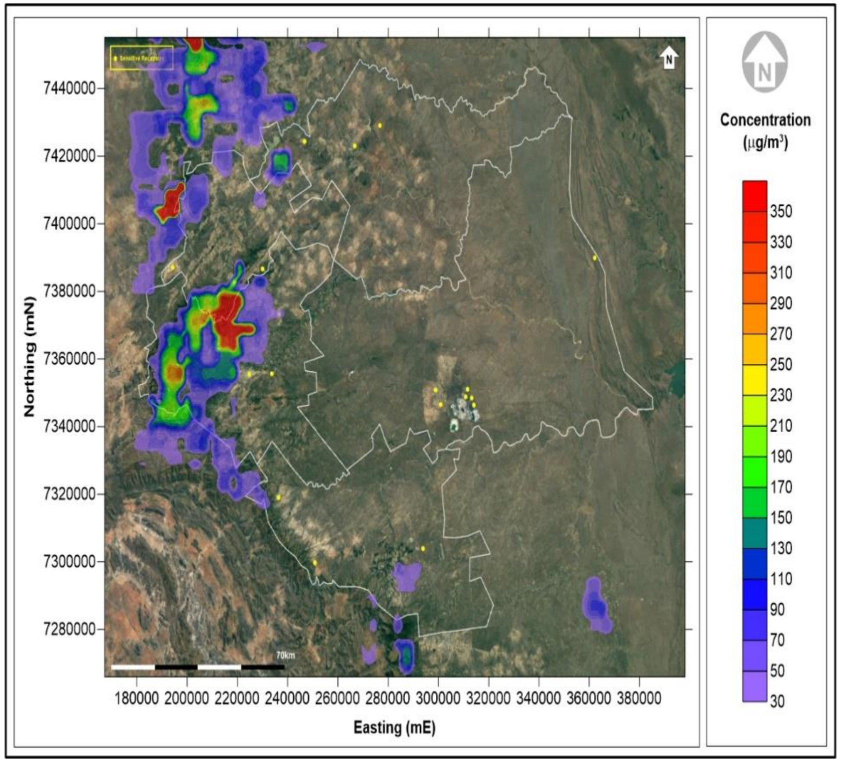
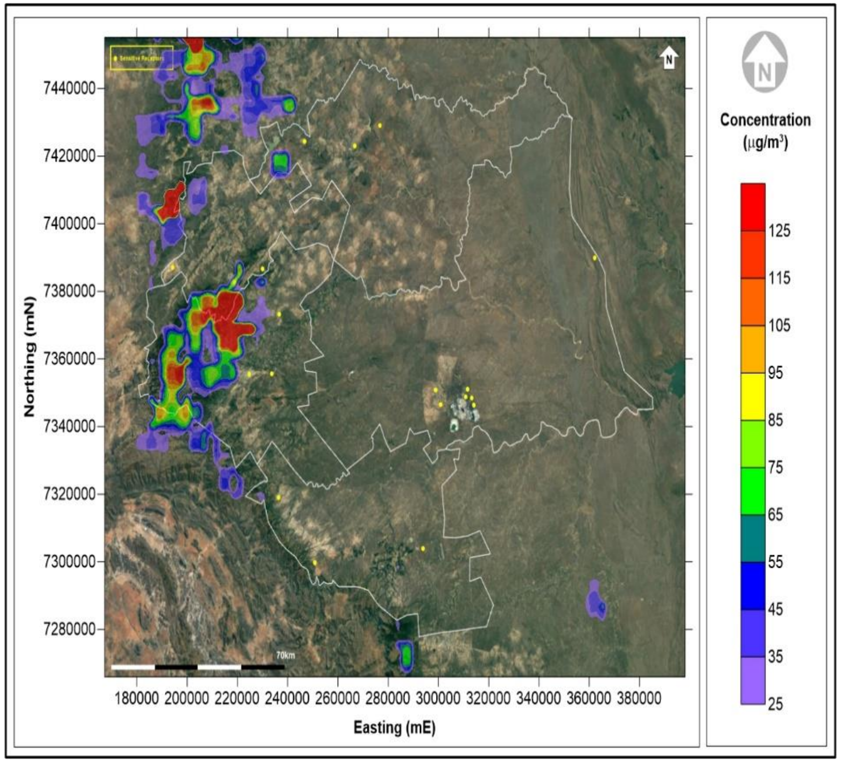
Elevated SO_2, PM_{10}, and $PM_{2.5}$ concentrations and exceedances were predicted based on the Biomass Burning emissions within the MDM.

PM_{10} (µg/m³) - 24-hour averaging period – 99th percentile	**PM_{10} (µg/m³) – annual averaging period**
	

A-24: Simulated results for the Biomass Burning Emission Sources (PM_{10} - µg/m³).

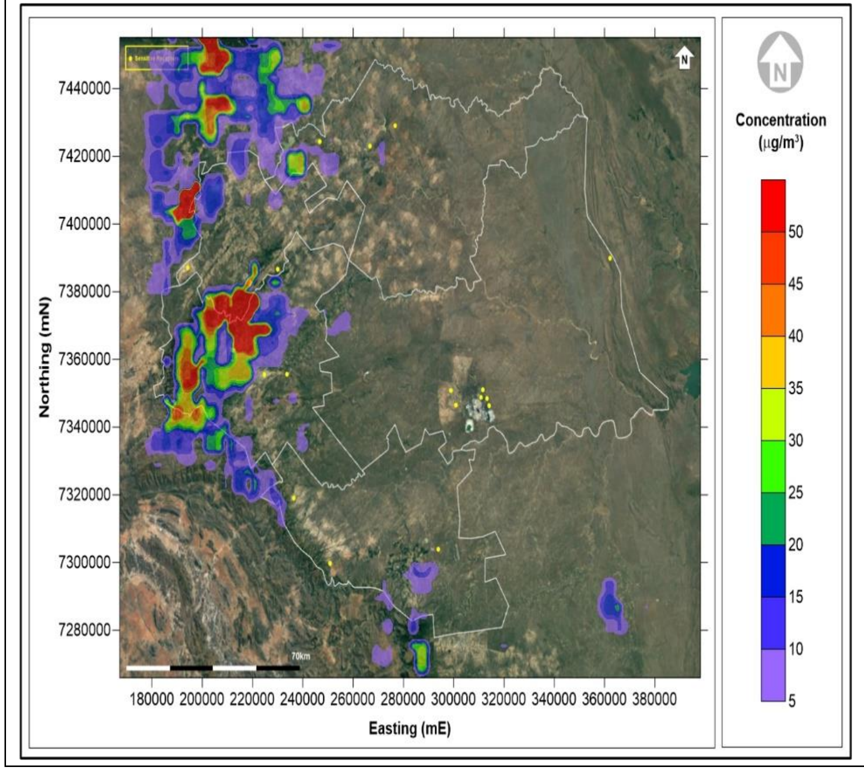
$PM_{2.5}$ ($\mu g/m^3$) - 24-hour averaging period – 99th percentile	$PM_{2.5}$ ($\mu g/m^3$) – annual averaging period
	

A-25: Simulated results for the Biomass Burning Emission Sources ($PM_{2.5}$ - $\mu g/m^3$).

SO₂ (µg/m³) - 1-hour averaging period – 99th percentile	SO₂ (µg/m³) – 24-hour averaging period – 99th percentile
	

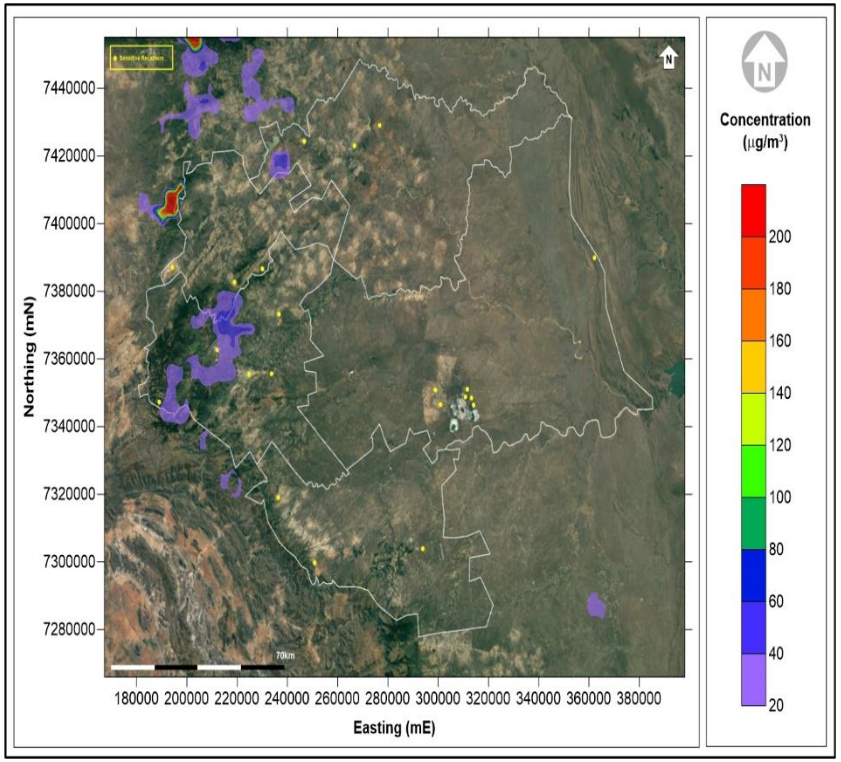
A-26: Simulated results for the Biomass Burning Emission Sources (SO_2 - µg/m³).

SO_2 (µg/m³) – annual averaging period

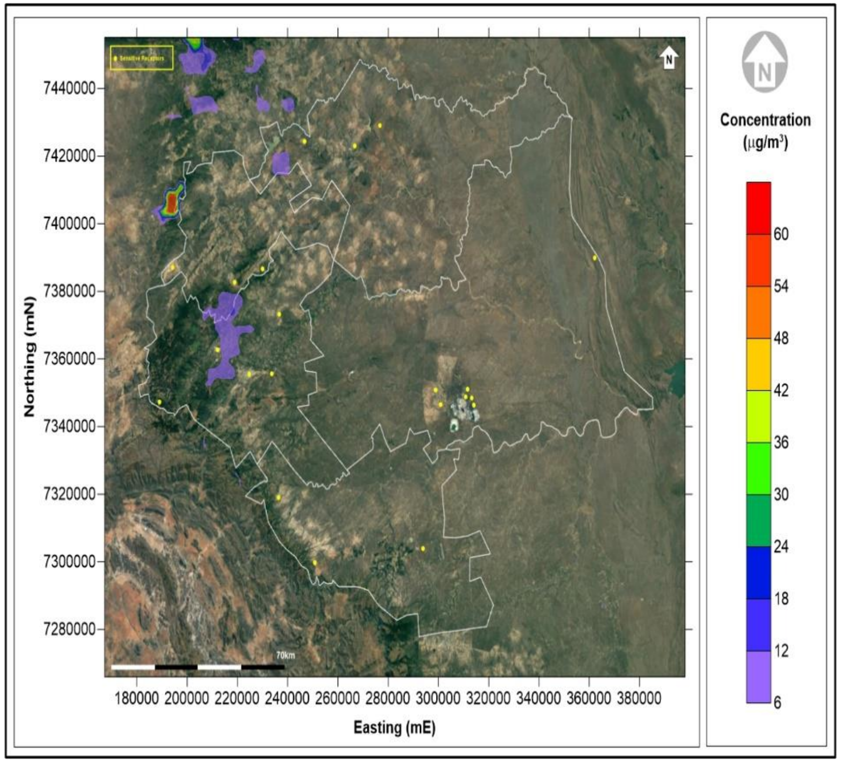


A-27: Simulated results for the Biomass Burning Emission Sources (SO_2 - µg/m³).

NO_2 (µg/m³) - 1-hour averaging period – 99th percentile

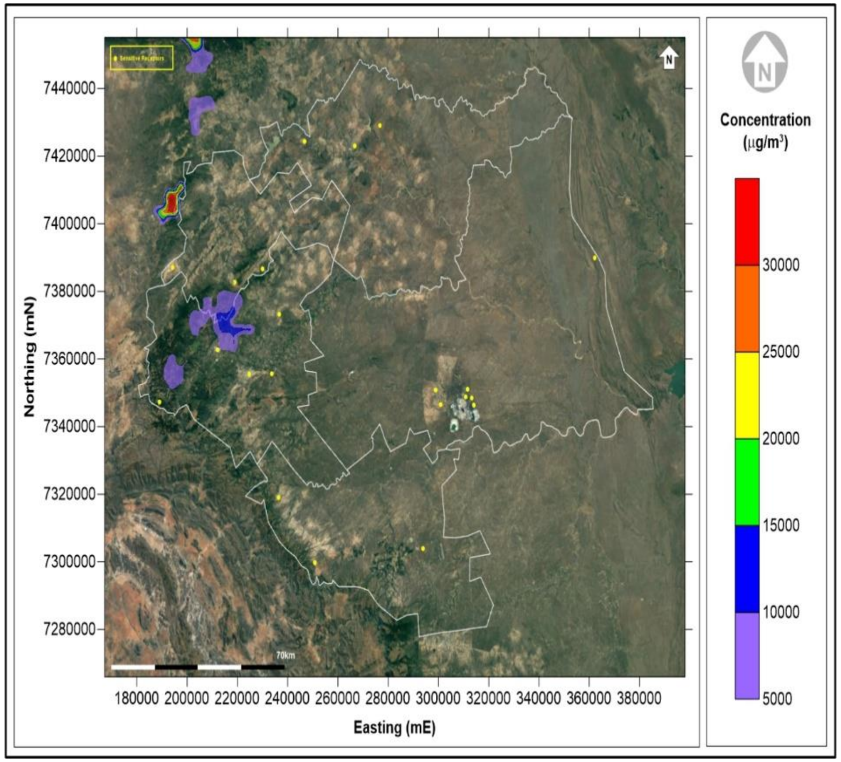


NO_2 (µg/m³) – annual averaging period

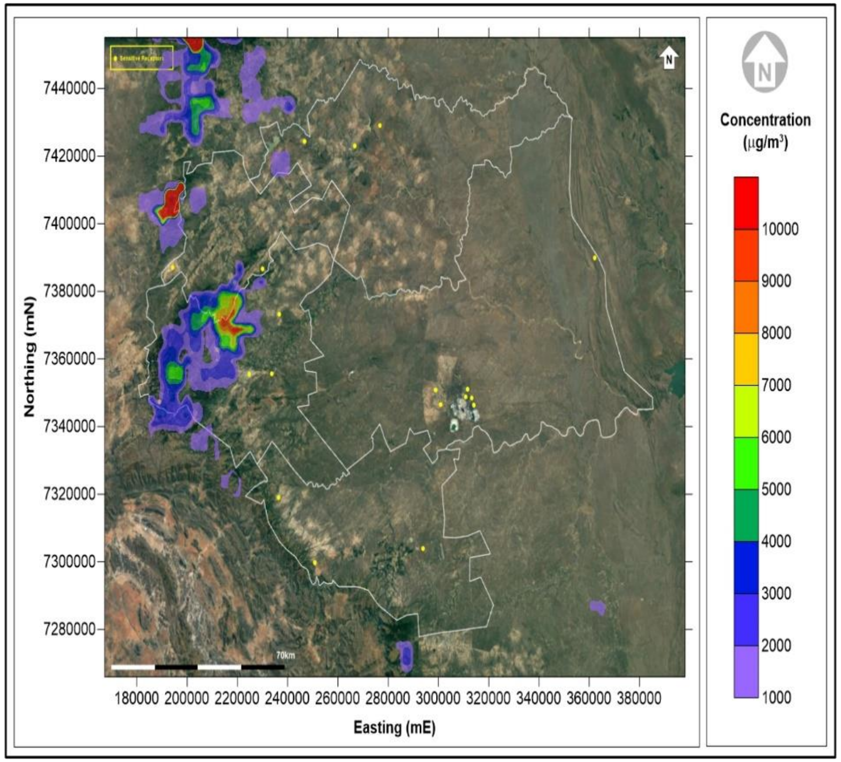


A-28: Simulated results for the Biomass Burning Emission Sources (NO_2 - µg/m³).

CO (µg/m³) - 1-hour averaging period – 99th percentile



CO (µg/m³) - 8-hour averaging period – 99th percentile

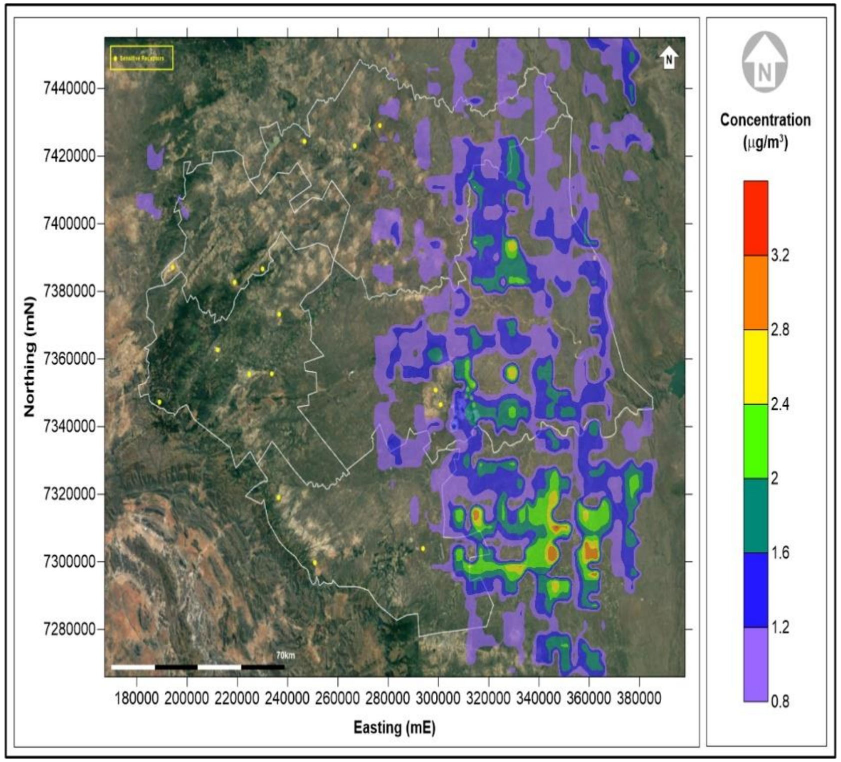
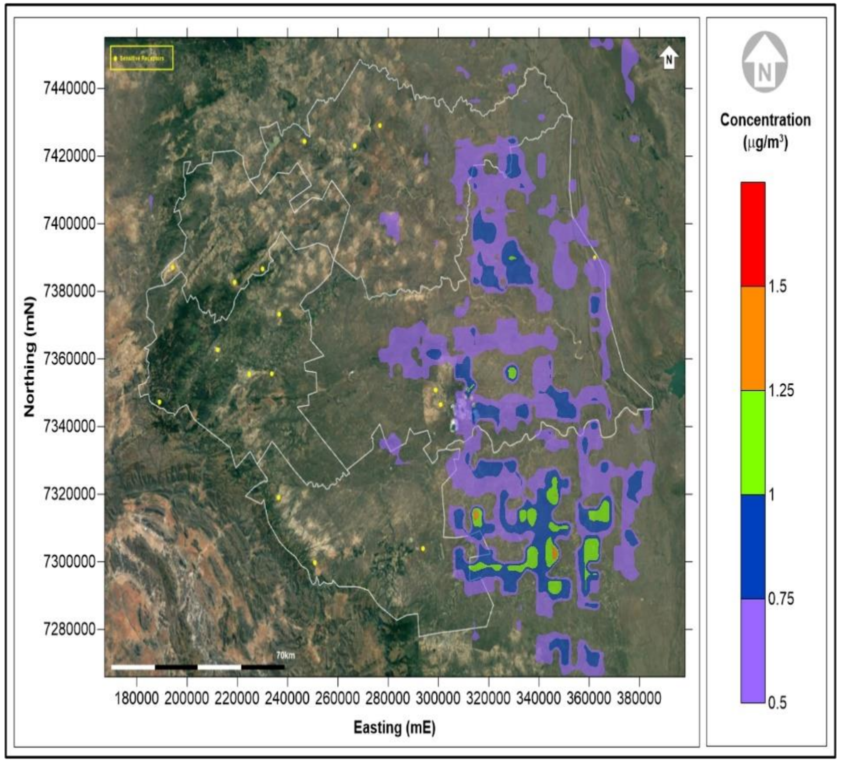


A-29: Simulated results for the Biomass Burning Emission Sources (CO - µg/m³).

Windblown Dust Emissions

Figures A-30 is a graphical representation of the impacts (ground level concentrations) associated with $PM_{2.5}$ emanating from windblown dust emissions within the MDM airshed.

In general, no exceedances and no elevated AAQ concentrations were predicted based on the windblown dust emissions within the MDM.

PM2.5 (µg/m³) - 24-hour averaging period – 99th percentile	PM2.5 (µg/m³) – annual averaging period
	

A-30: Simulated results for the Windblown Dust Emission Sources ($PM_{2.5}$ - µg/m³).