



CENTRAL KAROO

DISTRICT MUNICIPALITY

**63 Donkin Street
Private Bag X560
Beaufort West
6970**

**Tel: 023 – 449 1000
E-mail: manager@skdm.co.za**

Working together in development & growth

AIR QUALITY MANAGEMENT PLAN

(ADMINISTRATIVELY REVISED)

2026



**Revised by:
L Crafford
SNR EHP AIR QUALITY OFFICER WASTE MANAGER**

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A.**ABBREVIATIONS**

AQO	Air Quality Officer;
AQOF	Air Quality Officers Forum;
AQM	Air Quality Management;
AQMP	Air Quality Management Plan;
AEL	Atmospheric Emissions Licensing;
C₆H₆	Benzene
CKDM	Central Karoo District Municipality;
CO	Carbon monoxide;
DEA&DP	Department of Environmental Affairs and Development Planning;
DFFE	Department of Forestry, Fisheries and the Environment;
EIA	Environmental Impact Assessment;
EMI	Environmental Management Inspector
GHG	Green House Gas;
IDP	Integrated Development Plan
MSA	Municipal Systems Act;
NEM: AQA	National Environmental Management: Air Quality Act, Act 39 of 2004
NO	Nitric Oxide
NO₂	Nitrogen Dioxide;
NO_x	Nitrogen Oxides;
PM₁₀	Particulate Matter of aerodynamic diameter smaller than 10 micron;
SO₂	Sulphur Dioxide;
SA	South Africa.
VOC	Volatile Organic Compound

B. PURPOSE OF AIR QUALITY MANAGEMENT PLAN



Parliament saw fit to pass the NEM: AQA, Act 39 of 2004, in 2006. This Act resulted in a paradigm shift in air pollution control in SA as its main aim is to protect the environment by providing reasonable measures for the protection and enhancement of the quality of air in the Republic, the prevention of air pollution and ecological degradation; and securing ecologically sustainable development while promoting justifiable economic and social development; and generally to give effect to section 24(b) of the Constitution in order to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and well-being of people.

Its basis lies therefore in the Constitution of South Africa. In support of the Act DFFE formulated a National Framework for Air Quality Management in the Republic of South Africa.

Both the NEM: AQA and the National Framework place great emphasis on public participation in the decision-making process.

The Act requires municipalities to adopt AQMP's and is very specific in its definition regarding the goal of an AQMP. Of specific importance are the following:

- The improvement of air quality;
- Reducing negative impacts on human health and the environment;
- Addressing the effects of fossil fuels in residential applications;
- Addressing the effects of emissions from industrial sources: any point or non-point sources of air pollution;
- Implementing the republic's obligations in respect of international agreements; and,
- Giving effect to best practice in air quality management.

This AQMP will form the basis of a series of strategies and programs to ensure that all the principals of sustainability are adhered to. This will also enable the meeting of current needs as well as the maintenance of our resources for the benefit of future generations.

This Plan is also a commitment to certain principles and action plans needed to ensure sustainable utilization of resources and the management of air quality.

It is important that we all accept responsibility for the consequences of our actions and that we can make choices to reduce the impact. In this regard, local authorities have also an important role to play, representing the interest of the communities they serve.

The protection of the environment and resident's constitutional rights to clean air and an environment that is not harmful to their well being has been identified as a priority and can be seen as the driving force behind our effort to compile a comprehensive AQMP.

In addition, the Western Cape Provincial Government and / or Municipalities may change various plans and policies that may impact on the way in which air quality is managed in the Central Karoo District.

Such developments must be taken into account in future reviews of the AQMP.

C. LEGAL REQUIREMENTS



1. Constitution

Section 24 of the Constitution of South Africa (Act 108 of 1996) states that “Everyone has the right to an environment that is not harmful to their health or wellbeing and to have the environment protected through reasonable legislative measures.”

2. Air Quality Act

The National Environmental Management Act (Act 107 of 1998) was developed, and under this umbrella Act, Strategic Environmental Management Acts (SEMA's) were developed to place focus on specific environmental aspects. One such SEMA is the National Environmental Management: Air Quality Act (Act No. 39 of 2004; NEM: AQA).

Section 14, 15 and 17 of the NEM: AQA states, inter alia, the following municipal duties:

14. Appointment of air quality officers

- (3) *Each municipality must designate an air quality officer from its administration to be responsible for co-ordinating matters pertaining to air quality management in the municipality.*
- (4) (a) *An air quality officer must perform the duties or exercise the powers assigned or delegated to that officer in terms of this Act.*
 - (b) *An air quality officer may delegate a power or assign a duty to an official in the service of that officer's administration, subject to such limitations or conditions as may be prescribed by the Minister.*
- (5) *Air quality officers must co-ordinate their activities in such a manner as may be set out in the national framework or prescribed by the Minister.*

15. Air quality management plans

- (2) *Each municipality must include in its integrated development plan contemplated in Chapter 5 of the Municipal Systems Act, an air quality management plan.*

17. Reporting

Each Municipality must report annually on the implementation of its AQMP

In support of the NEM: AQA the following Sections of the National framework defines the air quality management responsibilities of municipalities:

3. Municipal by-laws

According to Section 156(2) of the Constitution, a municipality may make and administer by-laws for the effective administration of matters that it has the right to administer.

Air pollution is listed as a matter in which local government has authority and national or provincial government may not compromise or impede a municipality's right to exercise its powers or perform its functions.

Within this context, municipalities may develop by-laws that deal with air pollution.

4. Municipalities

As with DFFE and the Provincial Departments, municipalities have a number of responsibilities within the governance cycle which is described in Chapter 4.

However, each municipality has a number of exclusive air quality management powers as summarised below.

In this regard, the municipality must:

- Designate a municipal AQO from its administration;
- Develop an AQMP for inclusion in its IDP in accordance with Chapter 5 of the Municipal Systems Act;
- Prepare an annual report including progress regarding the implementation of the AQMP and compliance with the plan.

The municipality may also:

- Establish local standards for emissions from point, non-point and mobile sources if a municipality Identify a substance or mixture of substances in ambient air which through ambient concentrations, bioaccumulation, deposition or any other way, presents a threat to health or well-being or the environment, or which the municipality reasonably believes presents such a threat;
- Require the appointment of an Emission Control Officer in a given company (Section 48 of NEM: AQA), thereby extending the powers of the authority by ensuring that the Emission Control Officer is responsible for the company applying the correct measures to minimise emissions.

Special mention must be made of the following stipulation contained in Section 3.2.3 of the National Framework:

District Municipalities must:

- Implement the atmospheric emission licensing system, and carry out the responsibility for performing the functions of the licensing authority as set out in Chapter 5 of the NEM: AQA.

This paragraph implies that Category B-Municipalities is not entitled to issue atmospheric emissions licenses as this activity fall within the power granted to CKDM.

Nevertheless, Category B-Municipalities in the Central Karoo District are within their rights to provide input into the AEL decision making process.

Chapter 4 lists some of the following functions as the primary responsibility of a municipality:

- Monitor ambient air quality and point, non-point and mobile source emissions;
- The development of air quality management plans as a component of integrated development plans as required by the MSA;
- The setting of local standards for emissions from point, non-point or mobile sources in the municipality in respect of identified substances or mixtures of substances in ambient air which, through ambient concentrations, bioaccumulation, deposition or in any other way, present a threat to health, well- being or the environment in the municipality;
- Monitoring compliance in respect to reasonable steps to prevent the emission of any offensive odour caused by any activity;
- Monitoring compliance with directives to submit an atmospheric impact report.

Therefore, both the NEM: AQA (Section 15) and National Framework (Section 3.2.3) emphasize the fact that a municipality is required to compile an AQMP and to include such a plan in the municipality's IDP.

5. Public Participation

Various Sections of the Air Quality Act and Section 5.9.1 of the National Framework in particular, place significant importance on the participation of the general public in the air quality decision making process.

To meet the requirements of both the NEM: AQA and National Framework extensive steps must be taken to inform the public of the 5 yearly AQMP review process and to solicit comments as widely as possible. (A yearly administrative review will be an internal review without public participation)

D. THE CENTRAL KAROO DISTRICT IN A GLANCE



1. General info

The Central Karoo District is one of five districts in the Western Cape Province.

The district comprises of three Local Municipalities, namely Beaufort West, Prince Albert and Laingsburg.

With a population of 102 173, the Central Karoo is the smallest district in the province. The district is the largest in the Western Cape province by area, spanning a total of 38, 885 square kilometers.

The Central Karoo District is bounded by a number of mountain ranges, namely the Swart-and Witteberge in the South, the Sneeuberg in the East, the Nieuveld Mountain range in the North and the Koms- and Witteberge range in the West.

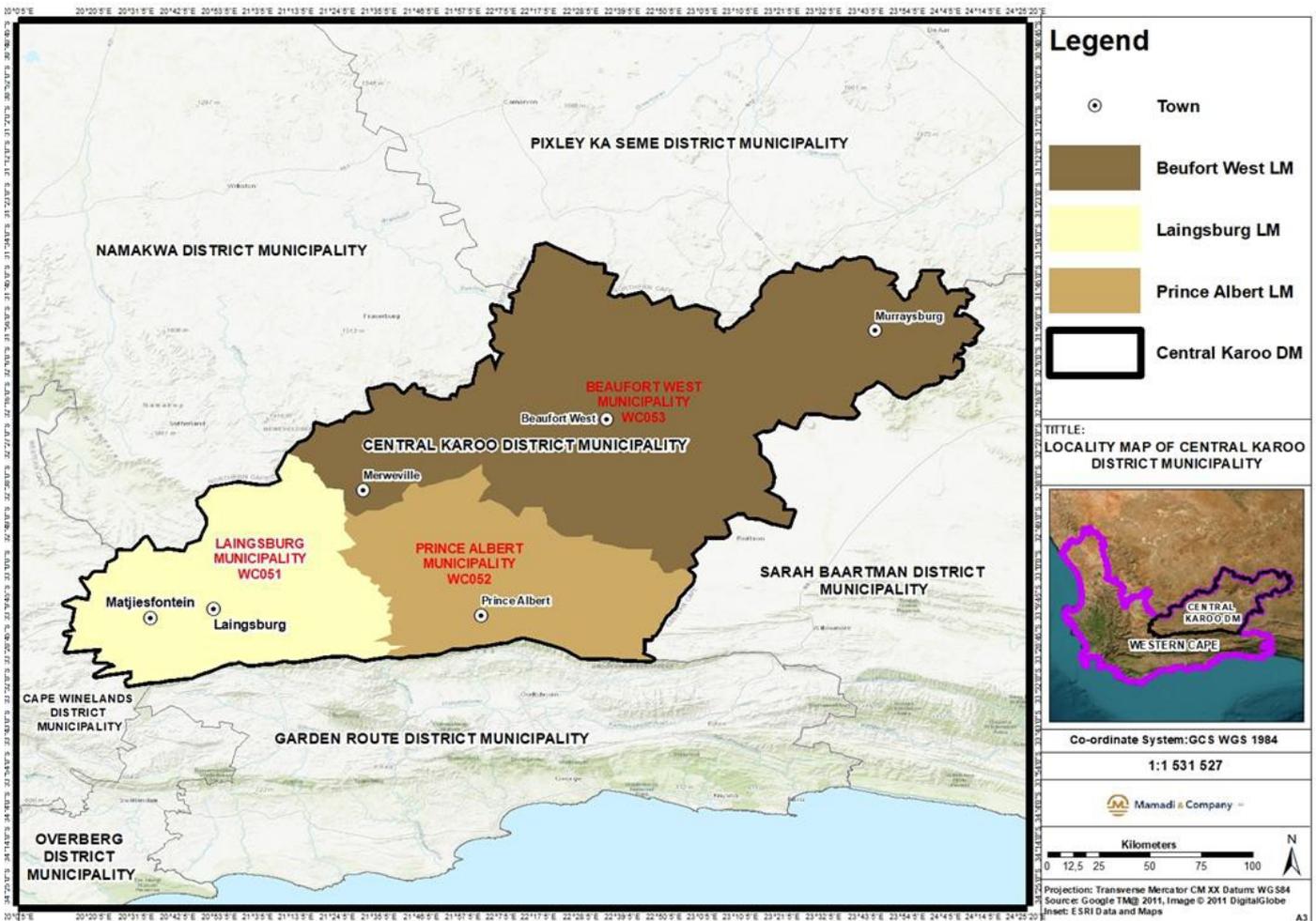
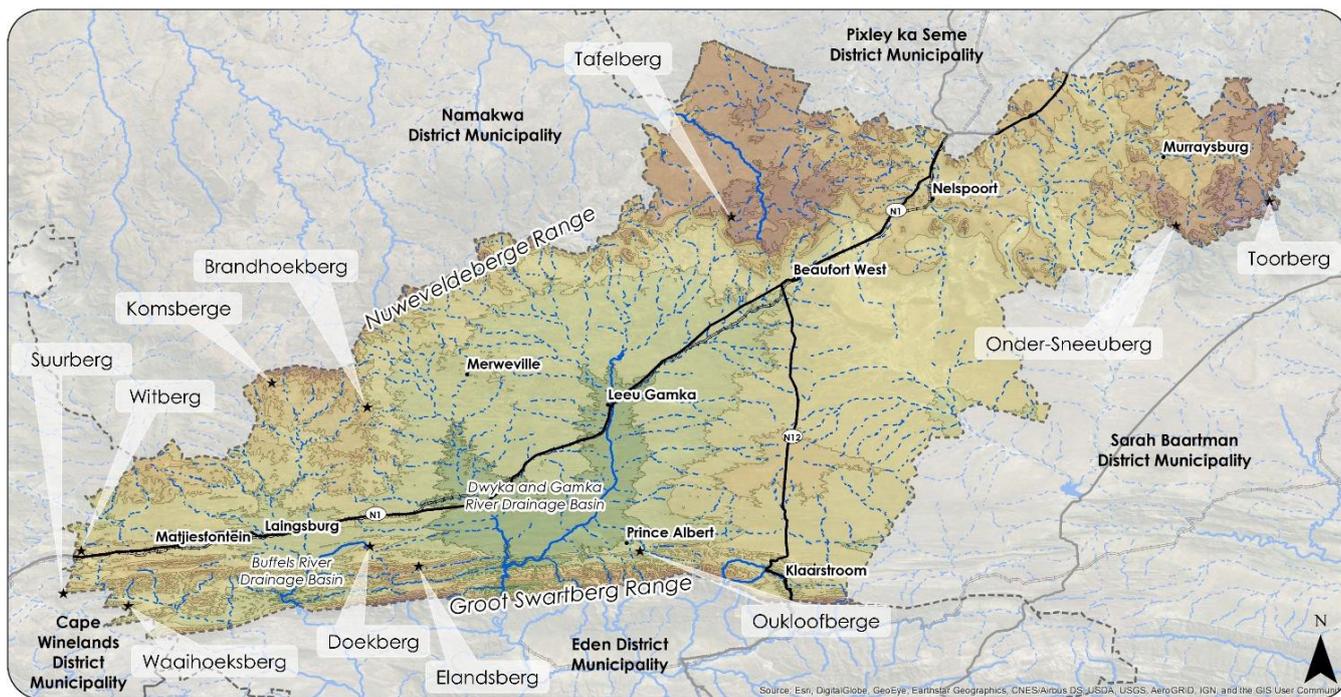


Figure 1: Locality Map of Central Karoo District



Elevation and Landscape Features Map: Central Karoo District Municipality

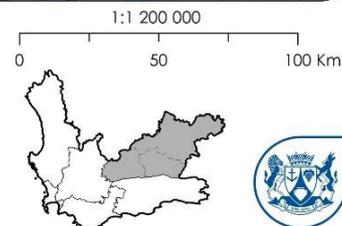


Figure 2: Schematic of the topography of the Central Karoo District

2. Socio-Economic Profile

Available information on the socio-economic profile of the Central Karoo District is as follow:

Growth and Demographic Profiles for CKDM (Stats SA, Census 2011 & 2022).

Population Growth		
Municipality Total Population (Stats SA, 2022)	102 173	
Population Growth Rate (%) (Stats SA, 2022)	3.99%	
Municipality Total Population (Stats SA, 2011)	71 011	
Averaged Population Growth rate (%) (Stats SA, 2011)	1.92	
Demographic Profiles		
Age		
Young (0 – 14 years)	27.6%	28 200
Middle Age/Working Age (15 – 64 years)	65.9%	67 332
Old Age (65+ years)	6.5%	6 641
Gender		
Male	47,9%	48 955
Female	52,1%	53 218
Education		
No Schooling (20+ years)	5.2%	5 313
Tertiary (20+ years)	6.7%	6 846

Population Groups		
Black African	11.9%	12 150
Coloured	80.7%	82 329
Indian/Asian	0.3%	341
White	5.6%	5 718
Other	1.4%	1 427

CKDM Employment Status

Municipality	Employment Status Stats 2011		Employment Status (Socio-Economic Profile 2022)	
	Employment	Unemployment	Employment	Unemployment
Laingsburg	2 935	638	2 704	2 707
Prince Albert	3 513	844	3 448	6 006
Beaufort West	11 012	3 772	11 477	19 647
Central Karoo	17 460	5 254	17 748	28 887

Income status of CKDM

Income statistics is not included in Stats SA 2022, as a result, Stats SA 2011 averages were used with the assumption that all income groups grew at the same rate. CKDM has 78.9% of its households falling within the low-income level and 1% in the high-income level.

(Stats SA, 2011 Estimate for 2022)

Income Levels	Households	%
Low income (No income – R76 400)	21788	78.9
Middle income (R76 401 – R614 400)	5537	20
High income (R614 001 – R2 457 601 or more)	318	1

Household Dwelling Types (Stats SA 2022)

Dwelling Types		
Formal dwelling	26 962	98.8%
Traditional dwelling	775	0,3%
Informal dwelling	225	0,8%
Other	29	0,1%

CKDM Population Growth Projections

Municipality	Census (2022)	Estimated (2032)	Estimated (2042)	Estimated (2052)
Laingsburg	11 366	15 832	22 053	30 721
Prince Albert	17 836	24 558	33 814	46 558
Beaufort West	72 972	111 066	169 047	257 297
Central Karoo	102 173	151 095	223 443	330 433

CKDM's Number of Households Projections (Stats SA,2011/2022)

Municipality	Census (2011)	Census (2022)	2011-2022	Estimated (2027)	Estimated 2032	Estimated 2042	Estimated 2052
				(5 years)	(10 years)	(20 years)	(30 years)
Laingsburg	2 408	3 314	906	3 907	4 616	6 430	8 957
Prince Albert	3 604	4 760	1 156	5 617	6 636	9 236	12 865
Beaufort West	13 088	19 216	6 128	23 706	29 247	44 516	67 755
Central Karoo	19 100	27 290	8 190	33 185	40 356	59 681	88 256

3. Rainfall

The climate of Central Karoo District is arid to semi-arid with approximately 75% of the district receiving less than 200 mm of rain per annum.

The highest rainfall occurs in the Groot Swartberg Mountain range south of Prince Albert and in the Sneeuberge southeast of Murraysburg.

Apart from the far western portion which receives mainly winter rain, the highest rainfall probability is during March and April.

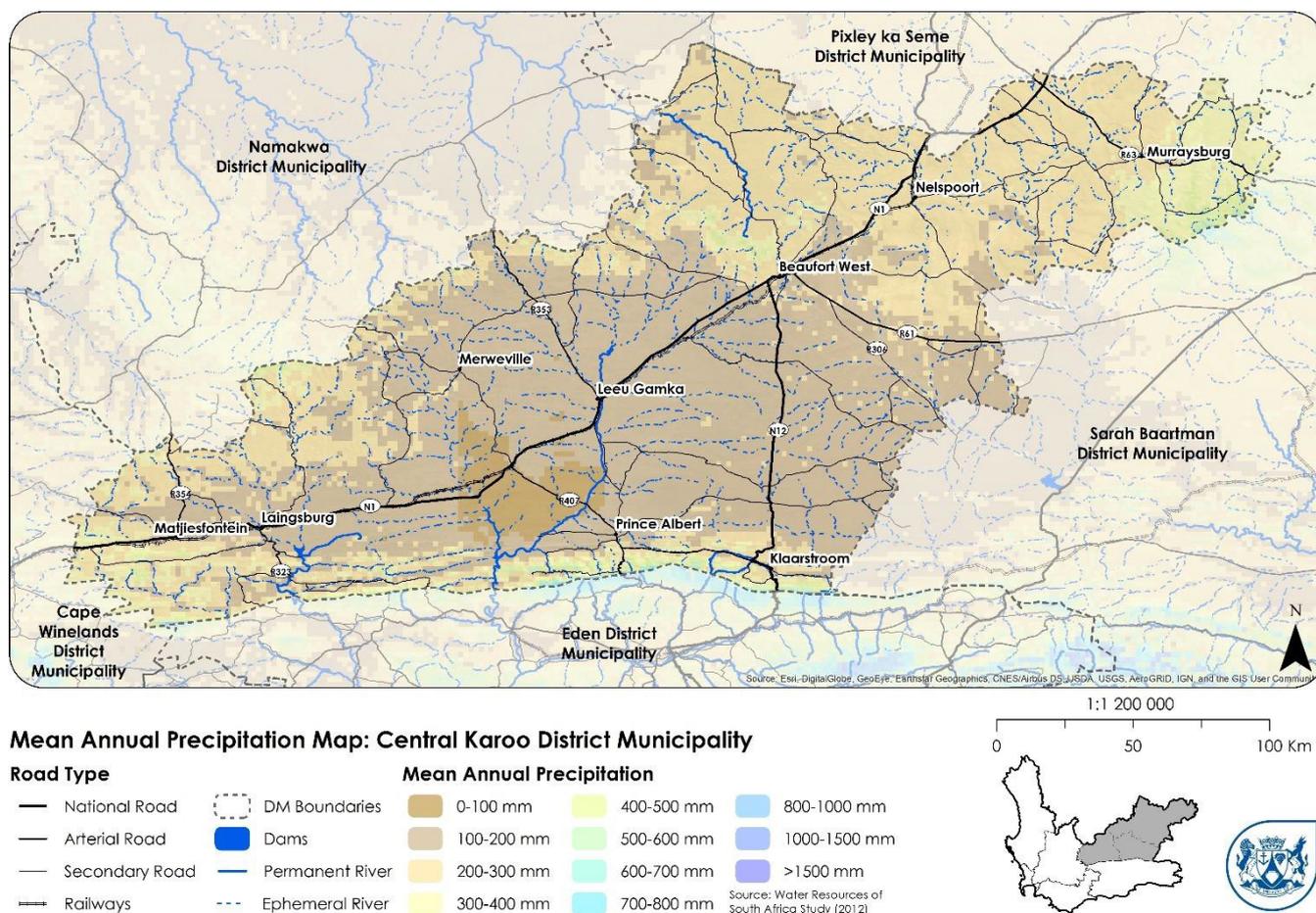


Figure 3: Mean Annual Precipitation Map for Central Karoo District Municipality

4. Wind

The wind varies across the Central Karoo DM. As an example, the winds at Beaufort West are predominantly from two sectors.

Firstly, winds from the sector northeast to east, with a relatively high frequency of light to moderate winds, and winds from the south-southwest to southwest that are generally stronger.

Winds from all other sectors are infrequent, but the occasional north westerlies are strong. More wind is experienced at Laingsburg, but the winds are generally lighter than at Beaufort West.

The dominant wind sectors are northwest to west-northwest and east to southeast. South-westerly winds also occur.

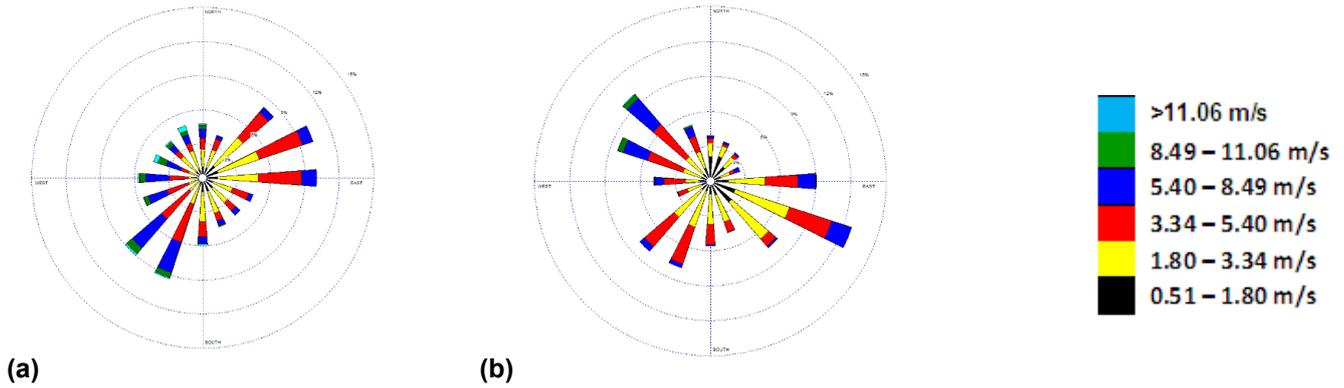


Figure 3: Annual wind roses for a) Beaufort West and b) Laingsburg for the 5-year period 2003 to 2007.

5. Temperature

The temperature regime of the Central Karoo District is typically continental, meaning there is a large difference between the mean temperature of the coldest and warmest month (11 – 13°C).

January is generally the warmest month with mean maximum temperatures between 28 and 32°C. Heat wave conditions do occur and could induce temperature in excess of 40°C.

The coldest months are June and July, with early morning temperatures regularly dropping to below 0°C. Frost is therefore common in the entire district, with severe frost at the higher altitudes.

6. Roads

Beaufort West is the gateway to the Western Cape as well as the main service and development centre for the area.

The N1 national road that bisects the Central Karoo is a key transport corridor for road-based freight transport, passenger services and private vehicles.

Running parallel to the N1 through the Central Karoo is the long-distance main railway line connecting Cape Town to Johannesburg/Pretoria and the other main urban centers of South Africa.

The road route to the Eastern Cape branches off at Beaufort West and goes via Aberdeen or Murraysburg. A second main road transport route, the N12, connects to the N1 south of Beaufort West, providing a link to Oudtshoorn and George. Map: Figure 2 shows the road and rail networks of the Central Karoo District.

The N1 national road runs through the Central Karoo District. This vital link bisects South Africa on a northeast-southwest axis, providing access to and between Limpopo Province, Gauteng, the Free State and the Western Cape. Within the Central Karoo District, it links the towns of Beaufort West, Leeu-Gamka, Laingsburg and Matjiesfontein.

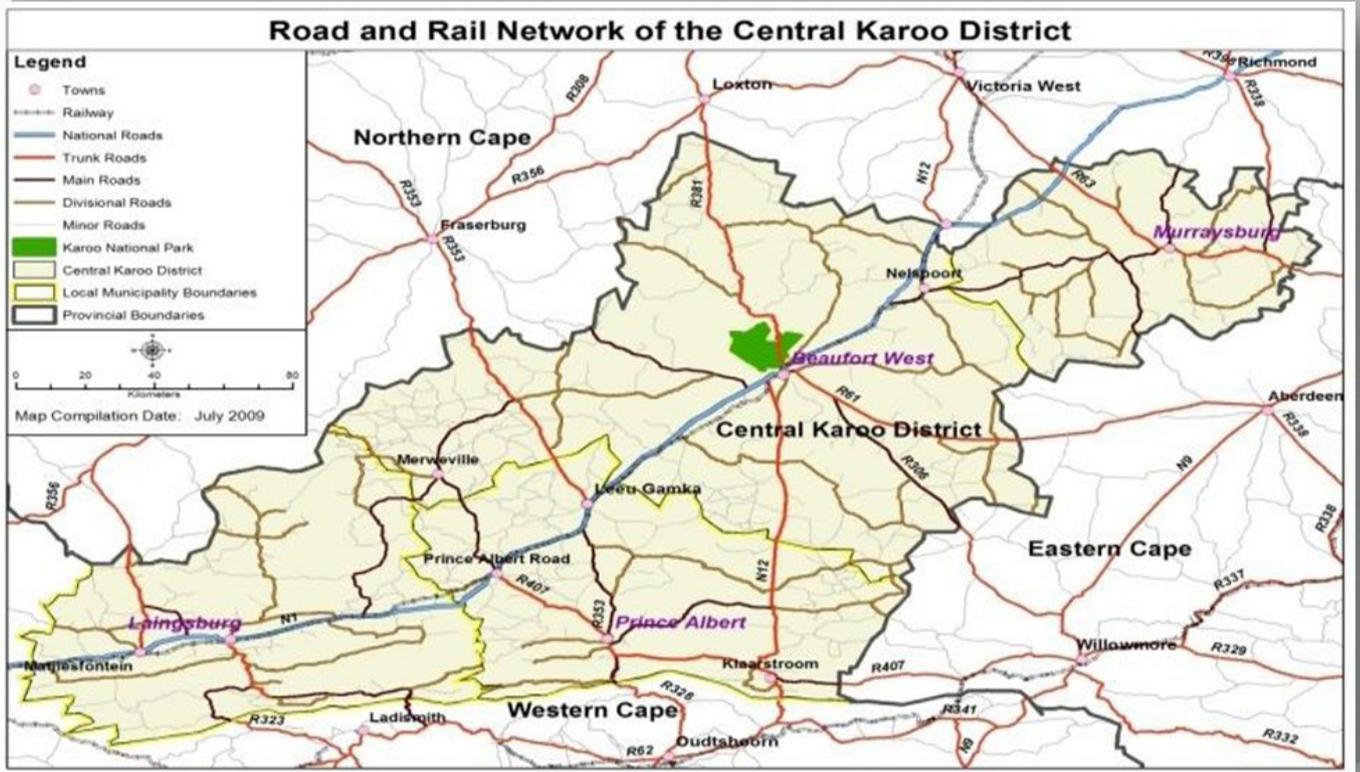


Figure 4: Road and Rail Networks of the Central Karoo District

7. Mining

The Central Karoo District is highly rich in minerals such as uranium as well as shale gas. There has been increasing interest in mining of these minerals in the area recently, as is evident by the increase in the number of prospecting applications.

This is significant as both prospecting and mining are associated with various environmental impacts. The extraction of shale gas has been a matter of great controversy national and international. This is a result of the potential environmental impact associated with this activity.

The establishment of the extraction / mining sites will also increase the transport activities, which may detract from the aesthetic value of the region which has been long preserved for local communities. During the extraction process, methane and carbon dioxide are released. It should be noted that methane is a more powerful greenhouse gas than carbon dioxide.

8. Climate Change

According to the Climate Change Strategy for the Western Cape, it is envisaged that the Western Cape will become significantly hotter and drier.

This has considerable implications for the Central Karoo District as it is already characterized by very high temperatures and a dry climate.

It is estimated that within 50 to 100 years, areas that support succulent Karoo vegetation's may become arid that only the hardiest plants of that biome will be able to survive.

An increased dry hot climate brings about a bigger possibility of fire, which can be devastating to whatever vegetation that is left within this district.

E. VISION & MISSION



The Central Karoo District’s greatest assets are its people and natural environment.

This unique environment must be protected from abuse and exploitation if the district is to remain a tourist attraction in years to come.

A key step in this protection is the effective management of the ambient air quality as it is a basic requirement for all living species. It is of sufficient importance to be included in Section 24 of the Constitution of South Africa.

This AQMP is aimed at achieving exactly that, namely the protection of the ambient air quality in the Central Karoo District.

To guide the AQMP the following vision and mission statement has been formulated:

Vision

To maintain air quality to such a standard that economic and social development will flourish without jeopardizing the environment.

Mission Statement

To minimise the impact of air pollutant emissions on the population and the natural environment of the Central Karoo District and to promote the use of renewable energy sources such as wind, sun and water in order to support global initiatives to prevent ozone depletion and global warming

F.

GOALS



Each of the four (4) goals of the AQMP address different aspects of our vision, these are:

- To ensure effective and consistent AQM. This goal aims to address the development and maintenance of the varied requirements for systems, skills and capacity for Air Quality Management, and the establishment of the necessary institutional arrangements;
- To ensure effective and consistent compliance monitoring and enforcement. This goal aims to improve compliance monitoring and enforcement in the district, and to ensure that ambient air quality standards for the protection of health are attained and continually met;
- To support climate change protection programmes, including promoting the reduction of Green House Gas emissions; and,
- To raise awareness with respect to air quality. This goal aims to improve awareness of air pollution issues in the Central Karoo District through awareness raising and education;

G. AIR QUALITY MANAGEMENT IN THE CENTRAL KAROO DISTRICT



1. Roles and responsibilities of the Central Karoo District Municipality

The roles and responsibilities of the District Municipality are outlined in the National Environmental Management: Air Quality Act, 2004 (Act 39 of 2004) (NEM: AQA) as well as the National Framework for air quality management in the Republic of South Africa.

These are:

- Monitor ambient air quality and point, non-point and mobile source emissions;
- The development of air quality management plans as a component of integrated development plans as required by the Municipal Systems Act;
- The setting of municipal standards for emissions from point, non-point or mobile sources in the municipality in respect of identified substances or mixtures of substances in ambient air which, through ambient concentrations, bioaccumulation, deposition or in any other way, present a threat to health, well-being or the environment in the municipality;
- Implement the NEM: AQA atmospheric emission licensing system referred to and for this purpose perform the functions of licensing authority as set out in Chapter 5 and other provisions of the NEM: AQA;

- Monitoring potential illegal listed activities;
- Monitoring compliance with emission standards in respect of the manufacture, sale or use of any appliance or conducting of an activity declared as a controlled emitter;
- Monitoring compliance in respect to reasonable steps to prevent the emission of any offensive odour caused by any activity;
- Monitoring compliance with directives to submit an atmospheric impact report;
- Monitoring compliance with conditions or requirements of an atmospheric emission license;
- Monitoring any application for an atmospheric emission license, or for the transfer, variation or renewal of such a license to ensure that it does not contain false or misleading information; and to,
- Monitoring any information provided to an air quality officer to ensure that it does not contain false or misleading information.

2. Institutional Functions

The District and Local Municipalities within the Central Karoo District currently cannot fully accept their responsibility with the implementation of the NEM: AQA.

Insufficient commitments, acceptance at political and municipal management level and personnel- and financial capacity constraints as well as good ambient air quality in general, with almost no industries, has resulted in inadequate financial and other resource provision.

In terms of Section 14 of the NEM: AQA each Municipality must designate an AQO from its administration to be responsible for co-ordinating matters pertaining to air quality management in a municipality.

An AQO has already been designated from the ranks of the Municipal Health Services component of the CKDM.

AQO's have also been appointed within the different Category B–Municipalities in the Central Karoo District.

The NEM: AQA and MSA both delegate powers of responsibility for air pollution related issues to municipalities, but to different levels. While the NEM: AQA delegates powers to the District Municipality, the MSA delegates responsibilities to individual municipalities within a district.

Should individual municipalities wish not to be directly involved with air quality management, e.g. due to a lack of suitable manpower, minimum of air pollution sources, etc., service-level agreements could be entered into between those municipalities and the CKDM. However, the CKDM currently don't have the capacity to go into service level agreements with Category B-Municipalities.

Air Quality Management Services are rendered in ten (10) communities in the Central Karoo Region, namely Beaufort West, Murraysburg, Nelspoort, Merweville, Prince Albert, Leeu-Gamka, Klaarstroom, Prince Albert Road, Laingsburg and Matjiesfontein, as well as in the rural areas of the Murraysburg, Beaufort West, Prince Albert and Laingsburg districts.

3. Potential air pollution sources have been identified as:

There are relatively few sources of air pollution in the Central Karoo District. As a result, ambient air quality is generally good.

- Industrial operations;
- Agricultural activities;
- Biomass burning (veld fires);
- Domestic fuel burning (particularly, wood and paraffin);
- Vehicle tailpipe emissions;
- Waste treatment and disposal (landfills and incineration);
- Vehicle entrainment of dust from paved and unpaved roads;
- Other fugitive dust sources such as wind erosion of exposed areas.

3.1 Air pollution sources and their associated emissions are as follows:

Source	PM10 ¹	SO ₂ ²	NO _x ³
Agricultural activities	✓		
Biomass burning	✓	✓	✓
Domestic fuel burning	✓	✓	✓
Industries	✓	✓	✓
Landfills	✓	✓	✓
Tyre burning	✓	✓	✓
Vehicle entrainment on unpaved roads	✓		
Vehicle tailpipe emissions	✓	✓	✓
Wind-blown dust	✓		
Trans-boundary transport	✓	✓	✓

¹ **PM10** - Particle pollution (also known as "particulate matter") in the air includes a mixture of solids and liquid droplets. Some particles are emitted directly; others are formed in the atmosphere when other pollutants react.

² **SO₂** - Combustion of fuel containing sulfur - mostly coal and oil. Also produced during metal smelting and other industrial processes.

³ **NO_x** is a generic term for the mono-nitrogen oxides NO and NO₂ (nitric oxide and nitrogen dioxide). They are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures.

In areas of high motor vehicle traffic, such as in large cities, the amount of nitrogen oxides emitted into the atmosphere as air pollution can be significant. NO_x gases are formed whenever combustion occurs in the presence of nitrogen – as in an air-breathing engine; they also are produced naturally by lightning. In atmospheric chemistry, the term means the total concentration of NO and NO₂. NO_x gases react to form smog and acid rain as well as being central to the formation of tropospheric ozone.

Health Effects: High concentrations of sulfur dioxide (SO₂) can result in breathing problems with asthmatic children and adults who are active outdoors. Short-term exposure has been linked to wheezing, chest tightness and shortness of breath. Other effects associated with longer-term exposure to sulfur dioxide, in conjunction with high levels of particulate soot, include respiratory illness, alterations in the lungs' defenses and aggravation of existing cardiovascular disease.

Environmental Effects: Sulfur dioxide and nitrogen oxides are the major precursors of acid rain, which can acidify soil, lakes and streams, accelerate corrosion of buildings and monuments, and reduce visibility. Sulfur dioxide also is a major precursor of fine particulate soot, which poses a significant health threat.

3.2 Polluting processes in the Central Karoo District Municipality

- Brick Works;
- Incinerator (waste);
- Vehicle Emissions
- Landfill Sites
- Domestic Fires

3.3 Industrial Pollution

Pollution from industrial activities in the urban and rural areas of the Central Karoo District is almost none-existent; except for a few brickworks, a waste reduction "incinerator" and vehicle emissions.

3.4 Residential pollution

Poor indoor and ambient air quality occurs in low income and informal settlements throughout the Central Karoo Region as a result of domestic fires and fuel burning by the poorest of the poor, refuse burning, dust from unpaved roads and wind-blown dust from denuded areas.

The burning of wood and paraffin is a common practice and produces SO₂ and PM₁₀ as well as VOC's. The relatively high population densities, together with the low release height of the pollutants, imply that there is also a health risk in these areas.

3.5 Transport Emissions

Motor vehicles are sources of CO, NO₂, PM₁₀ and VOC emissions, particularly during periods of idling and acceleration. Emissions from motor vehicles have been identified as the only major air quality polluter in Beaufort West and Laingsburg, especially during the peak season.

Virtually all of the road traffic, especially heavy diesel-powered vehicles, between the Western Cape and Gauteng pass through the towns of Laingsburg and Beaufort West and the average speeds of the traffic is very low, especially in the town centre.

The control and reduction of vehicle emissions is a challenge.

3.6 Agriculture

Pesticide use in agriculture results in spray drift, which can distribute chemicals in the vicinity and downwind of the spray area. Burning of general waste including waste tires to reduce solid waste in the Central Karoo District area generates smoke, toxic emissions and can contribute to atmospheric particulate loading.

The possible practice of burning waste etc. for various purposes needs to be substituted with more environmentally friendly options.

3.7 Waste treatment and waste disposal

Landfill

There are eight operational general landfill sites in the Central Karoo DM. No information is available on emissions from the landfills or ambient monitoring.

Local Municipality	Location
Beaufort West	Beaufort West Merweville Nelspoort Murraysburg
Laingsburg	Laingsburg
Prince Albert	Prince Albert Klaarstroom Leeu-Gamka

4. Licensing of listed activities

The state of preparedness to execute the AEL function remains a challenge.

The problem is further compounded by the lack of both financial and suitably skilled human resources. Further complexities may exist between the licensing function, the EIA and Town Planning authorisation processes.

6. Ambient air quality data and continuous monitoring

No continuous air quality monitoring has been conducted in the Central Karoo DM, a few small studies was done after the initial passive sample screening of DEA&DP was done in 2006.

6.1 DEA&DP screening study

As part of the DEA&DP screening study passive samplers were deployed for a one-week period, 25 July to 1 August 2006 at six locations (Figure 5). Average concentrations of SO₂, NO₂, O₃ and benzene were measured.

The main findings were:

- The concentrations of all gaseous pollutants were all well below their respective Lower Assessment Threshold (LAT), as may be expected in this vast open non-industrialised area;
- The highest concentration of SO₂ of 2 µg/m³ was recorded in the Murraysburg residential area;
- The average NO₂ concentration across the District was 5.8 µg/m³. The highest NO₂ concentration of 16 µg/m³ occurred at the Laingsburg site, located in the town about 8 m from the N1. Although this concentration is below the LAT, it is indicative of influence of vehicle emissions;
- An average O₃ concentration of 33 µg/m³ was recorded across the Central Karoo District Municipality. Concentrations above 40 µg/m³ were measured in Murraysburg (41 µg/m³), at the SA Police Station in Prince Albert (42 µg/m³) and in Beaufort West (48 µg/m³).

These concentrations are higher than in the City of Cape Town and higher than the background monitoring station at Cape Point. O₃ is a secondary pollutant that forms some distance from the sources of precursor gases. In the case of the Central Karoo, the O₃ concentrations are most likely an indication of relatively high regional concentrations.

- Benzene concentrations of 0.5 µg/m³ are low compared with the LAT.

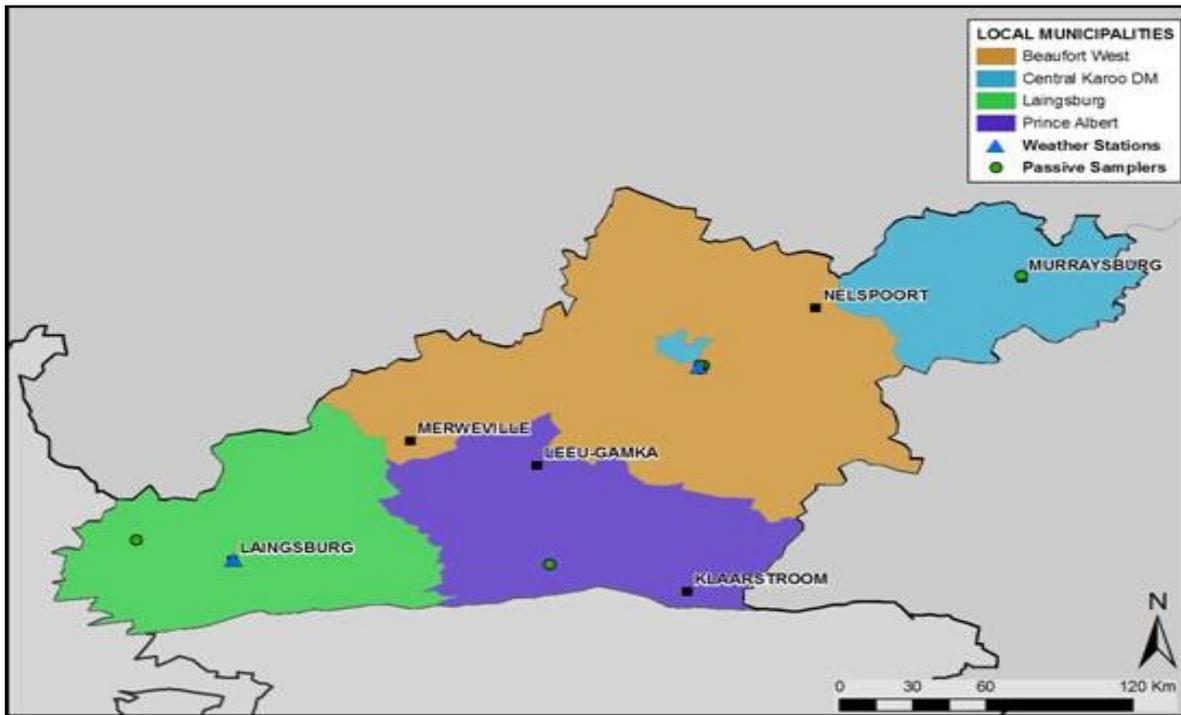


Figure: 5 Positions of the ambient monitoring sites in the Central Karoo DM

6.2 Baseline Study Dust Fallout, selected Metals, Particulates with Meteorological conditions in Beaufort West

Argos Scientific (South Africa) (Pty) Ltd. were contracted by the Central Karoo District Municipality to undertake the Baseline Air Quality Monitoring Study in 2018.

- Dust Fallout sampling was conducted at four (4) sites. Sampling commenced in February 2018 and continued for three (3) consecutive months of sampling (Dust and Metals) and five (5) months for PM-10 and Meteorology.
- There was no exceedance of the South African National Dust Control Regulations residential limit of 600mg/m²/day and no exceedance of the South African National Dust Control Regulations non-residential limit of 1200mg/m²/day.
- Molybdenum, thorium and uranium levels were in general below the detection limit, while potassium levels ranged between 0.2 to 0.7%.
- PM-10 levels were low and well below the RSA National Standard of 75µg/m³ as a daily average and data capture for PM-10 was on average 87% due to the failure of the PM10 monitor in mid April and >95% for meteorological conditions.
- Meteorological conditions over the period were characterised by light winds from the north east and south east quadrants with an occasional northerly bias.

6.3 Baseline Study particulate matter, nitrogen dioxide, carbon monoxide and methane.

Argos Scientific (South Africa) (Pty) Ltd. was contracted by the Central Karoo District Municipality to undertake the Baseline Air Quality study in 2019.

- Particulate matter (PM-10) levels were well below the RSA National Air Quality Standards for the period under review. There was however a period between the 15th and 20th April 2019 when elevated PM-10 levels were recorded in the afternoon between 13h00 and 18h00, possibly due to a nearby source.
- Nitrogen dioxide (NO₂) hourly means were well below the hourly standard with a peak hourly value of 146 µg/m³ being measured. The South African national NO₂ standard allows eighty-eight (88) exceedances per annum of a NO₂ hourly standard level of 200 µg/m³ and thus levels measured during the survey are not a cause for concern. The average for the six (6) month survey is also well below the annual standard of 40 µg/m³.
- Carbon monoxide (CO) hourly means were well below the hourly standard with a peak hourly value of 1.12 mg/m³ being measured, the standard allows eighty-eight (88) exceedances per annum of a CO standard level of 30 mg/m³ and thus CO levels are not a cause for concern.
- Methane levels were within background levels monitored at Cape Point by the World Global Watch Network and data analysis showed no nearby sources of methane over the period of the survey.
- Meteorological conditions were not recorded during the survey.

Due to no continuous monitoring information about the quality of the ambient air in the Central Karoo Region, it is not possible to make any clear deduction about any potential risk that may exist in the district, the few baseline studies indicated that air quality was below RSA National Standards.

The limited in-house skills for maintaining and operating monitoring equipment and networks present challenges.

The excessive costs of purchasing, commissioning, operating and maintaining ambient air quality monitoring equipment is problematic when competing with social priorities e.g., housing, education and health in the Central Karoo District.

Reliable continuous ambient air quality data is one of the corner stones of the air quality management system.

If possible, an automated ambient air quality monitoring station aimed at monitoring the impact of the heavy traffic flow on air quality needs to be established in Laingsburg and Beaufort West.

Screening methods are relatively inexpensive and fairly simple to operate, but the resulting data will be subject to substantial levels of uncertainty. The outcome of screening methods cannot be used for regulatory purposes and are, therefore, only suitable for monitoring purposes. An

example of a screening method is the use of passive samplers to monitor concentration of gases, over a short period of time.

Screening methods will provide average results over the sampling period which, in many cases, can be several days. As a result, screening methods will not provide short-term data, e.g., hourly or daily averaged concentrations.

Due to their relatively low costs, screening methods are used to indicate if an air quality problem potentially exists. Should results be significantly higher or significantly lower than ambient air quality standards it can be used to decide whether an air quality problem exists or whether the air quality is acceptable. However, if the results show marginal deviation from air quality standards screening methods do not have sufficient accuracy on which interpretations can be based.

The current absence of air quality monitoring activities is warranted and no such actions are foreseen. Nevertheless, the situation should be monitored and appropriate air quality surveillance should be initiated when deemed necessary.

DEA&DP should be requested to assist municipalities with the provision of temporary equipment for monitoring air quality in the district.

7. Emissions inventory

The CKDM do have an old inventory of known sources. Emissions from transport or diffuse sources, such as emissions from residential and agricultural areas are not identified or computed.

No measures have been implemented for GHG or to identify sources and report on these emissions.

The lack of information, the absence of reporting procedures and no in-stack monitoring by industry are issues that need to be addressed. Air pollution emission sources are usually grouped into four major headings.

These are:

- Industrial sources;
- Residential sources;
- Mobile emissions, e.g., vehicle emissions;
- Other sources, not included in those above.

Industrial sources can further be divided into two categories, i.e., point sources (e.g., chimney stacks) and area sources (e.g., stockpiles, disposal sites, tailings dams, etc.). Additional industrial sources, e.g., fugitive emissions, can be classified as one of these two major sources.

Residential sources are usually regarded as grid sources where the whole of a residential area is covered by a rectangular grid and the emissions per grid cell estimated from the population density and socio-economic level of the area.

Mobile sources consist of moving sources along roads, train lines, shipping lanes, etc.

Other sources contain those that do not readily fall into any one of those listed above, e.g. municipal waste disposal sites.

While a preliminary emission inventory has been compiled, it is limited by the fact that very little measured air pollution data exists.

No useful data could be derived for motor vehicle emissions, nor could any be derived for residential emissions. Both of these sources are regarded as of major importance in the Central Karoo District.

Compiling an emissions inventory is an ongoing activity. As it involves other municipal departments, e.g. traffic, housing, etc., it must be commenced with as early as is convenient.

8. Town and transport planning

Town and transport planning is a Category B-Municipality function and currently does not consider the impact of developments on the air quality of an area.

In addition, the potential negative impact of town and transport planning activities on the air quality of an area is not always considered when planning decisions are taken e.g. the siting of housing developments in areas bordering industrial areas and other sources of pollution magnifies the problem.

According to the NEM: AQA the AQMP must be included in the CKDM's IDP and it will, therefore, play a role in all future development activities in the district. Therefore, AQO's will provide an input into land-use and transport planning activities.

The aim is to ensure that the relevant authorities, policies, strategies and plans take into account the potential impact of land use and transport planning on air quality. This implies that inter-departmental communication channels must be set up to facilitate proper planning activities.

9. Capacity Building

Capacity constraints within the different Municipalities in the district hamper capacity building efforts.

Municipal officials also do not have the necessary skills level to deal with the variety and complexity of modern air pollution monitoring, modeling and control functions.

As a result, a training program needs to be established in order for officials can gain the level of expertise demanded by their functions. This will enable them to exercise their duties with more effectiveness, resulting in an improved level of air quality management across the Central Karoo District.

Officials must be capacitated through informal educational programs and Provincial Government will be called upon to assist us in furthermore formal training efforts.

Industry and private individuals, as well as civil society, must also be capacitated to develop the understanding that air is an important resource.

As and when required, municipalities may appoint specialist consultants to assist air quality officers to solve special problems that may arise in the district. In this process the air quality officers can also gain valuable expertise from the consultants and build up a substantial level of expertise over time.

9.1 Training requirements

9.1.1 Training as Environmental Management Inspectors (EMI's)

It is essential that AQO's receive EMI training, bearing in mind that effective air quality management is a complex and time-consuming task.

9.1.2 Training in the compilation of emissions inventories

Limited skills in this regard exist at the moment and must, therefore, be enhanced through a dedicated training program and one official must have prime responsibility for the task of maintaining the emissions inventory.

9.1.3 Training in data analysis and risk assessments

Long-term data interpretation and trend analysis requires a reasonable level of statistics knowledge.

A suitably trained person will, therefore be required to carry out proper analysis of the quantities of data generated by AQM stations, if any in the Central Karoo District. This will however only be required in the medium to long term.

9.2 Municipal Air Quality Officers Forum.

It is important that a local AQOF be established between the Central Karoo District Municipality and Category B-Municipalities in the district.

Air Quality Officers at District and Local Municipalities should at least meet on a bi-annual basis to discuss issues of common interest.

In order to ensure proper application and enforcement of the relevant air quality legislation, it is essential that an efficient and clear communication channel be established between municipalities.

9.3 Provincial Air Quality Officer's Forum

A Provincial-Municipal Air Quality Officer's Forum has been established in the Western Cape of which the overall objective is to ensure that an effective governance framework is developed, maintained and implemented.

Due to personnel capacity and financial constraints this Forum cannot always be attended.

10. Spirit of Co-Operation

The CKDM must try to create a spirit of co-operation between itself, members of the public and industry as such a spirit will provide the shortest route to effective air quality management in the district.

Steps that can be followed are, regular dissemination of information through the local media and social, etc.

Free and open discussion of all matters relating to air quality will give all interested and affected parties an opportunity to openly communicate their concerns in addition to being informed of the difficulties experienced by others.

11. Law Enforcement

The NEM: AQA charges the District Municipality with the responsibility to issue AEL's to industries listed in the Act and to enforce emission limits set on those industries by DFFE.

These powers will be used to define emission verification measures that industry will have to employ to prove that their emissions comply with limitations set by DFFE, DEA&DP and / or the CKDM.

It will also be used to define any specific air quality monitoring activities that a particular industry must embark on to show that its emissions do not result in an exceedance of ambient air quality limits or cause a nuisance to its neighbors.

11.1 By-Laws

Within the Central Karoo District, an air quality by-law has been established at the district level.

According to the Constitution of the Republic of South Africa a local authority may define and administer by-laws for the effective administration of, inter alia, air quality management. The only criteria for these by-laws are that they should not conflict with national or provincial legislation and thus would need to be more stringent.

Since air pollution is listed as a matter in which local government has authority, national or provincial government may not compromise or impede a municipality's right to exercise its powers or perform its functions.

Concept by-laws were developed by the then Department of Environmental Affairs (DEA) in an attempt to assist local authorities in the development of their own by-laws.

The set of by-laws are applicable to local and metropolitan municipalities only, but may require some localized customization. A copy of the draft by-laws is available from DFFE's web site at <https://www.environment.gov.za>.

12. Dissemination of Information

Currently the CKDM's is updating the web site so that data can be reported. All members of the public should be able to access data and gain first-hand information about the air quality and related matters.

13. Review of Air Quality Management Plan

This AQMP is only a plan according to which the CKDM will address air quality management in the municipal district.

The AQMP will operate in an ever-changing environment as infrastructure, legislation, industrial development, tourism trends, etc., vary over time. As a result, the plan must be adapted over time to meet the ever-changing air quality management requirements.

This AQMP will be administratively reviewed initially on an annual basis as the CKDM finds its feet in air quality management with a public participating review every 5 Years.

H. OBJECTIVES



As the objectives are met and the AQMP unfolds, it is possible that other objectives will be identified and prioritized. This process will lead to regular administrative review of this Plan.

Time scales have been suggested for meeting the various targets in each objective.

The time scales refer to “short term”, “medium term” and “long term”. A short-term time scale implies 1 to 2 years. A medium time scale implies 3 to 5 years and a long-term time scale implies more than 5 years.

All activities are currently unfunded.

Objectives	Targets	Activities	Timeframes
Establish Air Quality Forum to promote proper communication between affected parties	A committee/forum at a district level representing all interested and affected parties	CKDM take the leading role in the establishment and management of an Air Quality Officers Committee / Forum	Short
Effective Air Quality Management	Build capacity in air quality management within the MHS Section	Provide AQO with continuous training and development in air quality management	Continuous
	Build capacity in compliance monitoring within the district	Provide AQO with continuous training and development in compliance monitoring	Continuous
	Build capacity in air emissions licensing	Provide AQO with training and development in Air Emissions Licensing	Continuous
Implement and maintain an Air Quality Management System	Compilation of a comprehensive emissions inventory	Compile an emission inventory of all sources	Medium
Establish a compliance monitoring system		Design and implement a compliance monitoring system	Short-Medium

Objectives	Targets	Activities	Timeframes
Develop and implement an effective air emissions licensing system	Develop an air emissions licensing administration and management system	Develop forms, procedures, documentation and protocols for the administration of air emissions licensing	Short-Medium
Establish an emission reduction strategy.	Industries	Electronic database of all small industries to be regularly updated	Short-Medium
		Periodic site inspections and the request of emissions data	Short-Medium
		Develop a register for all non-listed activities	Short-Medium
	Domestic Fuel Burning	Create awareness campaigns around the negative health impacts of domestic fuel burning	Continuous
		Promote the integration of energy efficiency measures in low-cost houses such as housing insulation, solar panels and stove maintenance and replacement	Continuous
	Transportation	Review vehicle emissions database with updated traffic count data as these become available	Medium-Long
		Promote comprehensive vehicle emissions monitoring and diesel vehicle testing programmes in congested areas	Continuous
	Agriculture	Agriculture	Promote the safe and responsible use of pesticides throughout the district.
Promote safe and responsible agricultural burning practices.			Short-Medium
Biomass Burning		Identify and quantify emissions from biomass burning	Continuous
		Liaise with fire services to assist in air pollution control	Short-Medium
Waste Treatment and Disposal		Develop an emissions inventory of waste burning sources (incinerators, sewage and waste water treatment works)	Short-Medium

		Ensure all operating incinerators are licensed and are operating within their licensed requirements	Continuous
		Maintain a current database of permitted and non-permitted landfill sites	Continuous
		Introduce awareness programmes and public education of waste minimization and recycling initiatives.	Continuous
		Promote efficient service delivery in residential areas in order to reduce illegal dumping & burning of waste and creation of informal landfills	Continuous
Ensure continuous compliance with Atmospheric Emission Licensing Conditions	Control emissions from listed Processes	Periodic site inspections and retrieval emissions data.	Continuous
		Licensing conditions to ensure compulsory monitoring and reporting by industries to the CKDM	Short-Medium
Establish an annual AQMP administrative review process	Review systems, structures and processes to review progress in relation to the AQMP.	Establish review mechanism, systems, criteria and procedures	Short-Medium
		Establish comprehensive complaints register.	Short

I.

GAPS AND NEEDS



Some of the gaps / needs within the District are as follow:

- The current capability of the CKDM is limited by the shortage of personnel, skills and tools required for effective and coordinated air quality management.

Air quality responsibilities are mainly limited to the investigation of public complaints.

In terms of time allocation, Central Karoo DM, Laingsburg LM and Prince Albert LM spent between 0% and 20% of their time on AQM functions and Beaufort West Local Municipality has indicated between 20% and 40%.

- Air quality management is a complex issue as it involves various scientific disciplines and very few, if any, tertiary education courses adequately prepares a person for the practical work involved.

As a result, most if not all of the expertise required needs to be obtained through in-service training and exposure to the various issues involved.

- Air quality management tools are required in the District Municipality to effectively fulfill their air quality functions. Such tools include emissions inventory software, dispersion modeling software and air quality monitoring hardware.

Air quality monitoring options include continuous ambient air quality monitoring stations or passive sampling methods. A mobile monitoring station is the recommended option for the district as this will allow for 'hotspot' monitoring in identified areas of concern;

- Air Quality management requires cooperation from various disciplines within local government which includes amongst others, traffic, town planning, environmental services, cleansing services, housing, building control, Municipal Health Services, Law enforcement, social and developmental services and political buy in.

The successful implementation of an air quality management plan is thus strongly dependent upon cooperation and communication amongst all the local governments within the district.

- Inadequate financial provision specifically earmarked for AQM by all local authorities within the district;
- The personnel complement must, be assessed and the necessary operational structure developed so that municipalities can fulfil its air quality management duties as defined by the NEM: AQA;
- Meeting the objectives described above is not a one-man task. While the Air Quality Act states that the municipalities must appoint an air quality officer, it is clear that these officers will require a substantial support base if they have to carry out the responsibilities of this position effectively.

Support for air quality management should continue to be provided to the District by the Province

ANNEXURE 1



NATIONAL AMBIENT AIR QUALITY STANDARDS

SOUTH AFRICAN AMBIENT AIR QUALITY STANDARDS (DEA, 2009)

Applicable as amended.

SULPHUR DIOXIDE (SO ₂)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
10 minutes	500 µg/m ³ (191 ppb)	526	Immediate
1 hour	350 µg/m ³ (134 ppb)	88	Immediate
24 hours	125 µg/m ³ (48 ppb)	4	Immediate
1 year	50 µg/m ³ (19 ppb)	0	Immediate

The reference method for the analysis of sulphur dioxide shall be ISO 6767

NITROGEN DIOXIDE (NO ₂)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
1 hour	200 µg/m ³ (106 ppb)	88	Immediate
1 year	40 µg/m ³ (21 ppb)	0	Immediate

The reference method for the analysis of nitrogen dioxide shall be ISO 7996

PARTICULATE MATTER (PM ₁₀)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
24 hours	120 µg/m ³	4	Immediate-31 December 2014
24 hours	75 µg/m ³	4	1 January 2015
1 year	50 µg/m ³	0	Immediate-31 December 2014
1 year	40 µg/m ³	0	1 January 2015

The reference method for the determination of the particulate matter fraction of suspended particulate matter shall be EN 12341

PARTICULATE MATTER (PM _{2.5})			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
24 Hours	65 µg/m ³	4	Immediate-31 December 2015
24 Hours	40 µg/m ³	4	1 January 2016-31 December 2029
24 hours	25 µg/m ³	4	1 January 2030
1 year	25 µg/m ³	0	Immediate- 31 December 2015
1 Year	20 µg/m ³	0	1 January 2016 – 31 December 2029
1 Year	15 µg/m ³	0	1 January 2030

The reference method for the determination of PM_{2.5} fraction of suspended particulate matter shall be EN 14907

OZONE (O ₃)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
8 hours (running)	120 µg/m ³ (61 ppb)	11	Immediate

The reference method for the analysis of ozone shall be UV photometric method as described in SANS 13964

BENZENE (C₆H₆)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
1 year	10 µg/m ³ (3.2 ppb)	0	Immediate – 31 December 2014
1 year	5 µg/m ³ (1.6 ppb)	0	Immediate

The reference methods for the sampling and analysis of benzene shall either be EPA compendium method TO-14A or method TO-17

LEAD (PB)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
1 year	0.5 µg/m ³	0	Immediate

The reference method for the analysis of lead shall be ISO 9855

CARBON MONOXIDE (CO)			
Averaging period	Concentration	Frequency of Exceedance	Compliance date
1 hour	30 mg/m ³ (26 ppm)	88	Immediate
8 hours (calculated on 1 hourly averages)	10 mg/m ³ (8.7 ppm)	11	Immediate

The reference method for analysis of Carbon Monoxide shall be ISO 4224

WHO AIR QUALITY GUIDELINES (WHO, 2000)

HYDROGEN SULPHIDE (H₂S)	30 minutes	7 µg/m ³ (odour threshold)
	24 hours	150 µg/m ³ (health threshold)

NATIONAL STANDARDS FOR DUST FALLOUT (DEA, 2013)

LAND USE TYPE	DUST FALLOUT RATE (D) (IN mg/m²/DAY, 30 DAYS AVERAGE)	PERMITTED FREQUENCY OF EXCEEDANCE
Residential	D < 600	2 per annum, non-consecutive months
Non-residential	600 < D < 1200	2 per annum, non-consecutive months

ANNEXURE 2



AEL ACTIVITIES

All section 21 listed activities are required to apply for atmospheric emissions licenses (AEL).

The activities are classified into ten categories (with sub-categories)

- **Category 1:** Combustion Installations;
- **Category 2:** Petroleum Industry (the production of gaseous and liquid fuels as well as petrochemicals from crude oil, gas, coal or biomass);
- **Category 3:** Carbonization and Coal Gasification;
- **Category 4:** Metallurgical Industry;
- **Category 5:** Mineral Processing, Storage and Handling;
- **Category 6:** Organic Chemicals Industry;
- **Category 7:** Inorganic Chemicals Industry;
- **Category 8:** Thermal treatment of Hazardous and General Waste;
- **Category 9:** Pulp and Paper Manufacturing Activities, including by-product recovery;
- **Category 10:** Animal matter processing.

ANNEXURE 3



CRITERIA POLLUTANTS AND ASSOCIATED HEALTH AND ENVIRONMENTAL IMPACTS

CRITERIA POLLUTANTS AND ASSOCIATED HEALTH AND ENVIRONMENTAL IMPACTS

Deteriorating urban air quality has implications for human health, climate and visibility.

An overview of the criteria pollutants and associated human health and environmental impacts is discussed in the section below.

1. HUMAN HEALTH IMPACTS

1.1. Particulate Matter

Particles can be classified by their aerodynamic properties into coarse particles, PM₁₀ (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, PM_{2.5} (particulate matter with an aerodynamic diameter of less than 2.5 µm) (Harrison and van Grieken, 1998).

The fine particles contain the secondarily formed aerosols such as sulphates and nitrates, combustion particles and recondensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dust from roads and industries (Fenger, 2002).

In terms of health impacts, particulate air pollution is associated with effects of the respiratory system (WHO, 2000). Particle size is important for health because it controls where in the respiratory system a given particle deposits.

Fine particles have been found to be more damaging to human health than coarse particles as larger particles are less reparable in that they do not penetrate deep into the lungs compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extra thoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

- **Short-term exposure**

Recent studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 µg/m³). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function.

- **Long-term exposure**

Long-term exposure to low concentrations (~10 µg/m³) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000). Those most at risk include the elderly, individuals with preexisting heart or lung disease, asthmatics and children.

1.2. Sulphur dioxide

SO₂ originates from the combustion of sulphur-containing fuels and is a major air pollutant in many parts of the world. Health effects associated with exposure to SO₂ are also associated with the respiratory system. Being soluble, SO₂ is readily absorbed in the mucous membranes of the nose and upper respiratory tract (Maroni et al., 1995).

- **Short-term exposure**

Most information on the acute effects of SO₂ is derived from short-term exposure in controlled chamber experiments. These experiments have demonstrated a wide range of sensitivity amongst individuals. Acute exposure of SO₂ concentrations can lead to severe bronchi constriction in some individuals, while others remain completely unaffected. Response to SO₂ inhalation is rapid with the maximum effect experienced within a few minutes. Continued exposure does not increase the response. Effects of SO₂ exposure are short-lived with lung function returning to normal within a few minutes to hours (WHO, 2000).

- **Exposure over 24 hours**

The effects of exposure to SO₂, averaged over a 24 hour period, are derived from epidemiological studies in which the effects of SO₂, particulates and other associated pollutants are assessed. Studies of the health impact of emissions from the inefficient burning of coal in domestic appliances have shown that when SO₂ concentrations exceed 250 µg/m³ in the presence of particulate matter (as sulphates), an exacerbation of symptoms is observed in selected sensitive patients.

More recent studies of health impacts in ambient air polluted by industrial and vehicular activities have demonstrated at low levels effects on mortality (total, cardiovascular and respiratory) and increases in hospital admissions. In these studies, no obvious SO₂ threshold level was identified (WHO, 2000).

- **Long-term exposure**

Long-term exposure to SO₂ has been found to be associated with an exacerbation of respiratory symptoms and a small reduction in lung function in children in some cases. In adults, respiratory symptoms such as wheezing and coughing are increased.

1.3. Nitrogen dioxide

Nitric oxide (NO) is a primary pollutant emitted from the combustion of stationary sources (heating, power generation) and from motor vehicles. Nitrogen dioxide (NO₂) is formed through the oxidation of nitric oxide. Oxidation of NO by O₃ occurs rapidly, even at low levels of reactants present in the atmosphere. Altshuler (1956) calculated that 50% conversion of nitric oxide would take less than 1 minute at a NO concentration of 120 µg/m³ (0.1 ppm) in the presence of an O₃ concentration of 200 µg/m³ (0.1 ppm). As a result, this reaction is regarded as the most important route for nitrogen dioxide production in the atmosphere.

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

- **Short-term exposure**

At concentrations greater than 1880 $\mu\text{g}/\text{m}^3$ (1000 ppb), changes in the pulmonary function of adults is observed. Normal healthy people exposed at rest or with light exercise for less than 2 hours to concentrations above 4700 $\mu\text{g}/\text{m}^3$ (2500 ppb), experience pronounced decreases in pulmonary function.

Asthmatics are potentially the most sensitive subjects although various studies of the health effects on asthmatics have been inconclusive. The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30 – 110 minutes to 565 $\mu\text{g}/\text{m}^3$ (301 ppb) during intermittent exercise (WHO, 2000).

- **Long-term exposure**

Epidemiological studies have been undertaken on the indoor use of gas cooking appliances and health effects. Studies on adults and children under 2 years of age found no association between the use of gas cooking appliances and respiratory effects.

Children aged 5 – 12 years have a 20% increased risk for respiratory symptoms and disease for each increase of 28 $\mu\text{g}/\text{m}^3$ (15 ppb) NO_2 concentration, where the weekly average concentrations are in the range of 15 – 128 $\mu\text{g}/\text{m}^3$ (8 – 68 ppb) (WHO, 2000).

Outdoor studies consistently indicate that children with long-term ambient NO_2 exposures exhibit increased respiratory symptoms that are of a longer duration.

However, no evidence is provided for the association of long-term exposures with health effects in adults (WHO, 2000).

1.4. Ozone

Ozone in the atmosphere is a secondary pollutant formed through a complex series of photochemical reactions between NO_2 and VOCs in the presence of sunlight. Sources of these precursor pollutants include motor vehicles and industries. Atmospheric background concentrations are derived from both natural and anthropogenic sources.

Natural concentrations of O_3 vary with altitude and seasonal variations (i.e. summer conditions favour O_3 formation due to increased insolation). Diurnal patterns of O_3 vary according to location, depending on the balance of factors affecting its formation, transport and destruction.

From the minimal levels recorded in the early morning, concentrations increase as a result of photochemical processes and peak in the afternoon. During the night, O_3 is scavenged by nitric oxide.

Seasonal variations in O_3 concentrations also occur and are caused by changes in meteorological conditions and insolation. Quarterly mean (arithmetic average of daily values for a calendar quarter) O_3 concentrations are typically highest in summer (WHO, 2000).

Ozone contributes to the formation of significant amounts of organic and inorganic aerosols. Correlations between concentrations of O_3 and sulphuric acid, nitric acid, sulphates and nitrates have been observed (Grennfelt, 1984).

Ozone is a powerful oxidant and can react with a wide range of cellular components and biological materials. Health effects and the extent of the damage associated with O₃ exposure is dependent on O₃ concentrations, exposure duration, exposure pattern and ventilation (WHO, 2000).

- **Short-term exposure**

Short-term effects include respiratory symptoms, pulmonary function changes, increased airway responsiveness and inflammation. Field studies in vulnerable persons (children, adolescents, young adults, elderly and asthmatics) have indicated that pulmonary function decrements can occur as a result of short-term exposure to O₃ concentrations in the range 120 – 240 µg/m³ (61 – 122 ppb) and higher.

Ozone exposure has also been reported to be associated with increased hospital admissions for respiratory causes and exacerbation of asthma (WHO, 2000).

- **Long-term exposure**

There is limited information linking long-term O₃ exposure to chronic health effects, however, there are suggestions that cumulative O₃ exposures may be linked with increasing asthma severity and the possibility of increased risk of becoming asthmatic (Abbey et al. 1993).

Evidence provided by studies of health effects related to chronic ambient O₃ exposure is consistent in indicating chronic effects on the lung. Some studies have shown that long term exposure to concentrations of O₃ in the range 240 – 500 µg/m³ (122 – 255 ppb) causes morphological changes in the region of the lung resulting in a reduction in lung function (WHO, 2000).

1.5. Carbon monoxide

Carbon monoxide (CO) is one of the most common and widely distributed air pollutants.

CO is a tasteless, odorless and colourless gas which has a low solubility in water. In the human body, after reaching the lungs it diffuses rapidly across the alveolar and capillary membranes and binds reversibly with the haem proteins.

Approximately 80 -90% of CO binds to haemoglobin to form carboxy haemoglobin (COHb) which is a specific biomarker of exposure in blood. The affinity of haemoglobin for CO is 200 – 250 times that for oxygen. This causes a reduction in the oxygen-carrying capacity of the blood which leads to hypoxia as the body is starved of oxygen.

Anthropogenic emissions of CO originate from the incomplete combustion of carbonaceous materials. The largest proportion of these emissions is produced from exhausts of internal combustion engines, in particular petrol vehicles. Other sources include industrial processes, coal power plants and waste incinerators. Ambient CO concentrations in urban areas depend on the density of vehicles and are influenced by topography and weather conditions. In the streets, CO concentrations vary according to the distance from the traffic. In general, the concentration is highest at the leeward side of the 'street canyon' with a sharp decline in concentration from pavement to rooftop level (Rudolf, 1994).

- **Short and Long-term exposure**

The adverse health effects of CO vary depending on the concentration and time of exposure. Clinical symptoms range from headaches, nausea and vomiting, muscular weakness, and shortness of breath at low concentrations (10 ppm) to loss of consciousness and death after prolonged exposure or after acute exposure to high CO concentrations (>500 ppm). Poisoning may cause both reversible, short-lasting neurological deficits and severe, often delayed, neurological damage.

Neuro behavioural effects include impaired co-ordination, tracking, driving ability, vigilance and cognitive ability at COHb levels as low as 1.5 - 8.2% (WHO, 2000).

High risk patients with regards to CO exposure include persons with cardiovascular diseases (especially ischaemic heart disease), pregnant mothers and newborn infants. Epidemiological and clinical studies indicate that CO from smoking and environmental or occupational exposures may contribute to cardiovascular mortality (WHO, 2000).

1.6. Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are organic chemicals that easily vapourise at room temperature and are colourless. VOCs are released from vehicle exhaust gases either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels.

Short-term exposure to VOCs can cause eye and respiratory tract irritation and damage, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reactions, nausea, and memory impairment, damage the bone marrow and even death.

Long-term exposure to high levels of VOCs has been linked to an increase in occurrence of leukaemia. VOCs can also cause damage to the liver, kidneys and central nervous system.

1.6.1. Benzene

Benzene in air exists predominantly in the vapour phase, with residence times varying between a few hours and a few days, depending on the environment, climate and the concentration of other pollutants. The only benzene reaction, which is important in the lower atmosphere, is the reaction with hydroxy radicals.

The products of this reaction are phenols and aldehydes, which react quickly and are removed from air by rain.

Benzene is a natural component of crude oil, and petrol contains 1 – 5% by volume.

Benzene is produced in large quantities from petroleum sources and is used in the chemical synthesis of ethyl benzene, phenol, cyclohexane and other substituted aromatic hydrocarbons.

Benzene is emitted from industrial sources as well as from combustion sources such as motor engines, wood combustion and stationary fossil fuel combustion. The major source is exhaust emissions and evaporation losses from motor vehicles, and evaporation losses during the handling, distribution and storage of petrol.

Information on health effects from short-term exposure to benzene is fairly limited.

The most significant adverse effects from prolonged exposure to benzene are haematotoxicity, genotoxicity and carcinogenicity. Chronic benzene exposure can result in bone marrow depression expressed as leukopenia, anaemia and/or thrombocytopenia, leading to pancytopenia and aplastic anaemia.

Based on this evidence, benzene (C₆H₆) is recognized to be a human and animal carcinogen. An increased mortality from leukemia has been demonstrated in workers occupationally exposed (WHO, 2000).

1.6.2. Toluene

Toluene is produced from the catalytic conversion of petroleum and aromatization of aliphatic hydrocarbons and as a by-product of the coke oven industry.

The bulk of production is in the form of a benzene-toluene-xylene mixture that is used in the back blending of petrol to enhance octane ratings. Toluene is used as a solvent, carrier or thinner in the paint, rubber, printing, cosmetic, adhesives and resin industries, as a starting material for the synthesis of other chemicals and as a constituent of fuels (WHO,2000).

Toluene is believed to be the most prevalent hydrocarbon in the atmosphere. Reactions with hydroxy radicals are the main mechanisms by which toluene is removed from the atmosphere. The lifetime of toluene can range from a few days in summer to a few months in winter (WHO, 2000).

The short-term and long-term effects of toluene on the Central Nervous System are of great concern. Toluene may also cause developmental decrements and congenital abnormalities in humans.

The potential effects of toluene exposure on reproduction and hormonal imbalances in women are also of concern. Men occupationally exposed to toluene at 5 – 25 ppm have also been shown to exhibit hormonal imbalances.

Limited information suggests an association between occupational toluene exposure and spontaneous abortions at an average concentration 88 ppm.

Toluene has minimal effects on the liver and kidney, except in cases of toluene abuse. Studies have not indicated that toluene is carcinogenic (WHO, 2000).

1.2. ENVIRONMENTAL IMPACTS

Trace gases and aerosols impact climate through their effect on the radiative balance of the earth.

Trace gases such as greenhouse gases absorb and emit infrared radiation which raises the temperature of the earth's surface causing the enhanced greenhouse effect.

Aerosol particles have a direct effect by scattering and absorbing solar radiation and an indirect effect by acting as cloud condensation nuclei.

Atmospheric aerosol particles range from dust and smoke to mists, smogs and haze (IPCC, 2001). Smogs and haze are common in regions where certain geographic features, such as mountains, and weather conditions, such as temperature inversions, contribute to the trapping of air pollutants (Kumar and Mohan, 2002). Smogs and haze also contribute to visibility degradation through the absorption and scattering of radiation by gases and particulates (Elsom, 1996).

Other environmental impacts associated with air pollution include loss of biodiversity, damage to sensitive environments and acid rain.

Acid rain is a general term referring to a combination of wet and dry deposition from the atmosphere containing elevated amounts of sulphuric and nitric acid. Acid rain occurs when SO₂ and NO_x are emitted into the atmosphere, undergo chemical transformation and are absorbed by water droplets in clouds. The droplets then fall to earth as rain, snow, mist, dust, hail or sleet. This increases the acidity of soil and affects the chemical balance of dams and rivers.

Acid rain can also cause damage to buildings and infrastructure.