State of Air Report 2005

A report on the state of the air in South Africa





environmental affairs

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Published in 2009

ISBN 978-0-621-38724-7

Suggested citation for book
State of Air Report 2005. A report on the state of air in South Africa. Department of Environmental Affairs. 2009.

Publication
This publication is available both in hard copy and on the website of the Department of Environmental Affairs at www.environment.gov.za and the South African Air Quality Information System (SAAQIS) at www.saaqis.org.za.

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Printed and bound in South Africa by Burlington-Dataprint

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The department would like to acknowledge all those who supplied photographs.

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environmental affairs

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Environmental Affairs
REPUBLIC OF SOUTH AFRICA

FOREWORD

2005 was a significant year for air quality and air quality management in South Africa in that the then Minister of Environmental Affairs and Tourism brought the new Air Quality Act (AQA), the National Environmental Management: Air Quality Act (Act no. 39 of 2004) into effect.

From 1965 to 2005, the approach to air quality management in South Africa was informed and driven by the Atmospheric Pollution Prevention Act (APPA) (Act no. 45 of 1965). For many years, this Act was regarded as ineffective for a number of reasons, not least of which was the broadly-held belief that APPA, and specifically the way APPA was implemented, had not defended South Africa's air quality from the emergence of various air pollution "hotspots" around the country. In essence, the emergence of these hotspots is often considered to be a result of APPA's specific focus on individual source emissions without effectively considering the accumulative impacts of these emissions.

In this regard, the Constitution's Bill of Rights directly challenged the APPA approach by focusing on the quality of the environment and, by extension, the quality of the ambient air that we breathe. Government's Integrated Pollution and Waste Management Policy (IP&WM) 2000, put a further nail in APPA's coffin by requiring a new approach to air quality governance – an approach that used improved ambient air quality as the objective for governance.

To this end, the AQA marks a sea-change in South Africa's approach to air quality management, an approach that is now fully aligned with international best practice. In essence, the AQA sets the targets for air quality management in the form of national ambient air quality standards and then provides a host of regulatory tools to assist government in meeting these targets.

The promulgation of the AQA also marked a new vitality in the air quality management sector and we have witnessed, among many others: a number of air quality monitoring networks being established across the nation; the identification of national priority areas, plans for improving the air quality in the Vaal Triangle Airshed Priority Area published and plans for improving the air quality in the Highveld Priority Area at an advanced stage of development; the establishment of the 2007 National Framework for Air Quality Management; intergovernmental coordination and cooperation structures set up; various provinces and municipalities gearing themselves up to meet their air quality challenges; all sectors of society actively participating in standard-setting and planning processes; and the new South African Air Quality Information System (SAAQIS) starting to provide South Africans with access to national air quality information.

However, the proof of the pudding is in the eating – will the AQA prove more effective than APPA in ensuring ambient air quality that is not harmful to health and well-being?

This brings us to the significance of this document – the first South African State of the Air Report has been specifically aligned with the entry into effect of the AQA to provide all South Africans with a picture of what South Africa's air looked like at that time. In so doing, it also effectively provides the base-line for performance measurement.

Thus, the publication of this document provides a transparent means of establishing whether the AQA, and government's implementation of the AQA, progressively ensures ambient air quality that is not harmful to health and well-being.

Notwithstanding the above, this State of the Air Report 2005 also provides a detailed reference work for all South Africans who want to know more about the air they breathe and, in so-doing, aims to deepen our democracy by providing the means for informed participatory air quality governance.

PETER LUKEY
NATIONAL AIR QUALITY OFFICER

Acknowledgements

The project team acknowledges the invaluable contributions made by many organisations and individuals who graciously responded to the request for data. The contributions these role players made are too many to mention in detail but a summary of the role players is provided below, with a full list in Appendix C. Thanks are also extended to the team at Airshed Planning Professionals who have assisted in the collection of data through their associated project.

The following contributors are acknowledged for ambient air pollution data:

Nelson Mandela Metropolitan Council and specifically Kobus Slabbert

City of Johannesburg Metropolitan Municipality, and specifically Jane Eagle, Gideon Slabbert and Marguerite Richardson.

Ekurhuleni Metropolitan Municipality, and specifically Flip Visser.

City of Tshwane Metropolitan Municipality, and specifically Juan Mostert

Pietermaritzburg Metropolitan Council, and specifically Andrew Simpson.

eThekwini Municipality and specifically Siva Chetty

City of Cape Town, and specifically Grant Ravenscroft and Hans Linde

Coega Development Corporation, and specifically Shrina Padiachee and Lisa Guastello from Ecoserv

NACA Soweto, and specifically Jabu Sithole

Richards Bay Clean Air Association, and specifically Sandy Camminga, Venetia Michell, Lisa Guastello, and Quentin Hurt

University of KwaZulu-Natal, and specifically Andrew Simpson

Airkem, and specifically Flip Buys, Ellen van Dongen and Jozua Taljaard

APOLCOM, and specifically Owen Pretorius and Julius van Graan

EL Industrial Development Zone, and specifically Sisanda Peter

EL Regional Waste Disposal Site, and specifically Kitumba Kalule and Robin Bissett from Ecoserv

C&M Engineering, and specifically Chris Albertyn and Riaan Kruger

University of Northwest, and specifically Kobus Pienaar.

Data and information were supplied by The South African Weather Service (SAWS), from within the Trace gas Research and Atmosphere Change Monitoring (TRACM) Group, and operations from the Cape Point - Global Atmosphere Watch (GAW) Station, under the scientific leadership of Mr E-G Brunke, Mr J R Coetzee and TRACM staff.

Sasol, and specifically Owen Pretorius and Peter Hall

Eskom, and specifically Neil Snow, Eric Lynch and Eric Barr

Parabola Mining Company, and specifically Gabe vd Bergh

Anglo Platinum, and specifically Jacobus Malan

Mittal Steel, Vanderbijlpark, and specifically Patrick vd Bonn and Johan Hattingh

Sappi Saiccor, and specifically Derek Airey

Mondi, and specifically Tony Scheckle

Lonmin Platinum, and specifically Trusha Fakir

Mittal Steel, Saldanha Steel, and specifically Siegfried Spanig and Gerswain Manuel

Mittal Steel/Billiton, Middelburg, and specifically Peter Scurr

PetroSA, and specifically Eileen Green

Chrome International, Newcastle, and specifically Jacque Hunlun

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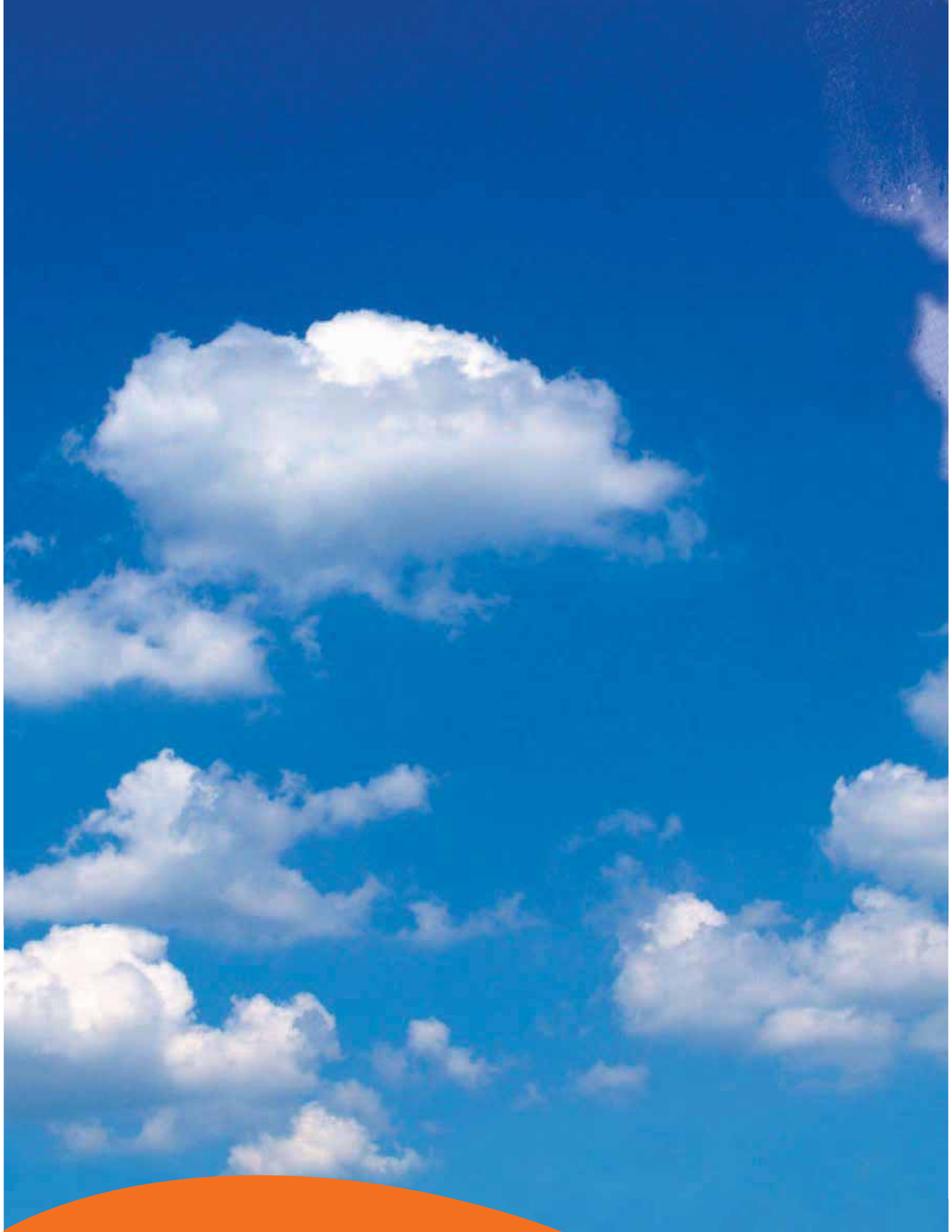


Executive summary

INTRODUCTION

The atmosphere is a shared resource. The quality of air depends on the quantities of natural and human-induced (anthropogenic) emissions to the atmosphere, as well as on the potential for dispersing and removing pollutants from the atmosphere. Air pollutants vary according to the impact that they have as well as the length of time they remain in the atmosphere.

Gases such as methane, nitrous oxide, and chlorofluorocarbons are long-lived and internationally significant because of their implications for global warming and stratospheric ozone depletion. The problem posed by carbon dioxide (CO_2) is that anthropogenic generation is faster than environmental re-utilization, and leads to a rise in atmospheric concentration, with consequent impact on global warming. Pollutants such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM) are significant, primarily in terms of local human health impacts. These gases also have local and regional ecological impacts.

The purpose of *State of Air for South Africa, 2005* is to give an overview of the state of air quality in South Africa, providing insight into the sources of emissions, and their associated health, welfare, and broader environmental effects. The identification of significant sources, pollutants, and impact areas is an important first step towards air quality management. The report also summarizes current air quality management practices, and explores opportunities for reducing emissions and improving the quality of the air. Although it focuses mainly on criteria (common) pollutants as per national framework and local and urban ambient air pollution issues, the report also refers to non-criteria pollutants, regional and global challenges, and health risks posed by exposure to indoor air pollution.

In characterizing the national state of air quality, reference is made to available information from source inventories, ambient air quality monitoring stations, and relevant literature. Air quality monitoring data for over 120 stations across the country were obtained for the purpose of informing *State of Air for South Africa, 2005*. All available data for the period 1994–2004 were collected.

In the supplementary report entitled *Technical Compilation to Inform the State of Air Report* (DEAT, 2006a), a detailed description of the entire dataset is given, and the quality of the data evaluated. Summary statistics are presented for all the data collected. This technical support document covers air quality monitoring activities and presents trends at all stations at which adequate data were



collected. Air quality trends for selected air pollution monitoring stations were extracted for inclusion in the *State of Air Report 2005* to illustrate the state of air in local environments, for example in heavy industrial areas, dense low income settlements, and areas where the roads carry high volumes of traffic.

Air quality management and sustainable development

The international challenge for air quality management is not simply to provide cleaner air, but to do so without detrimental effects on society and the economy. The National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004), pledges the country to prevent (in practice, to minimize) pollution, and to improve and maintain air quality concomitant with socio-economic development, and not at (unacceptable) expense to such development. The stated objective of this act is to protect the environment by providing reasonable measures for (a) the protection and enhancement of the quality of air in South Africa; (b) the prevention of air pollution and ecological degradation; and (c) securing ecologically sustainable development while promoting justifiable economic and social development.

Realizing the AQA's vision will require careful structuring of the regulations being developed and implemented under this framework act. To support regulatory development and implementation, reference is made to the experience gained and lessons learned by nations abroad, where air quality management has been refined and implemented over a long period of time – in the USA for more than 40 years, and in the European Union for more than 25 years, for example. It is relevant for South Africa to consider critical lessons learned at the 'environment' and 'economy' interface, the most important of which involve the following:

- Integration of air quality considerations into energy, transportation, land use, housing, and other development planning processes
- Integration of economic concerns in air quality management and planning, specifically by optimizing the costs of air quality monitoring systems, systematically analyzing the costs and benefits of air quality management policies, avoiding the mandated use of particular technologies to realize emission reductions, prioritizing sources on the basis of their impacts, and using flexible measures including market instruments.

Key points to consider in integrating the needs of society with those of the environment include the potential for reducing air pollution through poverty alleviation, the importance of addressing environmental injustice through air quality management, and the need to take into account the social acceptability of air quality interventions.

Sources of atmospheric emissions

Emissions are released into the atmosphere by natural processes as well as by human processes and activities. Natural sources include biogenic releases, wind-blown dust emissions, uncontrolled veld-fires and lightning-induced formation of nitrogen oxides (NO_x).

Emissions are released into the atmosphere by natural processes as well as by human processes and activities

Common anthropogenic sources of atmospheric emissions in South Africa include the following:

- *Industrial and commercial activities,* including Scheduled Processes – that is, processes identified in the Second Schedule of the Atmospheric Pollution Prevention Act (APPA) (Act no. 45 of 1965) as resulting potentially in significant atmospheric emissions – and the operations of smaller emitters such as dry-cleaners, as well as non-domestic fuel-burning equipment used by businesses, hospitals, and schools
- *Electricity generation*, specifically coal-fired and fuel-turbine power stations generating electricity for the national grid
- *Waste treatment and disposal*, including waste incineration, landfills, and wastewater treatment works
- *Residential activities,* specifically household combustion of coal, paraffin, liquid petroleum (LP) gas, dung, and wood
- *Transport,* including petrol- and diesel-driven vehicle exhaust emissions; road-dust raised by vehicles; brake- and tyre-wear fugitives and rail-, shipping-, and aviation-related emissions
- *Mining,* comprising fugitive dust releases and emissions from spontaneous combustion



- *Agriculture*, including emissions from burning crop residue, enteric fermentation, and the application of fertilizers and pesticides

- *Informal/miscellaneous,* including tyre burning and fugitive dust from construction activities and the erosion of open areas.

There is no current comprehensive national inventory for sources of atmospheric emissions. Local emissions inventories have however been developed, or are underway, in various parts of South Africa, including the Cities of Cape Town, Johannesburg, eThekwini and Tshwane, the Vaal Triangle and the Rustenburg region.

An inventory of fuel-burning related sources for the year 2002 within the electricity generation, industrial, commercial, residential, and agricultural sectors was compiled on behalf of the National Economic Development and Labour Council (NEDLAC) within the following conurbations and regions: Tshwane, Johannesburg, Ekurhuleni, Mpumalanga Highveld, Vaal Triangle, eThekwini, and Cape Town. The most significant combustion-related sources of atmospheric emissions within these conurbations were identified as follows (not ranked):

- *Industrial and commercial fuel-burning sector* – this was a significant source of particulates and SO_2 in all areas, but particularly in Cape Town, eThekwini, Vaal Triangle, Ekurhuleni, and Mpumalanga. This sector was also a contributor to NO_x emissions and to various greenhouse gas emissions (CO_2, N_2O).

- *Vehicle emissions* – in all the conurbations, these comprised a significant source of CO, NO_x, total organic compounds (TOCs), non-methane total organic compounds (NMTOC), benzene, lead, acetaldehyde, formaldehyde, and 1,3-butadiene emissions. This source also contributed approximately 30% to total fine particulate and SO_2 emissions from fuel-burning processes and was a significant source of greenhouse gas emissions (CO_2, methane [CH_4], and particularly nitrous oxide [N_2O]). Worth comment is the banning of lead additives from petrol formulations, with a resultant disappearance of lead emission from motor-vehicle exhausts[1]. Benzene is an additive to lead-free petrol formulation.

- *Domestic fuel-burning* – this significant source of low-level fine particulate and SO_2 emissions also contributed significantly to CO, TOC, and benzene emissions and to greenhouse gas emissions (CO_2, CH_4). Its contribution to fine particulate concentrations within coastal cities such as Cape Town and eThekwini was high because of the extent to which wood was burned (coal use is greater in the interior, whereas wood – which emits more fine particulate matter – tends to be burned at the coast). In inland areas, where coal-burning is more widespread, SO_2 and particulate emissions are higher from this sector.

- *Electricity generation (thermal combustion technology)* – this is a significant source of particulate, SO_2, NO_x, CO, and TOC emissions in Mpumalanga and the Vaal Triangle and, to a lesser extent, Tshwane. Despite tall-stack release of these emissions, important contributions to local ground-level concentrations are possible

Evening peak-hour traffic contributes to overnight pollution levels in Johannesburg as commuters drive along the highway.

Photography: Hot Tomato Communications

1. The "Joint Implementation Strategy for the Control of Exhaust Emissions from Road-Going Vehicles in the Republic of South Africa" was published as a General Notice in the Government Gazette in December 2003. This strategy is a cooperative governance effort of the Department of Minerals and Energy and the Department of Environmental Affairs and Tourism. It promulgated that lead, as an additive, would be completely removed from petrol in South Africa from 1 January 2006.

during unstable (turbulent) atmospheric conditions. The sector is also an important contributor of greenhouse gas emissions (CO_2, N_2O).

- *Biomass burning* (in the sense of veld-fires and crop burning) – this is a significant source of localized, episodic fine-particulate emissions. It also contributes to TOCs and greenhouse gas emissions (CH_4, N_2O).

The contribution of shipping, aircraft, and railway emissions was found to be relatively small, although it was recognized that shipping and aircraft emissions can contribute significantly to localized, ground-level emissions.

Significant non-combustion-related anthropogenic sources included industrial process emissions; waste disposal; dust from vehicles driving over paved and unpaved roads (vehicle-entrained dust); wind-blown dust from open areas (including mine dumps and open-cast mining); and agricultural activities. Furthermore, regionally-transported, aged aerosols contributed significantly to background air-pollutant concentrations, particularly over the interior.

The potential impact of large-scale heavy industries with poorly controlled process-related and fugitive dust sources is greater in areas with residential settlements nearby

An electricity transmission line.
Photography: Janet Peace

Source apportionment studies identified four major source-types, of regional significance, that are responsible for aerosol loading in the atmosphere. The four source categories include air-borne crustal material consisting of mineral soil dust; marine aerosols from adjacent oceans; particles from biomass

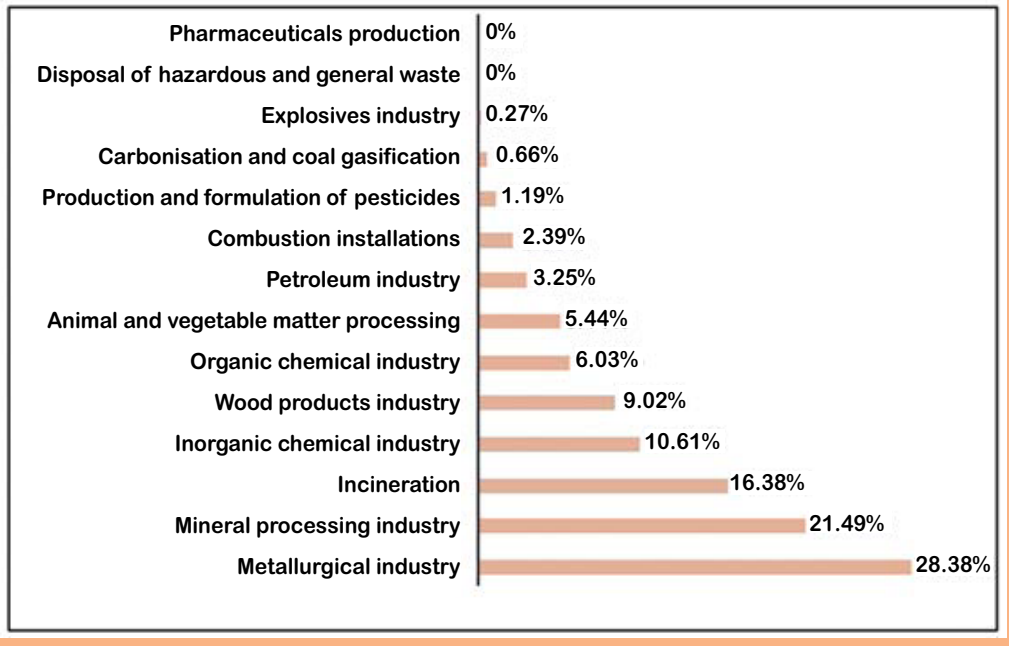


Figure A: Proportions of enterprises holding registration certificates under the Atmospheric Pollution Prevention Act, classified by broad industry type (DEAT, 2006)

burning (occurring mainly north of 20° latitude south); and aerosols from industrial emissions and power generation.

Types of industries that hold Registration Certificates to operate Scheduled Processes under the APPA are indicated in Figure A. There are about 1 500 permitted, operational industries in the country. Approximately 28% of these are classified as belonging to the metallurgical industry. The mineral processing industry (21%) and incineration (16%) rank next, because of the large number of brickwork operations and medical-waste incinerators in the mineral processing and incineration classifications, respectively. There are also numerous foundries and asphalt processors in operation, as well as coal-fired power stations and sawmills.

The potential impact of large-scale heavy industries with poorly controlled process-related and fugitive dust sources is greater in areas with residential settlements nearby. Large-scale storage of chemicals in tank farms located close to residences have similarly been identified as having the potential to expose communities to unacceptable levels of volatile organic compounds, such as benzene, toluene, and ethyl benzene.

Status of ambient air quality monitoring

The status of air quality monitoring in the country was assessed by the Council for Scientific and Industrial Research (CSIR) as part of the DEAT's National Air Quality Management Programme: Phase II – Transition Project, and documented in the *Air Quality Information Review* (Output (c.1.)) (DEAT, 2006b). The air quality monitoring data were further assessed to derive trends in air pollution concentrations, and the findings are documented in the supplementary report, *Technical Compilation to Inform the State of Air Report* (DEAT, 2006a). An overview of the status of ambient air quality monitoring for the year 2004 is presented in this report, with reference made to the 2005 monitoring guidelines published by Standards South Africa (SANS 1929). The status of monitoring was evaluated according to the number of stations in operation and the integrity of the data produced.

The location of ambient air quality monitoring stations across the country in relation to population distribution is shown in Figure B. Comparison of the number of stations required in SANS 1929:2005 with those in operation revealed sufficient monitoring networks in the major metropolitan areas and industrial development zones, but little attention being paid to air quality monitoring in areas where the population was less concentrated.

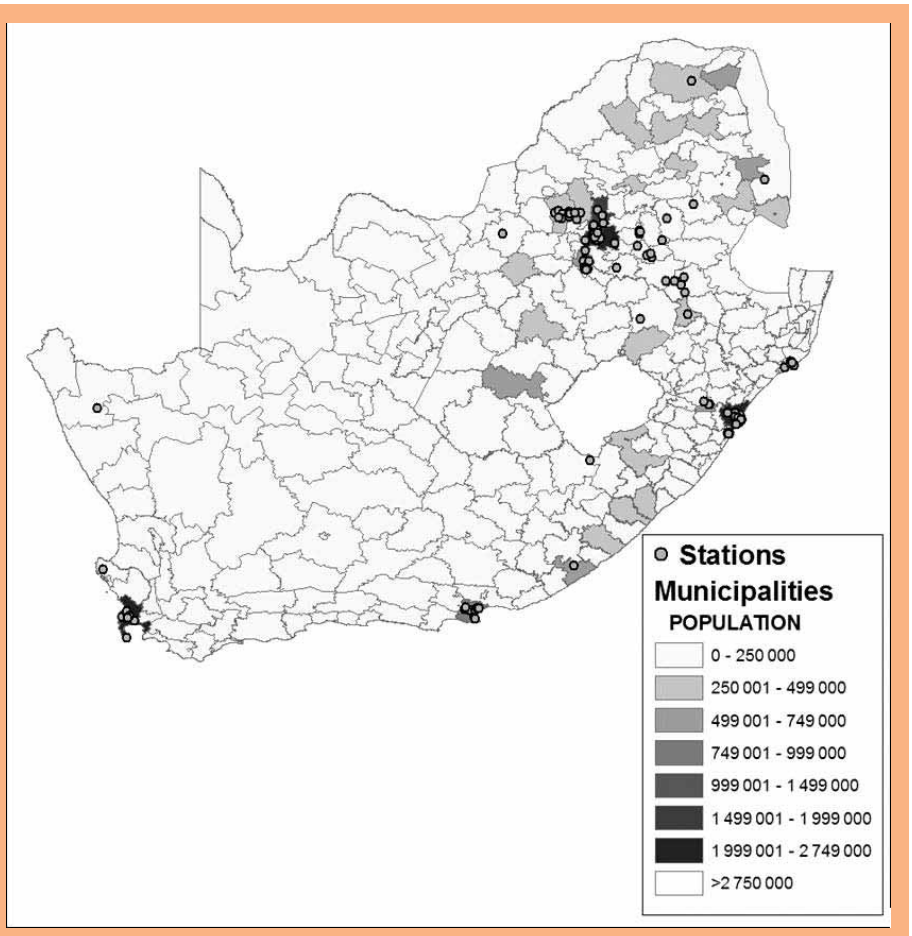


Figure B: South African population distribution by municipality, and the relative location of monitoring stations for ambient air quality. The municipal boundaries are demarcated, and the population bins used are those defined by SANS 1929:2005

Conclusions drawn from the review of air quality monitoring activities up to, and including, 2004 were as follows.[2]

- Air quality monitoring occurred mostly in industrial areas and central urban areas. Compromised air quality in dense low-income residential areas, arising from coal combustion for cooking and space heating, together with contributions from the use of unpaved roads, was either poorly

2. Since the assessment in 2004, monitoring networks have expanded in some cases, both in some of the areas indicated in the review, and into new ones.



monitored or not monitored at all. The data coverage was not sufficient to identify all potential priority areas, and was not supplemented by an emissions inventory or air dispersion modelling.

- At provincial and local government levels

  - Data coverage in all provinces other than Gauteng was inadequate for effective air quality management

  - Monitoring was generally limited to central urban and industrial areas and did not extend to rural areas. Effective air quality monitoring was conducted by a few local governments, including eThekwini, Richards Bay, the City of Cape Town, the City of Johannesburg, and the Ekurheleni Metropolitan Municipality

  - Monitoring was generally limited to a few pollutants, typically SO_2, NO_x and PM, while key urban pollutants such as ozone, $PM_{2.5}$ (that is, particulate matter with a diameter of less than 2.5 micrometres), and benzene were not widely monitored.

  - Not all local government monitoring networks had the required quality systems in place, nor were they audited by the calibration laboratories accredited by the South African National Accreditation System (SANAS).

- The air pollution monitoring data at the time may have been insufficient to assess air quality impacts on human health. In particular,

  - Air quality monitoring was focused mainly on metropolitan and industrial areas, and often neglected in high-density low-income residential areas, especially rural or semi-rural ones

  - Carcinogens, such as benzene and 1,3-butadiene, that typically occur within urban environments were not commonly monitored.

- To improve understanding of background levels of air pollutants, national monitoring needed to have been expanded beyond urbanized and industrial areas. This would provide insights into ways in which pollutants are transported across boundaries.

- The data may have been insufficient to assess ecological impacts. In particular,

  - Even though ozone is a common pollutant that poses the highest risk to vegetation, most ozone monitoring was conducted in urban environments and did not extend into agricultural or natural environments

  - Wet deposition monitoring was limited to the northeastern parts of South Africa

  - Limited dry deposition work was included in research programmes, and was confined to sulphates, nitrates and ozone.

Pollutant concentrations in Cape Town, contributing to the Brown Haze, are measured using instruments fitted to an aeroplane.

The study up to the year 2004 concluded that existing data coverage was insufficient to identify all potential priority areas accurately, or to quantify the effects of air pollution on human health and the environment.

The recommendation was to extend the spatial distribution of monitoring stations and the range of pollutants measured. Some issues would need to be addressed through a programme of monitoring, such as the monitoring of VOCs from smouldering coal-mine dumps. Furthermore, automated continuous



monitoring would need to be supplemented by other air quality monitoring and characterization techniques, with passive sampling used for spatial screening of regional pollution and for baseline characterization in small municipalities and less polluted areas. It was noted that remote sensing represents an important emerging tool for spatial screening and regional characterization, and that emissions inventories and atmospheric dispersion modelling represent critical components of cost-effective, ongoing air quality characterization. These techniques supplement monitoring by helping to predict spatial variations in air-pollutant concentrations. Dispersion modelling also allows projections to be made of changes in air quality, when new developments are considered and the implementation of emission reduction strategies planned.

Current challenges in ambient air quality

In addition to positioning itself to deal actively with emerging issues, South Africa faces the challenge of addressing a range of persistent air pollution problems. High ambient sulphur dioxide and fine particulate concentrations, arising primarily from fuel-burning within the domestic, industrial, and power-generation sectors, present persistent air pollution challenges in many areas.

Impacts on human health related to domestic coal- and wood-burning remain the most serious and pressing national air pollution problem. The location of heavy industries and communities close to each other is a continuing source of health risks and consequent conflict, exacerbated by rising pressure to position residential areas within former industrial buffer zones. Issues remain with respect to the impacts on the environment, and the transportation of pollution across boundaries, that come from elevated-stack emissions from petrochemical, metallurgical, mineral processing industries, and coal-fired power stations. Concerns have been raised about heavy metals, including mercury and chromium-VI. A consolidation of current knowledge and further research are necessary.

Emerging air pollution issues are closely associated with transport, particularly on the nation's roads. The growth in vehicle activity and the ageing of vehicles in the country are expected to offset planned and proposed measures to reduce national emissions by regulating fuel composition and through new vehicle technology. Although air quality limits for nitrogen oxide and ozone, aimed at alleviating acute effects on health, are seldom exceeded within South African cities, a notable increase in the concentrations of these pollutants is becoming apparent. Volatile organic compound releases from fuel filling-stations, and nitrogen oxide and hydrocarbon releases from major airports, have also highlighted the air quality implications of the country's transportation policies. Furthermore, the contribution of the transport sector to greenhouse gas emissions has increased significantly in the last decade (World Bank, 2006). In South Africa, transport was responsible for 27% of the final energy demand in 2000 (DME, 2005). This contribution has been increasing, particularly in urbanized populations, and, half a decade later, within the six largest metropolitan areas, transport accounted for 56% of energy consumption (SEA, 2006).

Particularly pressing challenges facing South Africa have been identified. They include (a) compliance with new, more stringent air quality standards, specifically for particulate matter; (b) understanding and addressing the risks to human health posed by exposure to air-borne hazardous materials; (c) responding to evidence that, for some pollutants, there may be no way to quantify the threshold below which exposure is no longer harmful; (d) mitigating air pollution impacts that disproportionately affect low-income communities; and (e) reducing industrial emissions without detrimental effects on society and the economy.

The challenges of climate change

Climate change is an international concern. It has given rise to the United Nations Framework Convention on Climate Change (UNFCCC), as well as the associated Kyoto Protocol that scheduled greenhouse gas emission reductions for 'developed' countries.

South Africa's estimated contribution to per capita greenhouse gas emissions is above the global average, being higher than most developing nations and equivalent to some in the developed world. National total CO_2-equivalent emissions increased by 9.4% between 1990 and 1994. This growth was primarily due to the significant increases in greenhouse gas emissions from the energy sector, whose contribution increased from 75% to 78% during this period. The three source groups

The study up to the year 2004 concluded that existing data coverage was insufficient to identify all potential priority areas accurately, or to quantify the effects of air pollution on human health and the environment

contributing most significantly to energy-sector CO_2-equivalent emissions are: energy industries (including coal- and fuel-oil-fired electricity generation for the national grid), industry, and transport. Carbon dioxide-equivalent emissions from these three groups increased during the period 1990–1994, and transport emissions increased the most (by 38% over this period). Road transportation has been reported to contribute more than half of the transport sector's emissions.

Despite its greenhouse gas contribution, and despite having signed and ratified the Kyoto Protocol, South Africa has not been required to reduce its greenhouse gas emissions, as it is classified as a 'developing' country in terms of the convention. Its current responsibilities in terms of the convention are largely limited to reporting on the national greenhouse gas emissions on a sectoral basis, and formulating adaptation strategies.

South Africa's climate is highly variable, both temporally and spatially. Given the expectations of global warming, it is predicted that this variability will be exacerbated by an increase in the frequency and intensity of droughts and floods. This will impact upon South Africa's commercial agricultural sector and affect human settlements lying close to rivers.

Most climate models have predicted that climate change will probably bring net drying to the western two-thirds of the subcontinent, south of about 10° latitude south. East-coast regions, where topography plays a significant role in rainfall precipitation, are expected to become wetter, although how far this wetting would extend into the interior is uncertain. The Western Cape appears to be facing a shorter rainfall season, with the province's eastern interior likely to experience increased rainfall in late summer. The country is expected to get hotter. The interior will experience the greatest increases, with temperatures predicted to rise by a maximum of 3–4 °C.

The potential impact of climate change on the health of the South African population has not been modelled, as has been done in countries such as the USA

The potential impact of climate change on the health of the South African population has not been modelled, as has been done in countries such as the USA. Potential indirect local health effects are anticipated to include higher mortality rates and an increase in developmental effects, infectious diseases, and respiratory diseases due to higher ambient temperatures. Further occurrence of epidemic infectious diseases could arise from changes in the distribution of disease vectors. Indirect effects of global climate change on human welfare are also related to the potential impacts on biodiversity, ecosystems, and the availability of agricultural land and water for irrigation. There is also the prospect of overcrowding, malnutrition and starvation, allergic diseases, and suffering due to weather extremes.

Field measurements taken during research projects provide valuable insight into the state of air.
Photoraphy: DEAT

Scientific advances

Considerable work and monitoring of air quality is done in South Africa through various scientific research programmes. Specific studies are normally planned to address identified research questions or hypotheses, with the purpose of adding information and contributing to a better understanding of South African air quality problems. Among the contributing research initiatives described in this report are: Cape Town Brown Haze Studies; the Southern Africa Regional Science Initiative (SAFARI 2000); regional-scale aircraft monitoring programmes; ozone modelling as part of the Cross Border Air Pollution Impact Assessment (CAPIA) project; acid deposition monitoring; biogenic volatile organic compound emission estimation; and regional-scale passive monitoring.

Developments in air quality management

The Air Quality Act of 2004 provides the framework for effective and integrated air quality management, in line with international best practice. The main aspects of this act include:

- Setting ambient air quality standards as goals for driving emission reductions
- Decentralizing air quality management responsibilities
- Requiring all significant sources to be identified, quantified, and addressed
- Recognizing source-based ('command and control') measures in addition to alternative measures, including market incentives and disincentives, voluntary programmes, and education and awareness
- Promoting cost-optimized mitigation and management measures
- Stipulating air quality management planning by authorities, and emission-reduction and management-planning by polluters
- Promoting access to air quality information and public consultation during air quality management processes.

Although the act provides for coherent, effective, and fair air quality management, its success requires a number of regulations to be set in the short term, and regulations to be reviewed and revised effectively in the medium- and long-term. Furthermore, it requires long-term resource allocation, close interdepartmental and intergovernmental cooperation, and support from business and civil society.

Progress made in the development of air quality management includes, but is not limited to, the following:

- Appointment of national, provincial, and local air quality officers and establishment of cooperative governance structures
- Publication of an air quality governance guideline series by national government
- Initiation of projects to aid the transition from air pollution regulation under the APPA to air quality management under the AQA, including: the Transitional Phase Project; the APPA Registration Certificate Review Project; the Listed Activities and Minimum Emission Standards Project; and the Air Quality Management Planning Project
- Revision of ambient air quality standards
- Conceptual design of the South African Air Quality Information System, to be hosted by the South African Weather Service
- Declaration of the Vaal Triangle as the first national priority area, and initiation of the Vaal Triangle Priority Area Air Quality Management Plan Development Project
- Improvements in the number and quality of air quality management courses offered by higher education institutions.

Further work is required in several areas, including: cost-optimization of air quality monitoring systems; integration of air quality considerations into transport, energy, and spatial development planning; emission offsetting and trading; use of multi-pollutant control strategies; applicability of various market mechanisms for realizing emission reductions; and mainstreaming air quality management and climate change strategies into local, provincial, and national planning.

Background

The Department of Environmental Affairs and Tourism (DEAT) embarked on a phased approach to the implementation of its National Air Quality Management Programme (NAQMP). Phase I, the "Definition Phase", initiated in June 2001, was completed in 2005 with the promulgation and implementation of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004). In Phase II, termed the "Transition Project", the DEAT invited specialist professionals and consulting firms with project management experience and specialist expertise in the field of air quality management to submit tenders in respect of the NAQMP's implementation. In May 2004, CSIR Environmentek was appointed to assist the DEAT in implementing aspects of the programme through the Phase II Transition Project.

The Phase II project comprises several activities. The one that is specific to this report is the compilation of the state of air in South Africa for the 11-year period 1994–2004.

The 1999 National State of the Environment Report (DEAT, 1999) contained information that provided the first understanding of the state of air on a national scale. It defined 19 indicators relating to climate and atmospheric change, and mapped trends for the period up to 1995 where data were available for each of these indicators. The National State of the Environment Report, updated in 2005 (DEAT, 2005), is the major mechanism through which resource management and environmental issues were reported and analyzed on scales that transcend both local authority and provincial boundaries. The material in this report was incorporated into *South Africa Environment Outlook* (DEAT, 2006f), which reflects on the state of the environment, human vulnerability to environmental change, and future prospects.

The *State of Air for South Africa, 2005* report for the Phase II Transition Project builds on the information contained in the two national state of environment reports, and it describes the state of air in South Africa with the purpose of helping to guide the implementation of the AQA. It identifies areas where air quality is compromised or may become compromised and it highlights pollutants of concern, so as to facilitate the prioritization of resources. It also establishes a foundation for subsequent state of air reports by providing a framework for presenting air quality data. The supplementary *Technical Compilation to Inform the State of Air Report* (DEAT, 2006), reproduced in the Appendix, documents the database compiled and the analysis undertaken to support this characterization of air quality. It was also used to inform the South African Air Quality Information System (SAAQIS), whose development was initiated in July 2007.

Furthermore, the *State of Air Report 2005* and the supplementary technical supporting material (see Appendix) offer an important source of information for many Air Quality Management Plans being developed by municipalities and provinces.

Chapter 1

Introduction

At a glance

Air quality depends on the quantities of natural and anthropogenic emissions to the atmosphere, and on the atmosphere's potential for dispersing and removing pollutants. Details about common pollutants, typical sources, and the nature of their effects on human health, the ecology, and climate change are provided in this chapter. The purpose of the ***State of Air Report 2005*** is to give an overview of the state of air quality in South Africa, providing insight into sources of emissions and associated health, welfare, and broader environmental impacts, as well as identifying significant sources, pollutants, and areas in which they have an impact. In addition, the report summarizes current air quality management practices and explores opportunities for realizing emission reductions and air quality improvements. The report focuses mostly on priority pollutants and local and urban ambient air pollution issues.

Ambient air quality is, for example, of primary concern in proximity to industrial and mining activities and busy traffic routes

The atmosphere is a shared resource. The quality of air depends on the quantities of natural and anthropogenic emissions to the atmosphere, and on the atmosphere's potential for dispersing and removing pollutants. Air pollutants vary in terms of their residence times in the atmosphere and the effects associated with them. Gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs) are long-lived and have international significance because of their respective implications for global warming and depletion of stratospheric ozone. Pollutants such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM) are significant primarily in terms of local human health impacts and local and regional environmental impacts. A list of common pollutants, typical sources, and the nature of their effects on human health, the ecology, and climate change, are summarized in Table 1.1.

In assessing air quality, it is necessary to distinguish between ambient (outdoor) air quality and indoor air pollution levels. Ambient air quality is, for example, of primary concern in proximity to industrial and mining activities and busy traffic routes. In such instances, indoor pollutant concentrations are generally lower than ambient air pollution levels. Indoor air pollutant concentrations within homes that burn fuels such as coal and wood are of considerable concern, particularly in poorly ventilated dwellings. In areas where households burn such fuels, people can be exposed to high indoor pollutant concentrations, in addition to being exposed to elevated ambient pollutant concentrations when outdoors. It is generally when they are out of doors that residents of households that do not burn such fuels experience their highest exposures to common combustion-related emissions such as PM, SO_2, NO_2, and CO. Poor ambient air quality and increased exposure to it are, in such instances, associated with pollutants emitted by neighbouring activities, for example vehicle activity along roadways, residential areas where wood and coal are burned (particularly where households have no access to electricity), and industrial and mining operations.

The cooling towers of a decommissioned coal-fired power station in Johannesburg.

The purpose of this report is to give an overview of the state of air quality in South Africa, providing insight into sources of emissions and associated health, welfare, and broader environmental impacts. Identifying significant sources, pollutants, and areas on which they have an effect, represents an important first step in air quality management. The report also summarizes current air quality management practices and explores opportunities for realizing emission reductions and air quality improvements. Although the focus is mainly on criteria (common) pollutants and local and urban ambient air pollution issues, reference is made to non-criteria pollutants, regional and global challenges, and health risks posed by indoor air pollution exposures.

In characterizing the national state of air quality, reference is made to existing and available information from source inventories, ambient air quality monitoring stations, and relevant literature. For the purpose of informing this *State of Air Report 2005*, air quality monitoring data were obtained from agencies for over 120 stations across the country and all available data for the period 1994–2004 were collected. A detailed description of the entire dataset is given, the quality of the data evaluated, and summary statistics presented for these data, in the supplementary report entitled *Technical Compilation to Inform the State of Air Report* (DEAT, 2006a), which is reproduced in the Appendix. This technical support document provides a full index of air quality monitoring efforts and presents trends at all stations from which sufficient data were collected. Air quality trends for selected air pollution monitoring stations were extracted for inclusion in the current report to illustrate the state of air quality in various local environments, such as heavy industrial areas, areas where households burn fuel (wood and coal), and sites characterized by high volumes of road traffic.

Table 1.1: Key pollutants, sources and impacts

Pollutants	Main contributing sources	Impacts
Particulate matter (PM) Less than 10 microns in size (PM_{10}) Dust, sand, ash, soot, smoke, pollen, exhaust emissions	· Household fuel combustion – primarily coal-burning on the Highveld and wood-burning in coastal areas · Industrial, commercial, and institutional fuel-burning appliances · Industrial process and fugitive emissions · Vehicle tail pipe emissions (primarily diesel vehicle emissions) · Mining and quarrying, including fugitive dust and smouldering coal dumps · Biomass burning, including wild-fires and crop-burning practices · Vehicle entrainment from paved and unpaved roads · Agriculture – fugitive dust emissions during ploughing · Windblown dust · Coal-fired base-load electricity generation · Diesel-powered locomotives and shipping · Other sources including: informal waste combustion, tyre-burning, waste incineration.	*Health* Exposure to PM has been associated with hospitalization for respiratory or cardiovascular diseases and exacerbation of respiratory diseases, such as asthma. The health effects depend on particle size and chemical composition. *Ecological* Wet and dry PM deposition can cause damage to plants, metal surfaces, fabrics, and buildings. Depending on chemical composition, PM can contaminate soil and water. Other impacts include reduced visibility and the production of haze.
Sulphur dioxide (SO_2)	· Industrial, commercial, and institutional fuel-burning appliances – specifically coal and heavy fuel oil (HFO) combustion · Coal-fired base-load electricity generation – specifically on the Mpumalanga Highveld · Gas-turbine peak-load electricity generation · Refineries · Industrial processes, including pulp and paper manufacture and metallurgical operations · Coal mining, including smouldering coal dumps (especially abandoned and defunct collieries), most of which are on the Mpumalanga Highveld · Household coal and wood combustion · Vehicle engine emissions (primarily diesel-powered vehicles) · Emissions from diesel-powered locomotives and shipping emissions (in harbour cities) · Biomass burning, including wild-fires and crop-burning.	*Health* Sulphur dioxide causes upper respiratory irritation and can aggravate existing respiratory diseases, especially asthma. *Ecological* Sulphur dioxide contributes to acid deposition, which causes acidification of dams and rivers, and damages trees and crops as well as buildings and statues. Leachates and percolates can contaminate subterranean aquifers.
Nitrogen oxides (NO_x, NO, NO_2)	· Vehicle tail pipe emissions – all areas · Industrial and other fuel-burning processes, specifically gas-burning appliances · Base-load electricity generation, specifically on the Mpumalanga Highveld · Gas-turbine peak-load electricity generation · Household fuel combustion – primarily coal-burning on the Highveld and wood-burning in coastal areas · Diesel-powered locomotive engines and shipping emissions (in harbour cities) · Airports – aircraft and passenger vehicle emissions at international airports (such as those in Cape Town, Johannesburg, and eThekwini), are significant sources · Biomass burning, including wild-fires and crop-burning practices · Tyre-burning is one of several minor sources.	*Health* Exposure to nitrogen dioxide (NO_2) increases the risk of respiratory infections. *Ecological* Nitrogen oxides play an important role in the atmospheric reactions that create ozone and contribute to acid deposition. Ozone can cause acidification of dams and rivers, damage trees and crops as well as buildings and statues, and also reduce visibility.

Table 1.1: Key pollutants, sources and impacts (continued)

Pollutants	Main contributing sources	Impacts
Ground-level ozone (O_3)	· Secondary pollutant, formed through a complex photochemical reaction sequence requiring reactive hydrocarbons, nitrogen dioxide, and sunlight and controllable only through reduction of the concentrations of nitrogen dioxide and/or hydrocarbons in ambient air · Production of ground-level O_3 takes time, so air masses could have moved away from the sources of precursors before peak concentrations are reached.	*Health* Ozone at ground level is a major health concern. This gas damages lung tissue and reduces lung function. It also reduces resistance to colds and other infections. *Ecological* Ozone is beneficial in the stratosphere because it shields the Earth from the Sun's harmful ultraviolet radiation. At ground level, it is a major component of smog, reducing visibility and impacting adversely on plant function and productivity. Ozone is also implicated in the deterioration of rubber, paints, plastics, and textiles. *Climate change* Ground-level ozone is a greenhouse gas, and modelling by NASA has shown O_3 to be responsible for between one-third and half of the observed warming trend in the Arctic during winter and spring (Pollution Online, 2006).
Carbon monoxide (CO)	Carbon monoxide is produced by incomplete combustion of carbon fuels (including petrol, diesel, wood, coal, and liquid petroleum gas) in the transportation, industrial, and household sectors.	*Health* When CO enters the bloodstream, it reduces the delivery of oxygen to the body's tissues and cells, because the haemoglobin in the red blood cells has a higher affinity for CO than for oxygen.
Carbon dioxide (CO_2)	Carbon dioxide is found naturally in the atmosphere. It is also a product of complete combustion of fossil fuels.	*Health* Carbon dioxide constitutes a health risk only at concentrations high enough to displace oxygen and cause asphyxiation. *Climate change* Carbon dioxide is a greenhouse gas.
Volatile organic compounds (VOCs) including hydrocarbons	· Commonly occurring VOCs including benzene, ethylbenzene, toluene, and xylene · Transport (petrol vehicles are a key contributor, as well as diesel vehicles and airport activities) · Industrial processes, particularly chemical manufacturing facilities and refineries – including stack emissions and diffuse sources such as evaporative emissions from chemical storage · Dry cleaners, paint spray booths, and residential use of solvents and paints · Household fuel-combustion · Waste disposal sites – trace releases of toxic and odoriferous VOCs · Biomass burning, including wild fires and crop burning	*Health* Some VOCs are respiratory irritants, others cause malodour (for example, limonene, amines, butyric acid), and some are carcinogens (such as benzene and methylene chloride). *Ecological* VOCs participate in the complex chemical reactions whereby O_3 is formed at ground level.
Methane (CH_4)	Landfill sites and livestock farming are important sources of methane.	*Health* Methane constitutes a health risk only at concentrations high enough to displace oxygen and cause asphyxiation. It is a serious hazard at explosive or combustible concentrations. *Climate change* Methane is a greenhouse gas, with a global warming potential (GWP) of 23[1].

1. Each greenhouse gas (GHG) has a calculated global warming potential (GWP), which is a measure of its contribution to global warming. The GWP is a relative scale, which compares the gas in question to the same mass of carbon dioxide (assigned a GWP of 1). GWP depends on the absorption of infrared radiation, the spectral location of its absorbing wavelengths, and the atmospheric lifetime of the species.

Table 1.1: Key pollutants, sources and impacts (continued)

Pollutants	Main contributing sources	Impacts
Ammonia (NH_3)	Sources of ammonia are industries (fertilizer and explosive manufacture); the natural decomposition of animals, plants, and manure; and the use of consumer products containing ammonia.	*Health* Ammonia is produced within the human body and contributes to the acid/base balance. Exposure to high concentrations can cause irritation to the eyes, nose, and throat. *Ecological* Ammonia in soil is a source of nitrogen for plants.
Hydrogen sulphide (H_2S) and total reduced sulphur (TRS)	Sources of H_2S are natural gas, sulphur springs, refineries, paper mills, iron smelters, food processing, sewage treatment, and landfill sites.	*Health* At low concentrations, hydrogen sulphide is associated with malodour and mild respiratory ailments. As concentration increases, it can cause eye, nose, and throat irritation, headache, nausea, and vomiting. At high concentrations, pulmonary oedema may develop. Exposure to concentrations greater than 500 ppm may cause death. *Ecological* Hydrogen sulphide can be oxidized in air to form sulphuric acid and elemental sulphur. In water, it can damage plants such as rice.
Lead (Pb)	Leaded petrol additives (leaded fuel), lead smelters, and battery plants are the main sources of lead in air.	*Health* Lead affects the human central nervous system and causes a decrease in IQ. Children are a sensitive population as they absorb Pb more readily than adults and their nervous system is still developing. Lead accumulates in bone. It also affects the kidneys, blood-forming system, and reproductive system. *Ecological* Lead is a widely used metal that can contaminate air, water, and soil.
Chromium (Cr), specifically hexavalent chromium (Cr^{6+}); cadmium (Cd)	· Cr^{6+} is generally produced by industrial processes, particularly ferro-chromium plants in the case of Cr · Particulate emissions from incinerators can contain heavy metals such as chromium and cadmium.	*Health* Cr^{6+} is a confirmed human carcinogen. Cd is a probable human carcinogen. *Ecological* The reduction of Cr^{6+} to Cr^{3+} is possible in aerobic soils. Cr^{6+} can be reduced to Cr^{3+} in water, if a suitable reducing agent (such as, for example, some organic substances) is available. Cadmium is highly toxic to wildlife; can be more toxic to plants at lower soil concentrations than other heavy metals; and is more readily absorbed than other metals.

Source: Intergovernmental Panel on Climate Change, 2001

Chapter 2

Air quality and sustainable development

At a glance

The "interdependent and mutually reinforcing pillars" of sustainable development are economic development, social development, and environmental protection. The international challenge in air quality management is to deliver cleaner air, and to do so without damaging society or the economy. The National Environmental Management: Air Quality Act clearly commits South Africa to preventing pollution and to improving and maintaining air quality, not at the expense of socio-economic development but in a way that complements it. The concept of 'sustainable cities' has emerged where environmental considerations, including air quality management, are systematically integrated into development plans, specifically those relating to energy, transportation, and land use. Some key aspects of sustainable air quality management include cost-effective air quality monitoring systems, appropriate air quality standards, the prioritization of sources based on impact, and future trends and cost-benefit analysis of strategies to reduce emissions. The task of addressing air pollution is connected to poverty alleviation, environmental justice, and considerations of the social acceptability of interventions.



Sustainable development is often misinterpreted as focusing solely on environmental issues. In reality it is a much broader concept, as sustainable development policies encompass three general policy areas: economic, environmental, and social. These "interdependent and mutually reinforcing pillars" of sustainable development are economic development, social development, and environmental protection (United Nations, 1987).

In committing themselves to sustainable development, nations commit to balancing and integrating the social, economic, and environmental components of their societies. To this end, services need to be planned and delivered so as to address the nations' social, economic, and environmental goals harmoniously and concurrently. Managing air quality within a sustainable development context emphasizes the 'interface' between the environment and the economy on the one hand, and between the economy and society on the other (OECD, 2005).

Photography: Janet Peace

The international challenge in air quality management is not simply to deliver cleaner air, but to do so without damaging society or the economy. South Africa has taken up this challenge, as is evident in the object of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004):

- To protect the environment by providing reasonable measures for:

  (a) The protection and enhancement of the quality of air in the country;

  (b) The prevention of air pollution and ecological degradation; and

  (c) Securing ecologically sustainable development while promoting justifiable economic and social development.

- 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.

The Air Quality Act clearly commits the country to preventing pollution and to improving and maintaining air quality, not at the expense of socio-economic development but in a way that coincides with it. Realizing this vision will require carefully tailoring the various regulations being developed and implemented under this framework act. To support regulatory development and roll-out, it is useful to consider the experience gained and lessons learned by other countries in managing air quality as well as to analyze key successes and failures both at the 'environment' and 'economy' interface and at the 'environment' and 'society' interface. The experiences of the USA and Europe are particularly helpful, as the USA has sculpted and implemented air quality management for over 40 years, and the European Union for over 25 years[1].

1. The US Clean Air Act of 1963 and Air Quality Act of 1967 set Air Quality Criteria and Air Quality Control Regions, and made provision for developing and implementing State Implementation Plans. Under these acts, federal government coordinates efforts through the US Environmental Protection Agency (US EPA) and sets national air quality standards and approaches to pollution mitigation, so as to provide a basic level of environmental protection to all individuals in the USA. State and local governments then develop, implement, and enforce specific strategies and control measures to achieve the national standards and goals.

In the European Union, air quality management started in 1980 with the publication of Directive 80/779/EEC, which set air quality limit values for sulphur dioxide and suspended particulates. The 1996 Air Quality Framework Directive and its daughter directives were a significant step aimed at establishing a harmonized structure for assessing and managing air quality throughout the EU. Within this structure, the EU member states have considerable scope to determine the actions they will take to meet their commitment to achieve air quality standards. They must, however, at the same time implement the other EU-level measures comprising the overall EU air quality management system, including stationary source emission controls, technical requirements to limit emissions from motor vehicles, fuel quality standards, and others.



2.1 ENVIRONMENTAL–ECONOMIC INTERFACE

The Organisation for Economic Co-operation and Development (OECD) review of key results in implementing sustainable development during the period 2001–2004 noted that more ambitious environmental objectives could have been achieved, for little or no additional cost, had policy-making incorporated environmental and economic concerns from the start. Noting the potential for abatement costs to rise markedly in future as environmental standards become stricter and 'low hanging fruit' and gross polluters are progressively eliminated, the need for cost-efficient options in the coming years is increasingly being emphasized (OECD, 2005).

The key mistakes made in air quality management, with specific examples, may be summarized as follows:

- Failure to integrate air quality considerations into energy, transportation, land use, housing, and other development planning processes has increased the cost of improving air quality, and impeded the management of emissions from significant sources such as vehicles, residential fuel-burning, and power generation.

- Failure to integrate economic concerns into air quality management and planning has strengthened the environmental pillar of sustainable development at a cost to the economic pillar, as a direct consequence of choosing relatively inefficient policies. Specific actions have included:

  - The adoption of costly air quality monitoring systems, with emphasis on continuous monitoring of 'everything, everywhere', regardless of the actual state of air quality at the relevant locality

  - The adoption of overly ambitious air quality objectives. The failure of countries to analyze costs and benefits of air quality management policies systematically, or to integrate such findings into decision-making, have largely been responsible for their adopting unrealistic objectives

  - The creation of regulations based on the mandated use of a particular technology to realize emission reduction. In many instances, such regulations have brought high costs and discouraged cost-saving innovations

  - Targeting sources on the basis of their contributions to total emissions rather than on their contributions to ambient air pollutant concentrations and, more specifically, to the impacts on health and the broader environment

  - Putting the primary focus on 'command and control' measures without formulating or implementing other mechanisms, such as market instruments.


The Cape Town city bowl.

The above mistakes have most successfully been addressed through the implementation of several approaches documented in the subsections that follow.

2.1.1 Sustainable cities

The concept of 'sustainable cities' has been developed where environmental considerations, including air quality management, are systematically integrated into development plans, specifically those relating to energy, transportation, and land use. This approach illustrates the recognition of the inherent links among issues of transport, environment, energy, and spatial development, and the need for closely coordinated policies. This broadened approach to air quality management is not being implemented just by

developed countries, but also increasingly by developing nations that realize that cost-effective and sustainable solutions require more than the adoption of stringent standards or the implementation of advanced air pollution control technologies.

The South African AQA provides the context for harmonizing air quality management and development planning. Each national department or province responsible for preparing an environmental implementation plan or environmental management plan in terms of Chapter 3 of the National Environmental Management Act (NEMA) (Act no. 107 of 1998) is required to include, as part of it, an air quality management plan.

National departments required to include an air quality management plan in their *environmental implementation plans* include those of Environmental Affairs and Tourism; Land Affairs; Agriculture; Housing; Trade and Industry; Water Affairs and Forestry; Transport; and Defence. National departments required to include an air quality management plan in their *environmental management plans* include those of Environmental Affairs and Tourism; Water Affairs and Forestry; Minerals and Energy; Land Affairs; Health; and Labour. These plans have to contain a description of policies, plans, and programmes that could significantly affect air quality, and a description of the manner in which the relevant national department or province will ensure that the policies, plans, and programmes comply with NEMA principles.

Chapter 5 of the Municipal Systems Act (Act no. 32 of 2000) requires each local government to prepare an integrated development plan (IDP), and the AQA requires each local government to prepare an air quality management plan as part of its IDP. The success of local air quality management planning will be gauged in terms of the extent to which pertinent aspects of the air quality management plan are reflected in the transportation, energy, housing, and spatial development policies and programmes documented in other sections of the IDPs.

Although the AQA has introduced an air quality management planning regime that fits seamlessly within existing planning regimes, government recognizes that much work remains to be done to ensure that such planning is properly implemented and fully integrated with existing plans.

Common international responses to non-compliance with mandatory air quality limits have been to allow offenders to deviate from the legislation

2.1.2 Cost-effective air quality monitoring systems

A broad approach to air quality monitoring is increasingly being adopted, which comprises various measurement techniques ranging from passive diffusive monitoring and biomonitoring to continuous, automated, near-real-time measurement. The use of cost-effective passive diffusive monitoring campaigns to screen areas and determine the need and most suitable locations for more costly continuous monitoring is common in Europe.

In addition to screening and varied monitoring, emission inventories and atmospheric dispersion modelling are widely used in Europe and elsewhere as supplementary activities.

- Dispersion models simulate the dispersion and deposition of pollutants, using the source and emissions data from inventories, as well as meteorological, terrain, and land-use data. Some dispersion models can also simulate chemical transformation in the atmosphere.

- While continuous monitoring is typically able to provide time-resolved information on air pollution concentrations at specific points, dispersion models can characterize spatial and temporal variations in air pollution concentrations for the entire domain and period for which source, emission, and meteorological data are available.

- Monitoring, when conducted properly, offers the most accurate information, so monitoring data are used to verify the completeness and accuracy of emission inventories and dispersion models.

The integration of emission inventories, dispersion modelling, and a range of monitoring techniques into comprehensive air quality monitoring systems is an efficient and cost-effective means for characterizing baseline air quality and for tracking trends.

2.1.3 Aligning air quality standards with sustainable development

Setting air quality limits at levels that cannot be achieved through reasonable policy approaches can potentially undermine the credibility of the air quality management system that such limits aim to support. Common

Passive diffusive samplers are used for monitoring air pollution concentrations.

Photography: Hans Linde

international responses to non-compliance with mandatory air quality limits have been to allow offenders to deviate from the legislation (NSCA, 2004). This has taken the form, for example, of relaxing the timeframe for compliance. For industry-related non-compliance, the most common approach is to allow older industrial installations to continue operating until a specified date outside the new regulations in instances where using pollution abatement equipment would render them uneconomical.

The European Commission (EC) approach to this problem has been to establish and implement a system of multiple levels of air quality objectives, which include: limit values, target values, and alert thresholds, defined as follows.

- *Limit values* have to be based on scientific knowledge, with the aim of avoiding, preventing, or reducing harmful effects on human health and the environment as a whole. Limit values must be attained within a given period and, once attained, are not to be exceeded.

- *Target values* are intended to avoid harmful long-term effects on human health, and environmental target levels are to be attained where possible over a given period. Such levels represent long-term goals to be pursued through cost-effective progressive methods, and are frequently termed 'long-term acceptable thresholds'. At these levels, pollutants are harmless to health and the environment, or, alternatively, unable to be reduced[2] because they occur naturally, for example.

- *Alert thresholds* refer to levels beyond which even brief exposure carries a risk to human health. Exceeding such thresholds means that immediate remedial steps must be taken.

The EC system also provides for what are known as 'margins of tolerance'. Each of these represents a proportion of the limit value by which that value may be exceeded, subject to the conditions laid down in the framework for standard implementation (see Figure 2.1). The margin of tolerance is reduced each year, so as to reach zero on the date by which the limit value must be met. The purpose of the margin of tolerance is to identify areas with the worst air quality (that is, Group 1 areas, in which the margin of tolerance is exceeded). It is also designed to distinguish between areas in which air pollutant concentrations exceed the limit value but are within the margin of tolerance (Group 2 areas), and areas in which concentrations are below limit values (Group 3 areas).

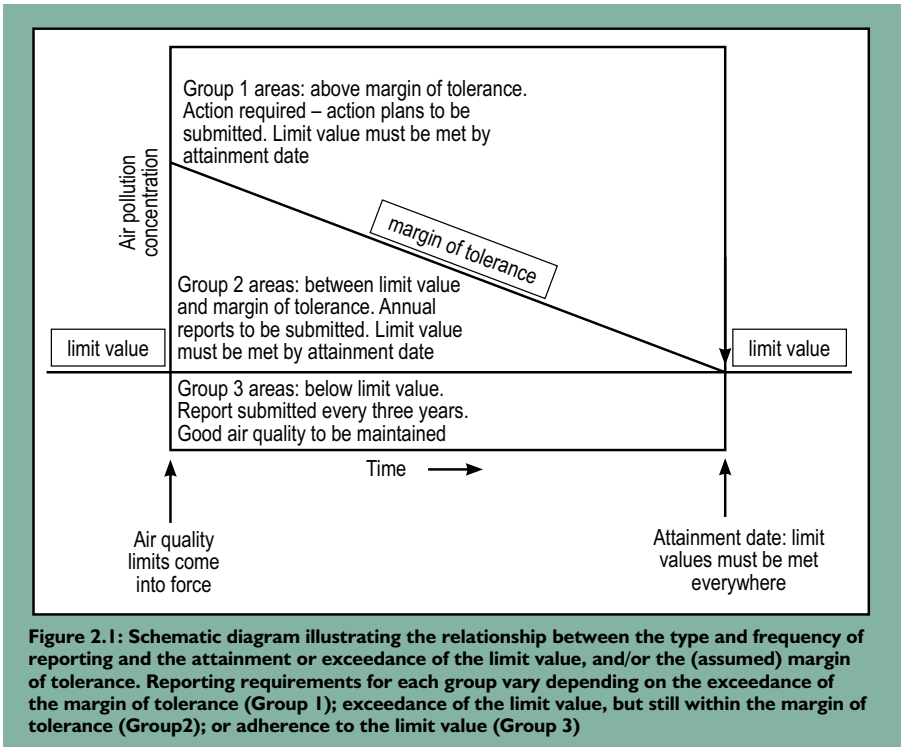
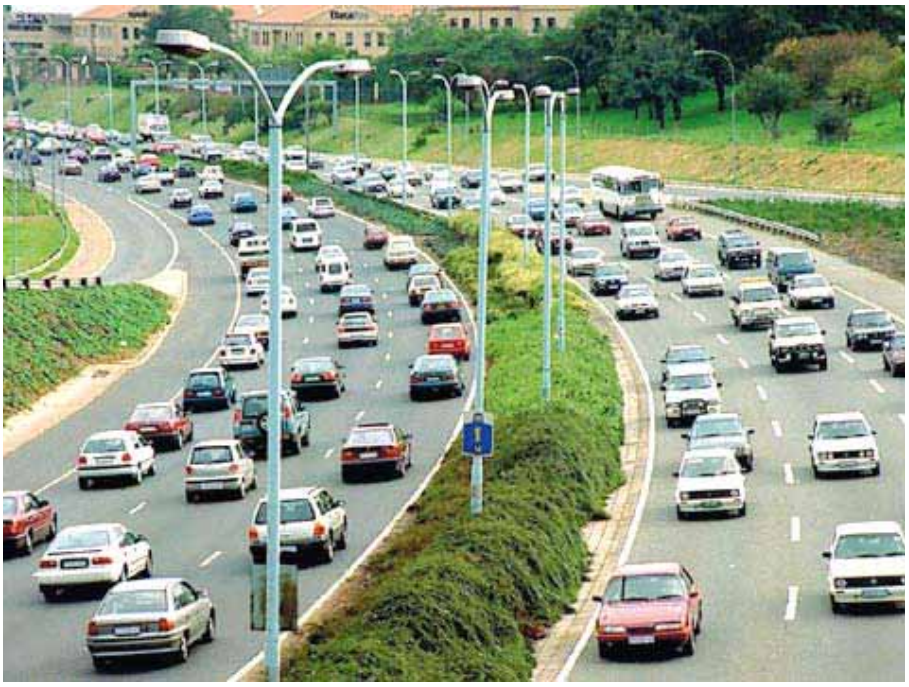


Figure 2.1: Schematic diagram illustrating the relationship between the type and frequency of reporting and the attainment or exceedance of the limit value, and/or the (assumed) margin of tolerance. Reporting requirements for each group vary depending on the exceedance of the margin of tolerance (Group 1); exceedance of the limit value, but still within the margin of tolerance (Group2); or adherence to the limit value (Group 3)

2. Sometimes, as in South Africa (as a result of natural veld fires, for instance), a certain level of pollution pre-exists in the atmosphere. No amount of abatement technology demanded of industry is able to remove this kind of naturally occurring level of pollution.





Air quality planning and reporting requirements are stipulated for each group, with the most stringent ones set for Group 1 areas. A margin of tolerance is therefore not a deviation from a limit value, but rather provides a trigger for action in the period before the limit value must be met.

The EC system of air quality objectives explicitly links air pollution concentrations to appropriate air quality planning and remedial action over suitable timescales. The system emphasizes the fact that changes in ambient air quality take place over extensive periods, and that long-term planning is more effective than corrective action that attempts instantaneous improvements.

The EC approach to setting and implementing air quality limits was adopted by Standards South Africa, as documented in its publications (SANS 69:2004, and SANS 1929:2005).

2.1.4 Prioritizing sources on the basis of impact and future trends

The extent and toxicity of emissions is not necessarily a concise indicator of contributions to ground-level air pollution concentrations or of risks to health and the environment. Such contributions are also a function of the height of emission, temporal variations in the release of pollutants, and the proximity of the source to the people or the environment affected by exposure to the pollutant (such as, for instance, children, or the elderly, or people who are ill, or others who may be particularly sensitive receptors to a specific pollutant above a certain concentration). If an industry is operating close to a school or hospital or centre for the elderly, the potential exposure (in combination with the other contributing factors) is high.

Three factors govern the significance of household fuel-burning emissions: (i) the low level of emissions (that is, their height above the ground is generally about 3 m, within people's breathing zone); (ii) the simultaneous occurrence of peak emissions (during the coldest months of winter and in the early mornings and throughout the evenings) and poor atmospheric dispersion (stable atmosphere with low wind speeds, with the possible development of temperature inversions); and (iii) the release of such emissions within high human exposure areas, given that such emissions generally occur in dense, low-income settlements where population density is high (in addition, the pollution is not only outdoors, but frequently indoors as well, due to poor ventilation, so it affects the whole family).

The significance of vehicle emissions as contributors to air-pollutant concentrations and health risks is similarly increased by the low level (close to the ground) of the emissions, and their proximity to highly populated areas – on highways, for example, with emissions being particularly high when traffic is congested. Vehicle emissions tend to peak early in the morning and in the evenings, when the potential for atmospheric dispersion is reduced (for example, wind speeds are generally low in the early mornings and evenings, reducing their potential for dispersing pollution).

Given the high volumes of pollutants emitted from fuel-burning within the industrial and power-generation sectors, their contribution to ambient concentrations and public health risks is often lower than might be expected. This is because these sources are generally characterized by constant releases, relatively high above ground level, and further away from residential settlements than are household fuel-burning and vehicle emissions.

Ranking the significance of different sources of pollution on the basis of the total emissions for which



each source is responsible would, for example, place industrial emissions above household fuel-burning. If the aim is to reduce impacts on human health, however, then household fuel-burning would need to be targeted as a top priority (Scorgie *et al.*, 2004d).

Future trends in emissions are a further consideration for ranking sources in terms of their significant effects. Vehicle emissions, for instance, are currently responsible only for infrequent exceedances of air quality limits at sites close to busy roads. It is, however, advisable for this source group to rank high as a priority, because of the significant rise vehicle activity in many South African urban areas and, as is evident from Europe's experience, the substantial lead-time required to reduce such emissions successfully.

2.1.5 Cost–benefit analysis of strategies to reduce emissions

Before adopting air quality standards and emission-reducing strategies, it is imperative for such standards and strategies to be reviewed for their economic (and social) consequences, and for the findings of such analyses to be integrated successfully into decision-making processes. Such reviews must examine not only the costs of implementing air quality standards and reducing emissions, but also include the consequent benefits arising from these actions, such as reduced health costs, for example.

In South Africa, a cost–benefit analysis was undertaken for several emission reduction options, targeting fuel-burning sources within the industrial, transportation, and residential sectors (Scorgie *et al.*, 2004e). Findings from this study have been taken into account by various government departments in considering cost-effective emission-reduction opportunities (for example, the departments of Environmental Affairs and Tourism, Minerals and Energy, and Trade and Industry).

Cost–benefit analysis helps not only in selecting cost-optimized mitigation measures for implementation across source sectors, but also with decisions about the types and groupings of pollutants to be targeted. Important lessons can be learned from Europe and the USA, whose emission-reduction strategies were historically developed for individual pollutants. They realized, however, that implementing emission-reduction strategies for individual pollutants was not the most effective or economically efficient way to reduce the ill-effects of air pollution on human health (NSCA, 2003). On the basis of their experiences, it is recommended that South Africa consider implementing health assessment methods and emission control measures for multiple pollutants.

The use of cost-benefit analysis is suggested in targeting source groups and multiple pollutants, and in designing solutions that achieve synergy between local air quality management and global climate protection strategies. It represents an effective way to achieve the highest level of human and environmental protection by the most cost-effective means.

2.1.6 A flexible approach to reducing the impact of air pollution

Historically, air pollution control in South Africa has primarily emphasized the implementation of 'command and control' measures in the industrial sector. The shift from source-based control, to the management of the air that people breathe, emphasizes the importance of targeting a wider range of sources and using more flexible and varied approaches. It means

Unpaved roads are a source of vehicle-entrained dust all over South Africa.
Photography: Janet Peace

paying greater attention to ambient air quality, as it is more important (and more cost-effective, in many cases) to make sure that the ambient air complies with air quality standards. This approach ensures that human and environmental health is protected and that the cumulative impact of pollution from a number of sources is addressed. Approaches adopted or considered for future implementation have included: regulation (for example, the use of Atmospheric Emission Licences for Listed Activities); market instruments (such as atmospheric user-charges and pollution taxes); the potential for voluntary agreements, education and awareness raising; and emissions trading.

International experience shows that adopting a mix of instruments and interventions is more effective than using a single instrument to improve air quality across various types of source. Although direct regulation remains important in controlling industrial sources, there is evidence that specifying emission limits is more effective than specifying the use of particular technologies, so as to give companies flexibility in selecting the method of achieving success that suits them best. This approach is advocated as being more cost-effective and more likely to stimulate technological advances in pollution control methods and production processes. For large point sources (that is, sources of pollution that are concentrated on one site, but that have large, constant volumes of many types of pollution) that are few in number, instruments such as emissions trading have been advocated as an effective way to manage pollutant emissions and reduce the costs of compliance.

The geographically dispersed nature of vehicular sources makes it difficult for monitoring and enforcement authorities to target each source

The geographically dispersed nature of vehicular sources makes it difficult for monitoring and enforcement authorities to target each source, so a mix of technical and non-technical measures is needed. Technological advances progressively reduce emissions from new vehicles through improved vehicle and fuel efficiencies. Internationally, however, such solutions alone have been found inadequate for addressing traffic emissions, and car ownership and the behaviour of users is also a major influence. In South Africa, the problem is aggravated by the fact that public transport is limited. Strategies to reduce vehicle emissions should also include other measures, such as transport demand and supply management, and traffic management, to reduce the incentive for using personal vehicles and to expand and promote the use of the public transport system.

Informal refuse burning is a source of dangerous atmospheric pollutants which are emitted into the human breathing zone.

Photography: Janet Peace

2.2 ENVIRONMENTAL–SOCIAL INTERFACE

2.2.1 Addressing air pollution through poverty alleviation

Implementing an efficient social protection system to alleviate poverty is central to maintaining conditions that facilitate not only economic growth but also environmental sustainability. Many South African households – including those with access to electricity – use coal, wood, and paraffin, due to the relative cost-effectiveness of such fuels for heating (that is, space heating) and cooking purposes.

Many low-cost housing developments and informal settlements are located close to industrial and mining operations, as such land is both available and inexpensive. Poorer communities are more likely to suffer from poor service delivery, including inadequate waste removal that sometimes results in refuse being set alight illegally.

These examples show that poverty alleviation could help to improve air quality by enabling people to choose practices that are friendlier to the environment.

2.2.2 Addressing environmental injustice

Environmental hazards, including exposure to air pollution, are known to have a disproportionately severe effect on people whose place in society has already compromised their health and nutritional status. Air quality management strategies must therefore aim to address environmental injustices by, for example, prioritizing sources of pollution that have an impact on marginalized communities. Integrating air quality considerations into land use planning also has significant benefits, for instance by ensuring that low-cost residential developments are not located close to potentially significant sources of emission, such as heavy industrial complexes.

Where air quality is persistently poor, or deteriorating unavoidably, it is necessary to minimize the burden on those people who are worst affected, through measures such as improvements to the medical system and compensation (using the 'polluter-pays' principle).

A mine tailings dam along the Johannesburg gold reef.
Photography: Janet Peace

2.2.3 The social acceptability of interventions

To be successful, air quality interventions must not only be technically viable and economically feasible but also socially acceptable. This lesson was learned in South Africa in the 1980s and 1990s, when the Department of Minerals and Energy (DME) investigated the introduction of low-smoke fuels as an alternative for coal- and wood-burning households.

During this period, various social studies revealed strong links between energy use and religious, cultural, and social factors and values. Both social and economic studies indicated that a single intervention was unlikely to succeed in reducing emissions from household fuel-burning, and that the DME needed to identify the least costly, most desirable, and most effective energy-mix options.

This revised approach, integrating socio-economic considerations with strategic development, was evident in the DME's Integrated Clean Household Energy Strategy adopted in 2003. This strategy refers to a range of interventions, including refining combustion methods and appliances; replacing coal with electricity, low-smoke fuels, renewable energy, and alternative fuels; and reducing the energy requirements of dwellings through insulation and solar passive design. The NEDLAC study (Scorgie *et al.*, 2004e) included a cost–benefit analysis of several of these interventions, and its findings have been used by the DME to inform the strategy's implementation.

Chapter 3

Air quality standards and objectives

At a glance

Air quality limits and thresholds are fundamental to effective air quality management. Ambient air quality limits serve to indicate what levels of exposure to pollution are generally safe for most people, including the very young and the elderly, over their lifetimes. While the World Health Organization (WHO) provides scientific guidance to all countries on the levels of pollution that adversely affect human health, its work does not take into consideration the socio-economic conditions prevalent within any country. As a result, the WHO produces guidelines that a country can then use to inform the development of its own standards. The pollutants for which South Africa has set air quality limits include particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, lead, ozone, benzene, and the deposition of dust. The health impacts of the criteria pollutants, for which limits have been set, are briefly described.



There is concern about PM_{10} and $PM_{2.5}$ because of the potential health risks that they pose, given that such fine particles are able to be deposited in, and cause damage to, the lower airways and gas-exchanging portions of the lungs

Air quality limits and thresholds are fundamental to effective air quality management, as they link the potential source of atmospheric emissions with the user of that air at the downwind receptor site[1]. Ambient air quality limits serve to indicate what levels of exposure to pollution are generally safe for most people, including vulnerable groups, over their entire lifetimes. Such limits are typically set for common air pollutants that are usually emitted into the atmosphere, sometimes in large quantities, through various industrial and other processes, and for which health and environmental impacts are relatively well-known.

Suspended fine particulate matter, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), lead (Pb), and ozone (O_3) are classified by most countries as 'criteria pollutants', and air quality limits are set for all of them (see §3.1 below). Such limits are not published for all possible air pollutants to which the public may be exposed, but are typically set only for common ones that are known to have detrimental effects. For constituents of air that are listed as pollutants but for which no limits are promulgated, dose-response thresholds have been published by public health bodies such as the WHO (see §3.2 below).

Air quality indexing systems are often used to communicate the extent and acceptability of air-pollution levels in a concise and readily understandable way, and are able to integrate information across a range of chemical compounds (specifically those relating to air pollution, such as SO_2) and averaging periods. The creation of bands, in the approach adopted by the UK, for example, helps to classify 24-hour periods into 'low', 'medium', 'high', and 'very high' air pollution days. Although various indexing systems are currently in use in different parts of South Africa, no single national air quality index had been adopted for national implementation by the end of 2004. The simple air quality classification system used in this report is outlined in §3.3.

3.1 AIR QUALITY LIMITS FOR CRITERIA POLLUTANTS

National air quality standards are given in Schedule 2 of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004). They largely reflect the national air quality guideline values established in the 1990s, and have become dated and in need of revision.

The Department of Environmental Affairs and Tourism (DEAT) has been reviewing and revising the national air quality standards published in the AQA, to ensure that these limits adequately protect human health and welfare. The review process began with the gazetting of a new interim guideline for SO_2 in December 2001, and this revised level was then included in the AQA. Subsequently, the DEAT engaged the South African Bureau of Standards (SABS) to facilitate the development of further health-based ambient air quality standards. Two documents were compiled during this process: *SANS 69:2004 – South African National Standard – Framework for setting & implementing national ambient air quality standards, and SANS 1929:2005 – South African National Standard – Ambient Air Quality – Limits for common pollutants*. The latter includes limits for particulate matter less than 10 μm in aerodynamic diameter (PM_{10}), dust deposition, SO_2, NO_2, O_3, CO, Pb, and benzene (C_6H_6). These SANS documents were finalized and published in 2004 and 2005. The adoption of the air quality limits documented in SANS 1929:2005 is under consideration by the Department. Finalizing these standards and having them accepted as national standards requires permissible frequencies of exceedance and compliance time-frames to be established.

The health impacts of criteria pollutants are briefly discussed below, and national air quality limits published locally for such pollutants are compared to widely-referenced limits published by other countries and international organizations. (For further details on the health and ecological impacts of common pollutants, see DEAT, 2006c.)

3.1.1 Suspended particulate matter

The potential of particles to be inhaled and deposited in the lungs is a function of the aerodynamic characteristics of these particles in the air, and it is related to their size, shape, and density. Their impact on human health largely depends on (i) particle characteristics, especially particle size and chemical composition, and (ii) the duration, frequency, and magnitude of people's exposure to them.

1. A downwind receptor site is any site downwind of a source of pollution – sometimes specific receptor sites are identified as communities, or as buildings or areas (such as a school), where people (or specified ecosystems) are affected by that particular source of pollution.



The deposition of particles in different regions of the human respiratory system depends on their size. Nasal openings allow large dust particles to enter the nose, along with much finer airborne particulates. The larger particles are deposited on the hairs in the nose or at the bends of the nasal passages. Smaller particles (PM_{10}) pass through the nasal region and are deposited in the windpipe and lung (tracheobronchial and pulmonary) regions. As they hit the bronchial walls, particles are removed from the inhaled air. When the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane[2] (CEPA/FPAC Working Group, 1998; Dockery & Pope, 1994). Such fine particles are able to be deposited in the lower airways and gas-exchanging portions of the lungs, and to cause damage there[3].

Air quality guidelines for particulates are given by various countries and organizations for various particle sizes, including total suspended particulates (TSP), *inhalable* particulates (PM_{10}), and *respirable* particulates ($PM_{2.5}$, defined as particulates with an aerodynamic diameter of less than 2.5 μm)[4]. Although the term TSP technically refers to all particulates with an aerodynamic diameter of less than 100 μm, it is normally applied to particulates with an upper aerodynamic diameter limit of 30 μm. There is concern about PM_{10} and $PM_{2.5}$ because of the potential health risks that they pose, given that such fine particles are able to be deposited in, and cause damage to, the lower airways and gas-exchanging portions of the lungs.

The PM_{10} limits and standards issued nationally and abroad are documented in Table 3.1. In addition to the PM_{10} standards published in Schedule 2 of the AQA, this act also includes standards for TSPs (namely, a 24-hour average maximum concentration of 300 $\mu g/m^3$ not to

Table 3.1: Air quality standard for inhalable particulates (PM_{10})

Authority	Maximum 24-hour concentration ($\mu g/m^3$)	Average annual concentration ($\mu g/m^3$)
SA standards (AQA)*	180[a]	60
SANS limits (SANS 1929:2005)	75[b] 50[c]	40[d] 30[e]
Australia	50[f]	–
EC	50[g]	30[h] 20[i]
World Bank (General Environmental Guidelines)	70[j]	50[j]
World Bank (Thermal Power Guidelines)	150[k]	50[k]
UK	50[l]	40[m]
US EPA	150[n]	50[o]
WHO	50[p]	20[p]

ABBREVIATIONS: EC, European Commission; SANS, South African National Standard; SA standards (AQA), South African standards (Air Quality Act); UK, United Kingdom; US EPA, United States Environmental Protection Agency; WHO, World Health Organization.

* On 9 June 2006, South Africa's Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (a 90-day comment period was given). The proposed PM_{10} standards were given as 75 $\mu g/m^3$ for highest daily (compared to the previous standard of 180 $\mu g/m^3$) and 40 $\mu g/m^3$ for annual averages (compared to 60 $\mu g/m^3$ previously) (*Government Gazette* No. 28899, 9 June 2006).

[a] Not to be exceeded more than three times in one year.

[b] Limit value. Permissible frequencies of exceedance, margin of tolerance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[c] Target value. Permissible frequencies of exceedance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[d] Limit value. Margin of tolerance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[e] Target value. Date by which limit value should be complied with to be determined through a complete standard-setting process through the SABS.

[f] Australian ambient air quality standards (www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more often than 5 days per year. Compliance by 2008.

[g] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year. (From 1 January 2010, no violations more often than 7 times per year will be permitted.)

[h] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005.

[i] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010.

[j] World Bank (1998), Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air conditions at property boundary.

[k] World Bank (1998), Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air quality in thermal power plants.

[l] UK Air Quality Objectives (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 35 times per year. Compliance by 31 December 2004.

[m] UK Air Quality Objectives (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2004.

[n] US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.

[o] US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). To attain this standard, the 3-year average of the weighted annual mean PM_{10} concentration at each monitor within an area must not exceed 50 $\mu g/m^3$.

[p] WHO (2000) issued linear dose-response relationships for PM_{10} concentrations and various health endpoints, with no specific guideline provided. WHO (2005), made available during early 2006, proposed several interim target levels (see following tables).

2. Brownian motion is the erratic random movement of microscopic particles in a fluid, as a result of continuous bombardment from molecules of the surrounding medium. The pollutant particles reach the alveolar membrane in the air that is breathed in.

3. The breathing process is a guide to understanding the way in which the damage is caused. As air enters the body through the nose or mouth, it passes the epiglottis and enters the trachea, continuing through the vocal cords in the larynx until it reaches the bronchi; from there it passes into each lung. Following narrower and narrower bronchioles, the air then reaches the alveoli. The oxygen concentration is high within each air sac, so oxygen passes or diffuses across the alveolar membrane into the pulmonary capillary. At the beginning of the pulmonary capillary, the haemoglobin in the red blood cells has CO_2 bound to it and very little oxygen. The oxygen binds to haemoglobin and the CO_2 is released – it is also released from sodium bicarbonate dissolved in the blood of the pulmonary capillary. The CO_2 concentration is high in the pulmonary capillary, so CO_2 leaves the blood and passes across the alveolar membrane into the air sac. This exchange of gases occurs rapidly (fractions of a second). When the person exhales, the CO_2 leaves the alveolus, and the oxygen-enriched blood returns to the heart. The purpose of breathing, therefore, is to keep the oxygen concentration high and the CO_2 concentration low in the alveoli, so that this gas exchange can occur.

4. In air quality, 'inhalable' refers to the depth in the lung to which PM_{10} particles penetrate, and 'respirable' refers to the level deeper down in the lung to which $PM_{2.5}$ particles penetrate.



be exceeded more than three times in one year, with an annual average limit of 100 $\mu g/m^3$).

During the 1990s, the WHO stated that no safe thresholds could be determined for exposure to particulates, and responded to the problem by publishing linear dose-response relationships for PM_{10} and $PM_{2.5}$ concentrations (World Health Organization, 2005). Dose-response relationships refer to the relationship between human exposure to a pollutant and the resultant health response to that exposure. In this case the relationship is linear, but that is not always the case. Linear dose-response relationship graphs were published to illustrate the fact that the relationship between PM concentration and various health indicators were roughly 'linear' – that is, as PM concentration increases, the percentage increase in daily mortality increases linearly. Similarly, as PM concentration increases, the proportional change in hospital admissions assigned, specifically, to PM_{10}, $PM_{2.5}$, and sulphates, also increase linearly; and as PM concentration increases, the proportional change in various health end-points (such as peak expiratory flow, coughing, symptom exacerbation, and bronchodilator use) is also linear.

This approach was not well accepted by air quality managers and policy-makers, so the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document define concentrations which, if achieved, would be expected to reduce the rates of adverse health effects. Such guidelines would provide air quality managers and policy-makers with explicit objectives when setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO Air Quality Guidelines (AQGs), the working group also proposed interim targets (IT), higher than the WHO's AQG levels, to promote steady progress towards meeting the AQG objectives (World Health Organization, 2005). (See Tables 3.2 and 3.3 for the air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter.)

Air quality standards for $PM_{2.5}$ had (by the end of 2006) been set by various countries such as the USA, Canada, and Australia (see Table 3.4). The EC is still in the process of developing its $PM_{2.5}$ limit. No air quality limits have yet been published in South Africa for this particulate size.

Table 3.2: WHO Air Quality Guideline and interim targets for particulate matter (annual mean)
(World Health Organization, 2005)

Annual WHO mean level	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels were estimated to be associated with long-term mortality, which is about 15% higher than at AQG levels
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% (2–11%) compared with IT-1
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risks by a further approximately 6% (2–11%) compared with IT-2 levels
WHO AQG	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase (with more than 95% confidence) in response to exposure to $PM_{2.5}$ (as demonstrated in the American Cancer Society study, Pope *et al*., 2002, as cited in WHO, 2005)

ABBREVIATIONS: WHO, World Health Organization; WHO AQG, WHO Air Quality Guideline.

Table 3.3: WHO Air Quality Guideline and interim targets for particulate matter (daily mean)
(World Health Organization, 2005)

Annual WHO mean level	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Basis for the selected level
Interim target-1 (IT-1)	150	75	Published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG)
Interim target-2 (IT-2)*	100	50	Published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG)
Interim target-3 (IT-3)†	75	37.5	Published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG)
WHO AQG	50	25	Relation between 24-hour and annual levels

ABBREVIATIONS: See Table 3.2.

* 99th percentile (3 days/year)

† For management purposes, based on annual average guideline values; precise value to be determined on the basis of local frequency distribution of daily means

3.1.2 Sulphur dioxide

Sulphur dioxide is an irritant gas, which is absorbed in the nose and aqueous surfaces of the upper respiratory tract, and is associated with reduced lung function and increased risk of mortality and morbidity. Adverse health effects of SO_2 include coughing, phlegm, chest discomfort, and bronchitis. Ambient air quality guidelines and standards for SO_2 have been issued for various countries and organizations (see Table 3.5).

The WHO AQGs published in 2000 for SO_2 were revised a few years later (World Health Organization, 2005). Although the 10-minute AQG of 500 $\mu g/m^3$ remained unchanged, the previously published daily



Table 3.4: Air quality standard for $PM_{2.5}$

Authority	Maximum 24-hour concentration ($\mu g/m^3$)	Average annual concentration ($\mu g/m^3$)
Australia	25[a]	8[a]
US EPA	35[b]	15
Canada[c]	30	–

ABBREVIATIONS: US EPA, United States Environmental Protection Agency.

[a] Advisory reporting standards and goal for particles as $PM_{2.5}$. Measure schedule commenced in 2005 (www.deh.gov.au/atmosphere/airquality/standards.html).

[b] To attain this standard, the 3-year average of the 98th percentile of the 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 $\mu g/m^3$ (www.epa.gov/air/criteria.html).

[c] Canada-Wide Standards issued by the Canadian Council of Ministers of the Environment.

Table 3.5: Ambient air quality guidelines and standards for SO_2 for various countries and organizations

Authority	Maximum 10-minute average ($\mu g/m^3$)	Maximum 1-hour average ($\mu g/m^3$)	Maximum 24-hour average ($\mu g/m^3$)	Annual average concentration ($\mu g/m^3$)
SA standards (AQA)	500[a]	–	125[a]	50
SANS limits (SANS 1929:2005)	500[b]	–	125[b]	50
Proposed SA standards (*Government Gazette* No. 28899, 9 June 2006)	500[a]	350[a]	125[a]	50
Australia	–	524[c]	209[c]	52
EC	–	350[d]	125[e]	20[f]
World Bank (General Environmental Guidelines)	–	–	125[g]	50[g]
World Bank (Thermal Power Guidelines)	–	–	150[h]	80[h]
UK	266[i]	350[j]	125[k]	20[l]
US EPA	–	–	365[m]	80
WHO (2000)	500[n]	–	125[n]	50[n] 10–30[o]
WHO (2005)	500[p]	–	20[p]	–[p]

ABBREVIATIONS: See Table 3.1.

[a] No permissible frequencies of exceedance specified.

[b] Limit value. Permissible frequencies of exceedance, margin of tolerance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[c] Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more often than 1 day per year. Compliance by 2008.

[d] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).

[e] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).

[f] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limited value to protect ecosystems. Applicable two years from entry into force (date of publication) of the Air Quality Framework Directive 96/62/EC.

[g] World Bank, 1998. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air conditions at property boundary.

[h] World Bank, 1998. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air quality in thermal power plants.

[i] UK Air Quality Objective for 15-minute averaging period (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 35 times per year. Compliance by 31 December 2005.

[j] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 24 times per year. Compliance by 31 December 2004.

[k] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 3 times per year. Compliance by 31 December 2004.

[l] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2000.

[m] US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.

[n] WHO Guidelines for the protection of human health (World Health Organization, 2000).

[o] Represents the critical level of ecotoxic effects (issued by WHO for Europe); a range is given to account for the different sensitivities of various vegetation types (World Health Organization, 2000).

[p] The new WHO guidelines (World Health Organization, 2005) are documented primarily for the protection of human health. The 10-minute guideline of 500 $\mu g/m^3$ published in 2000 remains unchanged, but the daily guideline is significantly reduced from 125 $\mu g/m^3$ to 20 $\mu g/m^3$ (in line with the precautionary principle). An annual guideline is not deemed necessary, since "compliance with the 24-hour level will assure lower levels for the annual average".



guideline (which was based on epidemiological studies) was significantly reduced from 125 $\mu g/m^3$ to 20 $\mu g/m^3$. More recent evidence (cited in World Health Organization, 2005) suggested the occurrence of health risks at lower concentrations. Considerable uncertainty is acknowledged in WHO (2005) as to the extent to which SO_2 is the pollutant responsible for the observed adverse effects (these could also be due to ultra-fine particles or other correlated substances), but, nevertheless, in line with the precautionary

Table 3.6: WHO Air Quality Guidelines and interim guidelines for SO_2 (World Health Organization, 2005)

WHO mean levels	24-hour average SO_2 ($\mu g/m^3$)	10-minute average SO_2 ($\mu g/m^3$)
Interim target-1 (IT-1) (2000 AQG level)	125	
Interim target-2 (IT-2)	50*	
WHO AQG	20	500

ABBREVIATIONS: See Table 3.2.

* Intermediate goal based on controlling (i) motor vehicle emissions; (ii) industrial emissions; and/or (iii) power production: this would be a reasonable and feasible goal to be achieved within a few years for some developing countries, and lead to significant health improvements that would justify further improvements (such as aiming for the guideline).

Table 3.7: Ambient air quality guidelines and standards for NO_2 for various countries and organizations

Authority	Instantaneous peak ($\mu g/m^3$)	Maximum 1-hourly average ($\mu g/m^3$)	Maximum 24-hour average ($\mu g/m^3$)	Maximum 1-month average ($\mu g/m^3$)	Annual average concentration ($\mu g/m^3$)
SA standards (AQA)*	940[a]	376[a]	188[a]	150[a]	94
SANS limits (SANS 1929:2005)	–	200[b]	–	–	40[b]
Australia	–	226[c]	–	–	56
EC	–	200[d]	–	–	40[e]
World Bank (General Environmental Guidelines)	–	–	150 (as NO_x)[f]	–	–
World Bank (Thermal Power Guidelines)	–	–	150[g]	–	100[g]
UK	–	200[h]	–	–	40[i] 30[j]
US EPA	–	–	–	–	100(k)
WHO (2000, 2005)	–	200[l]	–	–	40[l]

ABBREVIATIONS: See Table 3.1.

* On 9 June 2006, South Africa's Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (a 90-day comment period was given). The proposed NO_2 standards were given as 200 $\mu g/m^3$ for highest daily and 40 $\mu g/m^3$ for annual averages (in line with the SANS limits). See Government Gazette No. 28899, 9 June 2006.

The standards and guidelines of most countries and organizations are given exclusively for NO_2 concentrations. South Africa's NO_2 standards are compared with various widely referenced foreign standards and guidelines in this table.

[a] No permissible frequencies of exceedance specified.

[b] Limit value. Permissible frequencies of exceedance, margin of tolerance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[c] Australian ambient air quality standards (www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more often than 1 day per year. Compliance by 2008.

[d] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Not to be exceeded more often than 18 times per year. This limit is to be complied with by 1 January 2010.

[e] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value for the protection of human health, to be complied with by 1 January 2010.

[f] World Bank, 1998. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air conditions at property boundary.

[g] World Bank, 1998. Pollution Prevention and Abatement Handbook (www.worldbank.org). Ambient air quality in thermal power plants.

[h] UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Not to be exceeded more often than 18 times per year. Compliance by 31 December 2005.

[i] UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2005.

[j] UK Air Quality Objective for NO_x for the protection of vegetation (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2000.

[k] US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html).

[l] WHO Guidelines for the protection of human health (World Health Organization, 2000). AQGs remain unchanged according to WHO (2005).



principle, the WHO decided to publish a stringent daily guideline. An annual guideline was thought not to be needed for protecting human health, since compliance with the 24-hour level would assure sufficiently lower levels to reduce the annual average. Given that the 24-hour WHO AQG of 20 $\mu g/m^3$ was anticipated to be difficult for some countries to achieve in the short term, the WHO (2005) recommended a step-by-step approach using interim goals (see Table 3.6).

3.1.3 Oxides of nitrogen

Oxides of nitrogen, primarily in the form of nitric oxide (NO), comprise a primary pollutant emitted during combustion. Nitrogen dioxide (NO_2) is formed through oxidation of these oxides once they are released into the air, and is an irritant gas, which is absorbed by the mucous membrane of the respiratory tract. The worst health effect occurs at the junction of the conducting airway and the gas exchange region of the lungs. The upper-airways are less affected, because NO_2 is relatively insoluble in aqueous surfaces. Exposure to NO_2 is linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics, and reduced pulmonary function.

3.1.4 Carbon monoxide

Carbon monoxide absorbed through the lungs reduces the blood's capacity to transport available oxygen to the tissues. This is because approximately 80–90% of the absorbed CO binds with haemoglobin to form carboxyhaemoglobin (COHb), lowering the oxygen level in blood, and, as a result, the heart needs to work harder to supply sufficient oxygen to the organs. This process is the main cause of tissue hypoxia (that is, deficiency in the amount of oxygen delivered to the body tissues) due to CO at low exposure levels. At higher concentrations, the rest of the absorbed CO binds with other haem proteins such as myoglobin and with cytochrome oxidase and cytochrome P-450. Taking in CO impairs perception and thinking, slows reflexes, and can cause drowsiness, angina, unconsciousness, or even death. (For the ambient air quality guidelines and other standards issued for various countries and organizations for CO, see Table 3.8.)

3.1.5 Ozone

Ozone is one of the most toxic pollutants regulated under ambient air quality guidelines and standards. Exposure to sufficient quantities can cause severe damage to lung tissue and weaken the body's defences against bacteria and viruses. Changes in lung function depend on the concentrations of ozone, and these increase with deeper breathing. Chronic exposures to ozone can result in the premature ageing of the lungs. Health effects associated with ozone exposures include increased incidence and severity of asthma attacks and increased pulmonary resistance. High exposure

Table 3.8: Ambient air quality guidelines and standards for CO for various countries and organizations

Authority	Maximum 1-hour CO average ($\mu g/m^3$)	Maximum 8-hour CO average ($\mu g/m^3$)
SA guidelines[a]	40 000[a]	10 000[a]
SANS limits (SANS 1929:2005)	30 000[b]	10 000[b]
Australia	–	10 000[c]
EC	–	10 000[d]
World Bank	–	–
UK	–	10 000[d]
US EPA	40 000[f]	10 000[f]
WHO	30 000[g]	10 000[g]

ABBREVIATIONS: See Table 3.1.

[a] Issued in the 1990s by the Chief Air Pollution Control Officer (CAPCO). No air quality standards for CO were included in South Africa's National Environmental Management: Air Quality Act.

[b] Limit value. Permissible frequencies of exceedance, margin of tolerance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[c] Australian ambient air quality standards (www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more often than 1 day per year. Compliance by 2008.

[d] EC Second Daughter Directive, 2000/69/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value to be complied with by 1 January 2005.

[e] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Maximum daily running 8-hourly mean. Compliance by 31 December 2003.

[f] US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.

[g] WHO Guidelines for the protection of human health (World Health Organization, 2000).

Venting of pollution from a low-rise building.
Photography: Zies van Zyl

levels are associated with an impaired capacity to diffuse carbon monoxide, headaches, and possible acute bronchiolitis (the inflammation of the bronchioles, the smallest air passages of the lungs). (For air quality guidelines and standards for ozone, see Table 3.9.)

The WHO (2005) published interim targets in addition to the AQG it stipulated for ozone (see Table 3.10). In addition to the target value for the protection of human health, the EC published a target value for ozone, to protect vegetation, which was given as 18 000 $\mu g/m^3$ per hour averaged over five years (referred to as AOT40, calculated from 1-hour values from May to July, where AOT40 means the sum of the difference between hourly concentrations greater than 80 $\mu g/m^3$ and 80 $\mu g/m^3$ over a given period, using only the 1-hour values measured between 08h00 and 20h00 Central European Time each day).

3.1.6 Benzene

Benzene has been classified as a known human carcinogen, having been linked to increases in the incidence of leukemia in humans. Acute neurological effects after people have been inhaling benzene include drowsiness, dizziness, headaches, convulsions, and even death. Exposure to vapour can irritate the skin, eyes, and upper respiratory tract. Chronic exposures cause disorders in the blood in humans and specifically affect bone marrow. Other effects that may occur include aplastic anemia, excessive bleeding, and damage to the immune system, due to changes in blood levels of antibodies and loss of white blood cells.

Table 3.9: Ambient air quality guidelines and standards for ozone for various countries and organizations

Authority	Instantaneous peak ($\mu g/m^3$)	Maximum 1-hour average ($\mu g/m^3$)	Maximum 8-hour average ($\mu g/m^3$)
SA standards (AQA)*	472 (0.25 ppm)	226 (0.12 ppm)	
SANS target values (SANS 1929:2005)		200[a]	120[a, b]
Australia[c]		189 (0.1 pm) (maximum 1-hour average) 151 (0.08 ppm) (maximum 4-hour average)	
WHO (2005)			100[d]
UK			100[e]
EC[f]			100[g]

ABBREVIATIONS: See Table 3.1.

* On 9 June 2006, South Africa's Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (a 90-day comment period was given). The proposed standards for ozone concentrations were the same as those issued by the SANS (Government Gazette No. 28899, 9 June 2006).

[a] SANS 1929:2005 target values. Permissible frequencies of exceedance, margin of tolerance, and date by which limit value should be complied with, to be determined through a complete standard-setting process through the SABS.

[b] This is an 8-hourly running average calculated on hourly averages; designed to protect human health.

[c] Australian ambient air quality standards (http://www.deh.gov.au/atmosphere/airquality/standards.html). Goal to be achieved by 2008, with a maximum allowable exceedance of 1 day per year.

[d] WHO (2005), value set for daily maximum 8-hour mean.

[e] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Maximum daily running 8-hourly mean. Compliance by 31 December 2005. Not to be exceeded more often than 10 times per year.

[f] EC Directive, 2002/3/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Target value for the protection of human health.

[g] Maximum daily 8-hour mean, not to be exceeded on more than 25 days per calendar year averaged over three years. Compliance with target values to be assessed as of this value. Data for the year 2010 will be the first to be used in calculating compliance over the following three or five years, as appropriate.

Table 3.10: WHO (2005) Air Quality Guidelines and interim guidelines for ozone

WHO mean levels	Daily maximum 8-hour mean (μg/m³)	Effects at selected ozone level
High level	240	Significant health effects, with a substantial proportion of the vulnerable human population affected.
Interim target-1 (IT-1)	160	Important health effects: this is an intermediate target for populations exposed to ozone concentrations above this level; it does not provide adequate public health protection*.
WHO AQG	100	This concentration level gives adequate public health protection, though some adverse health effects may occur at levels below it†.

* The rationale for this level is based on the following evidence: (i) it is the lower level of 6.6-hour chamber exposures to ozone by healthy exercising young adults at which physiological and inflammatory effects on the lungs are revealed; (ii) it is the ambient level of ozone at various summer camp studies at which there are effects on children's health; (iii) it is the level at which there is an estimated 3–5% increase in daily mortality* (based on findings of daily time-series studies). Human deaths attributable to ozone concentrations above estimated baseline of 70 μg/m³, based on range of 0.3–0.5% increase in daily mortality for 10 μg/m³ 8-hour ozone.

† The rationale for this level is based on the following evidence: (i) estimated 1–3% increase in mortality (based on findings of daily time-series studies); (ii) extrapolation from chamber and field studies based on the likelihood that real-life exposure tends to be repetitive and chamber studies do not study highly sensitive or clinically compromised subjects or children; (iii) the likelihood that ambient ozone is a marker for related oxidants.

South Africa's published air quality limit for benzene (SANS 1929:2005) is given as 5 μg/m³ averaged over any 12-month period, in line with the EC limit value for benzene which is also 5 μg/m³, to be met by 1 January 2010. The EC limit starts at 10 μg/m³ on 1 January 2006, decreasing by 1 μg/m³ each year (for example, down to 9 μg/m³ on 1 January 2007) until 2010, when the EC limit of 5 μg/m³ comes into effect.

3.1.7 Dust deposition

Dust deposition has been evaluated according to the following categories:

Slight	–	less than 250 mg/m² per day
Moderate	–	250–500 mg/m² per day
Heavy	–	500–1 200 mg/m² per day
Very heavy	–	more than 1 200 mg/m² per day

Emissions from large veld fires result in local and regional haze.
Photography: Janet Peace



Table 3.11: Bands of dustfall rates proposed for adoption in South Africa (SANS 1929:2005)

Band number	Band description label	Dustfall rate (D) (30-day average; mg/m² per day)	Comment
1	Residential	D<600	Permissible for residential and light commercial areas
2	Industrial	600<D<1 200	Permissible for heavy commercial and industrial areas
3	Action	1 200<D<2 400	Requires investigation and remediation if two sequential months lie in this band, or if there are more than three occurrences in any 12-month period
4	Alert	2 400<D	Immediate action and remediation required following the first exceedance, with an incident report to be submitted to the relevant authority

Table 3.12: Target, action and alert thresholds for ambient dustfall in South Africa (SANS 1929:2005)

Level	Dustfall rate (D) (mg/m² per day, 30-day average)	Averaging period	Permitted frequency of exceedances
Target	300	Annual	
Action residential	600	30 days	Three within any 12-month period; not in two sequential months
Action industrial	1 200	30 days	Three within any 12-month period; not in sequential months
Alert threshold	2 400	30 days	None. First exceedance requires remediation and compulsory report to authorities

Table 3.13: Ambient air quality guidelines and standards for lead for various countries and organizations

Authority	Maximum 1-month/quarterly average (µg/m³)	Annual average (µg/m³)
SA standard (AQA)	2.5 (1-month)	–
SANS limits (SANS 1929:2005)	–	0.5[a] 0.25[b]
Ekurhuleni Local Objective	–	0.5[c]
EC	–	0.5[d]
World Bank	–	–
UK	–	0.5[e] 0.25[f]
US EPA	1.5 (quarterly)[g]	–
WHO	–	0.5[h]

ABBREVIATIONS: See Table 3.1.

[a] Limit value. Compliance date to be determined through a complete standard-setting process through the SABS.
[b] Target value. Compliance date to be determined through a complete standard-setting process through the SABS.
[c] Local objective listed in Ekurhuleni Metropolitan Municipality Air Quality Management Plan AQMP (2005).
[d] EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value to be complied with by 1 January 2010.
[e] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2004.
[f] UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2008.
[g] US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html).
[h] WHO Guidelines for the protection of human health (World Health Organization, 2000).

The 1 200-mg/m² per day threshold level has typically been used in practice to indicate what (if any) action is required. Exceedance of this dustfall rate indicates the need to investigate the specific cause(s) of high dustfall and to take remedial steps. "Slight" dustfall is barely visible to the naked eye; "heavy" dustfall indicates a fine layer of dust on a surface; and "very heavy" dustfall is easily visible when a surface is not cleaned for a few days. Dustfall levels of >2 000 mg/m² per day are characterized by a layer of dust thick enough to allow a person to 'write' words in the dust with their fingers.

A perceived weakness of these dustfall guidelines is that they are purely descriptive, without specific guidance for action or remediation made explicit in the guidelines. It is stipulated in SANS 1929:2005 that dustfall rates should be evaluated against a four-band scale, as presented in Table 3.11. Target, action, and alert thresholds for ambient dust deposition are given in Table 3.12.

In terms of the proposed dustfall limits, an enterprise may submit a request to the authorities to operate within the "Band 3 Action" range for a limited period, provided that this is essential for the practical operation of the enterprise (for example, to accommodate the final removal of a tailings deposit), and provided that the best available control technology is applied for the duration. No margin of tolerance is to be granted for operations that result in dustfall rates in the "Band 4 Alert" range.

3.1.8 Metals

Lead is a toxic element, with a variety of effects at low dose levels. In people, brain damage, kidney damage, and gastrointestinal distress result from acute exposure to high levels of lead. Chronic exposure to lead in humans affects the blood, central nervous system (CNS), blood pressure, kidneys, and vitamin D metabolism. Children are particularly sensitive to chronic exposure to lead, with reported effects including slowed cognitive development and reduced growth (IRIS, 1998). Air quality guidelines and standards are issued by various countries including South Africa for lead (see Table 3.13).

Internationally, there is an increasing trend towards specifying air quality limits for certain metals. The limits published by the EC for arsenic, nickel, and cadmium, all of which are carcinogenic, are



summarized in Table 3.14. No air quality limits have been set for such metals in South Africa.

3.2 AIR QUALITY THRESHOLDS FOR NON-CRITERIA POLLUTANTS

3.2.1 Health-based air quality thresholds

Health thresholds for non-criteria pollutants are published by various sources. (The most widely-referenced of these are documented in Table 3.15.)

WHO guideline values are based on the no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL). Although most guideline values are based on NOAELs and/or LOAELs related to human health endpoints, certain of the guidelines given for 30-minute averaging periods are related to odour thresholds. The short-term effect screening levels (ESLs) issued by the Toxicology and Risk Assessment (TARA) Division of the Texan Natural Resource Conservation Commission for certain odourous compounds are similarly intended to be used for screening purposes, to assess potential nuisance impacts related to bad smell (malodour).

Inhalation reference concentrations (RfCs) related to inhalation exposures are published in the US EPA's Integrated Risk Information System (IRIS) database. These RfCs are used to estimate non-carcinogenic effects, representing a level of environmental exposure at or below which no adverse effect is expected to occur. An RfC is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive sub-groups) that is likely to be without appreciable risk of deleterious effects during a lifetime" (IRIS, 1998). Non-carcinogenic effects are evaluated by calculating the ratio, or hazard index, between a dose (in this case the dosage) and the pollutant-specific inhalation RfC. In the current study, reference is made to the chronic inhalation toxicity values published by the US EPA (IRIS, 1998)[5].

The RfCs are based on an assumption of lifetime exposure, so they provide a conservative estimate when applied to shorter-than-lifetime exposure situations. The RfC is not a direct or absolute estimator of risk, but rather a reference point for gauging potential effects. Doses at or below the RfC are not likely to be associated with any adverse health effects, and exceedance of the RfC does not imply that an adverse health effect will necessarily occur. As the amount and frequency of exposures exceeding the RfC increase, however, so does the probability that adverse effects may be observed in the human population. The US EPA has therefore specified that although doses below the RfC are acceptable, doses above the RfC are not necessarily unsafe.

Table 3.14: Ambient air quality target values issued by the EC for metals (EC Fourth Daughter Directive, 2004/107/EC)

Pollutant	Target value (for the total content in the PM_{10} fraction averaged over a calendar year) (ng/m^3)
Arsenic	6
Cadmium	5
Nickel	20

Table 3.15: Widely-referenced sources of health threshold information for non-criteria pollutants

Widely-referenced information sources of health thresholds	Threshold type	Averaging period	Website
US EPA (IRIS)	Sub-chronic inhalation reference concentrations	Sub-chronic – weeks to months	www.epa.gov/iris
	Chronic inhalation reference concentrations	Chronic – 1-year average or longer	www.epa.gov/iris
	Cancer unit risk factors	Chronic – 1-year average or longer (assuming exposures over a 70-year lifetime)	www.epa.gov/iris
California Environmental Protection Agency – Office of Environmental Health Hazard Assessment	Acute RELs	Acute – typically 1-hour average ranging to 8-hourly average, depending on pollutant	www.oehha.ca.gov
	Chronic RELs	Chronic – 1-year average or longer	www.oehha.ca.gov
ATSDR	MRLs		www.atsdr.cdc.gov/mrls.html
WHO	Guideline values and tolerable concentrations	Various averaging periods, including: 30-minutes; 1-hour; 24-hour; annual average	www.who.int/en/
	Cancer unit risks	Chronic – 1-year average or longer (assuming exposures over a 70-year lifetime)	www.who.int/en/

ABBREVIATIONS: ATSDR, US Federal Agency for Toxic Substances and Disease Registry; IRIS, Integrated Risk Information System; MRL, minimal risk level; REL, reference exposure level; US EPA, United States Environmental Protection Agency; WHO, World Health Organization.

5. The Integrated Risk Information System (IRIS), prepared and maintained by the US Environmental Protection Agency (US EPA), is an electronic database containing information on human health effects that may result from exposure to various chemicals in the environment. This database was initially developed for EPA staff in response to a growing demand for consistent information on chemical substances for use in risk assessments, decision-making, and regulatory activities. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences.

Table 3.16: Inhalation-based health thresholds for selected non-criteria pollutants (µg/m³)

Constituent	WHO Guidelines (2000)		US EPA (IRIS) inhalation reference concentrations	California OEHHA (first adopted as of August 2003)	
	Acute and sub-acute guideline value (average period)	Chronic guidelines (exposure for longer than 1 year)	Chronic inhalation RfCs	Acute RELs (average period, hours)	Chronic RELs
Benzene			30	1 300 (6)	60
Cadmium		0.005 (GV)			0.02
Carbon tetrachloride		6.1 (TC)		1 900 (7)	40
Chloroform				150 (7)	300
Chromium (VI) compounds			0.1		0.2
Copper				100 (1)	
Ethylbenzene		22 000 (GV)	1 000		2 000
Hydrogen sulphide	7 (30 min)[a]; 150 (24 h)		2	42 (1)	10
Toluene	1 000 (30 min)[a]; 260 (1 week)		400	37 000 (1)	300
Xylene	4 800 (24 h)	870 (GV)	100	22 000 (1)	700

ABBREVIATIONS: ATSDR, US Federal Agency for Toxic Substances and Disease Registry; ESL, effect screening level; GV, guideline value; IRIS, Integrated Risk Information System; MRL, maximum risk level; OEHHA, Office of Environmental Health Hazard Assessment; REL, reference exposure level; RfC, inhalation reference concentration; TARA, Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division; TC, tolerable concentration; WHO, World Health Organization.

[a] Given for odour.

The US Federal Agency for Toxic Substances and Disease Registry (ATSDR) uses the no-observed-adverse-effect-level/uncertainty factor (NOAEL/UF) approach to derive minimal risk levels (MRLs) for hazardous substances. They are set below levels that, based on information current at the time, might cause adverse health effects in the people most sensitive to such substance-induced effects. The MRLs are derived for acute (1–14 days), intermediate (>14–364 days), and chronic (365 days and longer) exposure durations, and for oral as well as inhaled exposure. These levels are generally based on the most sensitive substance-induced end point considered relevant to humans. The ATSDR does not use serious health effects (such as irreparable damage to the liver or kidneys, or birth defects) as a basis for establishing MRLs. Exposure to a level above the MRL does not mean that adverse health effects will necessarily occur.

The intention of MRLs is to serve as a screening tool that helps public health professionals decide where to look more closely. They are also a mechanism for identifying hazardous waste sites that are not expected to cause adverse health effects. Most MRLs contain some degree of uncertainty because of the lack of precise toxicological information about the people who might be most sensitive to effects of hazardous substances (for example, infants, the elderly, and those who are nutritionally or immunologically compromised). The ATSDR uses a conservative (that is, protective) approach to address these uncertainties, consistent with the public health principle of prevention. Although human data are preferred, MRLs often have to be based on animal studies because relevant studies on people are lacking. In the absence of evidence to the contrary, the ATSDR assumes that humans are more sensitive than animals to the effects of hazardous substances, and that certain people or groups may be particularly sensitive. The resulting MRL, therefore, may be as much as a hundredfold below levels shown to be nontoxic in laboratory animals. When adequate information is available, physiologically based pharmacokinetic (PBPK) modelling and benchmark dose (BMD) modelling have also been used as an adjunct to the NOAEL/UF approach in deriving MRLs.

Proposed MRLs undergo a rigorous assessment process. They are reviewed by the Health Effects/MRL Workgroup within the Division of Toxicology of the US Federal Agency for Toxic Substances and Disease Registry (ATSDR); an expert panel of external peer reviewers; the agency-wide MRL Workgroup, with participation from other federal agencies, including EPA. They are also submitted

Table 3.17: Odour threshold values for common sources of odour (µg/m³)

Pollutant	Odour recognition thresholds		Other odour thresholds	WHO guideline value (30 min)
	100% recognition	50% recognition		
Ammonia			500[a]	
Hydrogen sulphide	1 430	11.2	4.29[b]	7

[a] Odour threshold concentration (Verschueren, 1996)

[b] South African guideline (personal communication, M. Lloyd, 8 October 1998)

for public comment through the toxicological profile public comment period. Each MRL is subject to change as new information becomes available, which results in the updating of the toxicological profile of the substance. The MRLs in most recent toxicological profiles supersede previous published levels. (For a synopsis of the health-based air quality criteria extracted for use in the current study, see Table 3.16.)

3.2.2 Odour thresholds

Odour thresholds are defined in several ways, including absolute perception thresholds, recognition thresholds, and objectionability thresholds. At the perception threshold, one is certain that an odour is detected but it is too faint to identify further. Recognition thresholds are normally given for 50% and 100% recognition by an odour panel. (For various odour thresholds published in the literature for odorous compounds of interest in the current study, see Table 3.17.)

Reported odour threshold data vary considerably, as much as by four orders of magnitude for certain chemicals. Reasons for this variability include differences in experimental methods used, and in human responses to smell.

3.3 DEFINITION OF HIGH POLLUTION DAYS

A comprehensive overview of international best practice and local developments in the use of air pollution indices for the purpose of communicating air quality information is given in the *Technical Compilation Document to Inform the State of Air Report* (DEAT, 2006a), reproduced in the Appendix. Pending the national adoption in South Africa of an air quality indexing system for the routine reporting of air pollution

Poorly managed waste may result in malodorous emissions.
Photography: Ignatius Gerber

levels in the country, the following approach was employed in this report to define "low", "moderate", and "high" pollution days.

Air pollution data for PM_{10}, SO_2, NO_2, CO, O_3, and hydrogen sulphide (H_2S) were selected for use in calculating high pollution days. Hourly- and daily-averaged air pollution data were analyzed, with hours and days initially classified into pollutant-specific categories based on health-related thresholds.

All days with one or more exceedances of the hourly-average threshold given for "high" gaseous pollution concentrations, or of the daily-average threshold given for "high" PM_{10} concentrations, were classified as "high pollution days", and the pollutants resulting in this classification noted.

Table 3.18: Pollutant thresholds

Pollutant*	PM_{10}	SO_2	NO_2	CO	O^3	H_2S
Units	µg/m³	µg/m³	µg/m³	mg/m³	µg/m³	µg/m³
Low	<50	<245	<140	<21	<140	<30
Moderate	50–75	245–350	140–200	21–30	140–200	30–42
High	>75	>350	>200	>30	>200	>42

* Each entry corresponds to an hourly averaging period

Chapter 4

Atmospheric emission sources

At a glance

Emissions are released into the atmosphere by natural processes as well as by human processes and activities. Natural sources include biogenic releases, wind-blown dust, uncontrolled veld fires, and lightning-induced formation of nitrogen oxides. Common anthropogenic sources of atmospheric emissions include industrial and commercial activities, electricity generation, waste treatment and disposal, residential activities (including informal refuse burning), transport, mining, agriculture, tyre-burning, fugitive dust from construction activities, and the erosion of open areas. The consequences of domestic fuel-burning and vehicle emissions are high due to their release at ground level and generally in areas of high population density. The contribution of fuel-burning within the industrial and power generation sectors was often lower than expected since these sources emit constant, elevated releases, usually further away from residential settlements. Sugarcane and crop-residue burning have been found to represent significant sources of combustion-related emissions associated with agricultural activity.



Emissions are released into the atmosphere by natural processes as well as by human processes and activities. Natural sources include biogenic releases, wind-blown dust emissions, uncontrolled veld-fires, and lightning-induced formation of nitrogen oxides (NO_x).

Common anthropogenic sources of atmospheric emissions in South Africa include the following:

- *Industrial and commercial activities,* including Scheduled Processes – that is, processes identified in the Second Schedule of the Atmospheric Pollution Prevention Act (APPA) (Act no. 45 of 1965) as resulting potentially in significant atmospheric emissions – and non-domestic fuel-burning equipment used by businesses, hospitals, and schools
- *Electricity generation* – specifically coal-fired and fuel-turbine power stations generating electricity for the national grid
- *Waste treatment and disposal* – including waste incineration, landfills, and wastewater treatment works
- *Residential activities* – household combustion of paraffin, liquid petroleum gas (LPG), dung, wood, and coal
- *Transport* – including petrol- and diesel-driven vehicle exhaust emissions; road-dust raised by vehicles; brake- and tyre-wear fugitives[1]; and rail-, shipping-, and aviation-related emissions
- *Mining* – fugitive[1] dust releases and emissions from spontaneous combustion
- *Agriculture* – including emissions from burning crop residue, enteric fermentation, and the application of fertilizers and pesticides
- *Informal/miscellaneous* – including tyre-burning and fugitive[1] dust from construction activities and the erosion of open areas.

There is no current comprehensive national inventory for sources of atmospheric emissions. Local emissions inventories have however been developed, or are under way, in various parts of South Africa, including the Cities of Cape Town, Johannesburg, eThekwini, and Tshwane, the Vaal Triangle, and the Rustenburg region. Furthermore, an inventory of fuel-burning-related sources within the electricity generation, industrial, commercial, residential, and agricultural sectors has been compiled on behalf of the National Economic Development and Labour Council (NEDLAC) within the following conurbations and regions: Tshwane, Johannesburg, Ekurhuleni, Mpumalanga Highveld, Vaal Triangle, eThekwini, and Cape Town for the year 2002.

The contribution of emission sources to total atmospheric emissions is explored elsewhere in this *State of Air Report 2005* with reference to the NEDLAC fuel-burning source characterization study. Given that fuel-burning is estimated to account for over 80% of human-induced criteria-pollutant emissions, and that the regions covered comprise over 40% of South Africa's population, this NEDLAC emissions inventory becomes an important source of information, pending the completion of a comprehensive and detailed national emissions inventory. Reference is also made in this *State of Air Report 2005* to the emissions inventory information from the City of Cape Town in order to highlight the significance of source contributions to total emissions.

Reference is also made in this State of Air Report 2005 to the emissions inventory information from the City of Cape Town in order to highlight the significance of source contributions to total emissions

4.1 FUEL COMBUSTION-RELATED SOURCES

Total annual emissions estimated for 2002 from fuel-burning activities within Tshwane, Johannesburg, Ekurhuleni, Mpumalanga highveld, Vaal Triangle, eThekwini, and Cape Town are summarized in Table 4.1, with source contributions illustrated in Figure 4.1.

The extent of emissions was found not to be a significant indicator of contributions to ground-level air-pollution concentrations or to health and environmental risks. Such contributions depended in addition upon the height of emission above the ground and the distance between the source and sensitive receptors (that is, people or environment potentially affected by it).

1. 'Fugitives' are air-pollutant emissions that are not actively emitted into the atmosphere but that 'escape' from the source, for example wind-blown dust off the top of a mine dump, and petrol fumes that escape into the atmosphere at the petrol pump. They are often due to equipment leaks, evaporative processes, bulk-handling or -processing of raw materials, and windblown disturbances.



The consequences of domestic fuel-burning emissions were greater from releases at ground level, as well as from those generated in areas of high population density. The significance of vehicle emissions as contributors to air pollutant concentrations and health risks is similarly greater the closer the emissions are to ground level and the nearer they are to populated areas. Furthermore, vehicle emissions also tend to peak during the early mornings and evenings, when the potential for dispersion in the atmosphere (by wind, for example) is lower than at other times of the day. Biomass burning (in the sense of veld-fires and crop-burning) is a significant, localized source of episodic emissions, exacerbated by its release at ground level and its greater frequency during the dry-spell fire-risk 'burn' season.

The contribution of fuel-burning within the industrial and power generation sectors to air pollutant concentrations and health risks was often lower than expected, given the extent of emissions. This was because these sources characteristically emit constant, elevated (emission stack) releases, usually further away from residential settlements than household fuel-burning and vehicle emissions. The impact of industrial emissions on residential settlements has increased since the mid-1990s, however, as a result of human occupation of areas formerly retained as industrial buffer zones.

Taking these considerations into account, the following most significant combustion-related sources within the various major conurbations were identified (not ranked) (Scorgie *et al.*, 2004a):

- *Biomass burning* (in the sense of veld-fires and crop-burning) – a significant source of localized, episodic fine particulate emissions. This sector also contributed to total organic compounds (TOCs) and greenhouse gas emissions (methane [CH_4], nitrous oxide [N_2O]). The extent of biomass burning was quantified on the basis of burn scar data from satellite imagery.

- *Industrial and commercial fuel-burning sector* – a significant source of particulates and SO_2 in all areas, but particularly Cape Town, eThekwini, Vaal Triangle, Ekurhuleni, and Mpumalanga; also noted as a contributor to emissions of NO_x and greenhouse gases (carbon dioxide [CO_2], N_2O).

Table 4.1: Total annual emissions (tonnes per annum) estimated from fuel-burning activities within Tshwane, Johannesburg, Ekurhuleni, Mpumalanga Highveld, Vaal Triangle, eThekwini and Cape Town (Scorgie *et al.*, 2004a)

Source group	Estimated annual emissions (tpa)		
	Total particulates	Sulphur dioxide	Nitrogen oxides
Industrial, commercial, & institutional fuel-burning	81 807	571 860	288 238
Electricity generation	66 723	1 519 288	687 434
Vehicles (direct emissions from road vehicles)	8 704	42 448	266 495
Shipping (within South Africa's maritime zone)	227	2 064	3 136
Aircraft	33	219	1 459
Biomass burning (veld fires and crop burning)	11 441	686	3 547
Domestic fuel-burning (for cooking and space heating in the residential environment)	16 370	17 351	2 919
TOTAL	**185 304**	**2 153 917**	**1 253 229**

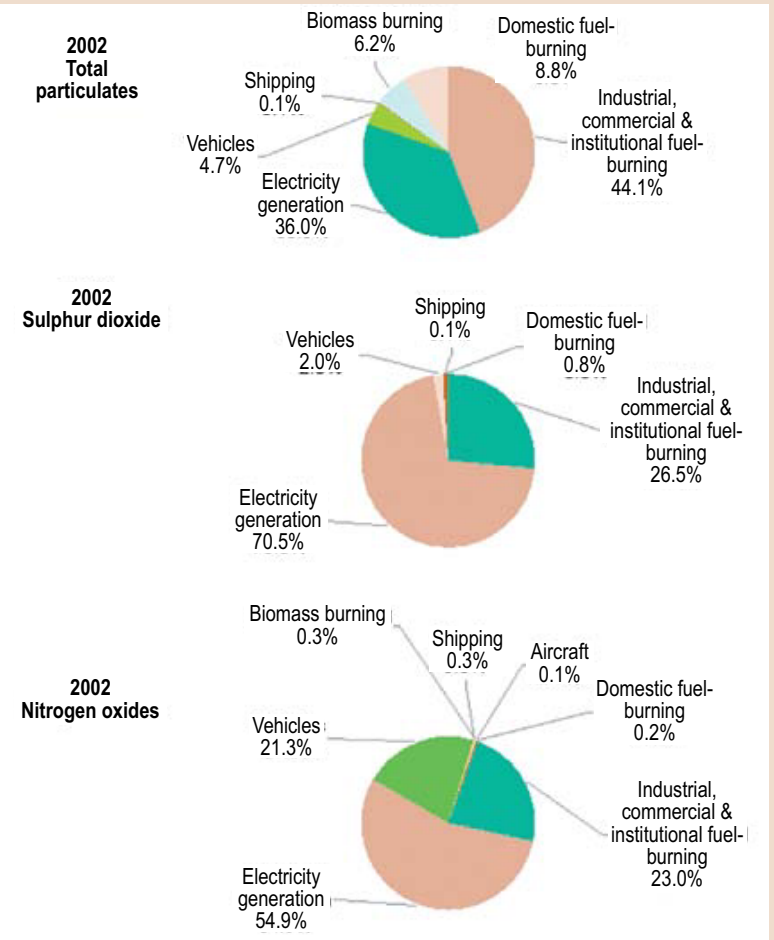
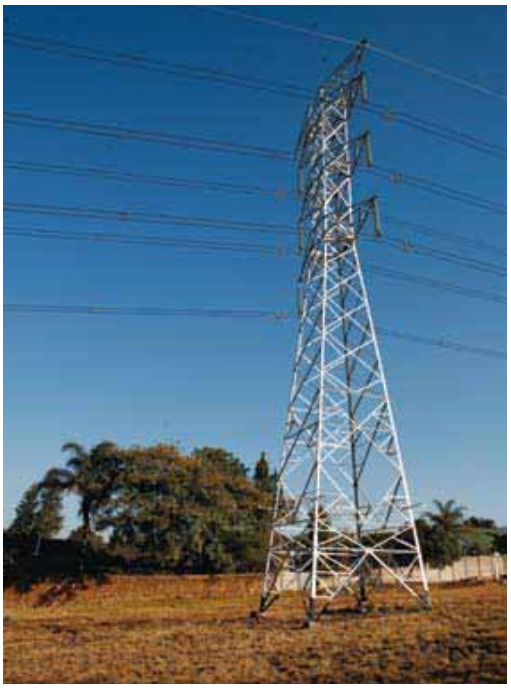


Figure 4.1: Contribution of various source groups to estimated total particulate, sulphur dioxide, and nitrogen oxide emissions from fuel-burning related sources within Tshwane, Johannesburg, Ekurhuleni, Mpumalanga Highveld, Vaal Triangle, eThekwini and Cape Town for the year 2002. *Source: After Scorgie et al., 2004e*



it is expected that emissions from electricity generation will continue to increase.

- *Vehicle emissions* – a significant source of CO, NO_x, TOC, NMTOC, benzene, lead, acetaldehyde, formaldehyde, and 1,3-butadiene emissions in all conurbations. This sector also contributes approximately 30% to total fine particulate and sulphur dioxide (SO_2) emissions from fuel-burning processes and is a significant source of greenhouse gas emissions (CO_2, CH_4, and particularly N_2O).

- *Domestic fuel-burning* – a significant source of low-level fine particulate and SO_2 emissions. This sector also contributes significantly to CO, TOC, and benzene[2] emissions, as well as to greenhouse gas emissions (CO_2, CH_4). Its contribution to fine particulate concentrations within coastal cities such as Cape Town and eThekwini is greater because of the large quantities of wood burned in these parts of the country; in contrast, this sector's SO_2 emissions are higher for inland areas, where domestic coal-burning is more prevalent.

- *Electricity generation* – a significant source of particulate, SO_2, NO_x, CO, and TOC emissions in Mpumalanga and the Vaal Triangle and, to a lesser extent, in Tshwane. Despite elevated smoke-stack emission release, significant contributions to local ground-level concentrations are possible during turbulent atmospheric conditions. The sector is also an important greenhouse gas emission contributor (CO_2, N_2O).

The contribution from shipping, aircraft, and railway emissions (diesel traction) was found to be relatively small, although it was recognized that shipping and aircraft emissions could contribute significantly to localized, low-level emissions at harbours and airports.

4.1.1 Electricity generation

Over 90% of South African electricity comes from coal-fired power stations (see Figure 4.2). During the period 1995–2002, coal consumption by the electricity generation sector increased by an annual average rate of approximately 3%. The proportional contribution of coal to total electricity generation diminished from 93.2% in 1992 to 91.8% in 2000, however, due to increased contributions from nuclear power, hydroelectric power, and pumped storage[3] (see Figure 4.3).

The demand for electricity rose steadily by 23% from 1992 to 2000 (see Figure 4.4). In 2002, industry was the greatest consumer of electricity (68%), followed by the residential (17%) and commercial (10%) sectors. Whereas consumption by other sectors has remained relatively constant, industrial electricity demand has grown significantly, from 60% of total electricity demand in 1992, to 64% in 2000. By 2004,

2. Benzene is 'isolated' from a range of aromatic hydrocarbons as a compound known to affect people's health adversely (the effect of other aromatic hydrocarbons is not yet fully quantified), and countries around the world have established protective guidelines and air quality standards relating to this substance.

3. While pumped storage does not reduce coal consumption directly, the indirect benefit is that operating a turbine to generate electricity during peak demand reduces the need to generate as much electricity from coal-fired processes at this time. This is because the demand for electricity is not even during the day: there are peaks in the morning and evening, and providing extra generating capacity just to meet these peaks would be inordinately expensive. An alternative is to find some way of using the extra capacity during off-peak times in order to store energy, which can later be released at peak times. The most usual way of doing this is by 'pumped storage', which involves pumping water uphill during off-peak times, and allowing it to run downhill through a turbine to generate electricity at peak times. South Africa has three pumped storage schemes: Drakensberg, Palmiet, and Steenbras, with a combined capacity of 1 580 megawatt-equivalent (MWe). In future, with increased peaks due to greater demand for residential electricity, there is a good chance of further such schemes (DME, 2002b).

it was estimated that about 70% of households were electrified (80% in urban areas and 50% in rural areas). Dependence on coal-fired electricity generation, albeit at improved efficiency, is expected to continue in the short- to medium-term, despite increased contributions from nuclear, biomass (in this context, material such as bark and black liquor used extensively in the pulp mills, and bagasse in sugar refineries), and hydro energy resources. Given the aim of the Integrated National Electrification Programme of ensuring that all households have access to electricity by 2010/2011, as well as continued growth in industrial electricity consumption, it is expected that emissions from electricity generation will continue to increase. Technology for the mitigation of coal-fired power station atmospheric emissions, planned to become mandatory, is expected to constrain the adverse air pollution effects of growth in this sector.

4.1.2 Commercial and industrial fuel combustion (excluding the electricity-generating sector)

Coal consumption by the commercial and industrial sector increased by 19% during the period 1989–1999, while petroleum product consumption in the same period remained relatively constant. The greatest coal consumer by far was the iron and steel industry (it was responsible for 30% of all coal consumed by the industrial sector during 2000). The iron and steel sub-sector needs large quantities of coking coal for producing coke and gas, and is also the largest industrial consumer of fuel oil. Other industrial sub-sectors responsible for substantial coal consumption include the chemical and petrochemical, food and tobacco, pulp and paper, and non-metallurgical sub-sectors (sectoral fuel use

Table 4.2: Electricity use per capita and percentage of households electrified, for 1996 and 2001
(Statistics South Africa, 2002)

Year	1996	2001
Electricity use, MWh/capita per year	3.7	3.5
Households electrified (%)	93.8 (excludes former 'homelands')	69.6 (includes former 'homelands', TLBV states)

ABBREVIATIONS: TLBV, Transkei, Lebowa, Bophuthatswana, and Venda (T, B, L, and V representing what were styled 'independent' states in pre-1994 South Africa).

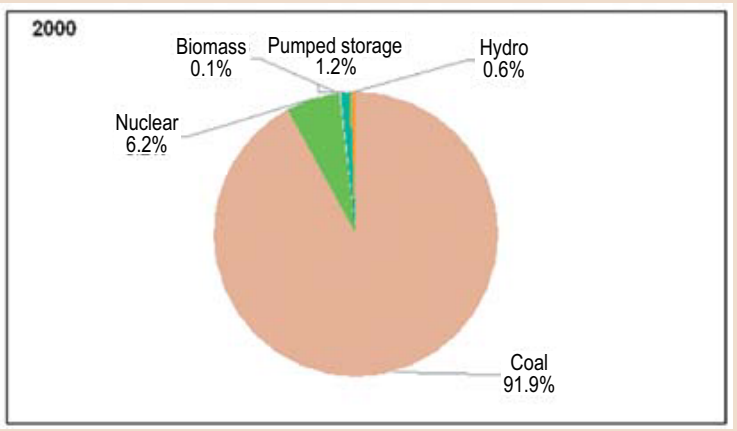


Figure 4.2: Electricity generation per fuel type during 2000
Source: DME, 2002

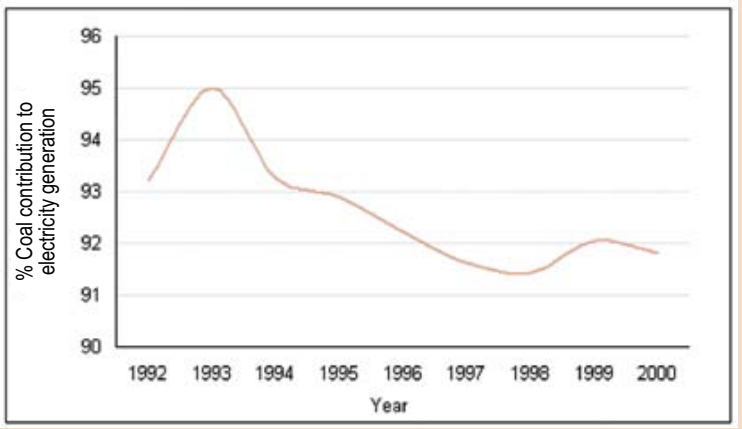


Figure 4.3: Contribution of coal to electricity generation, 1992–2000
Source: DME, 2002

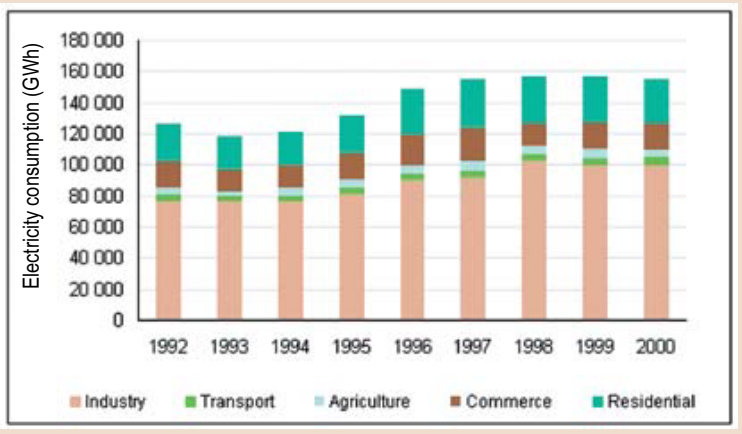


Figure 4.4: Electricity consumption per sector, 1992–2000
Source: DME, 2002



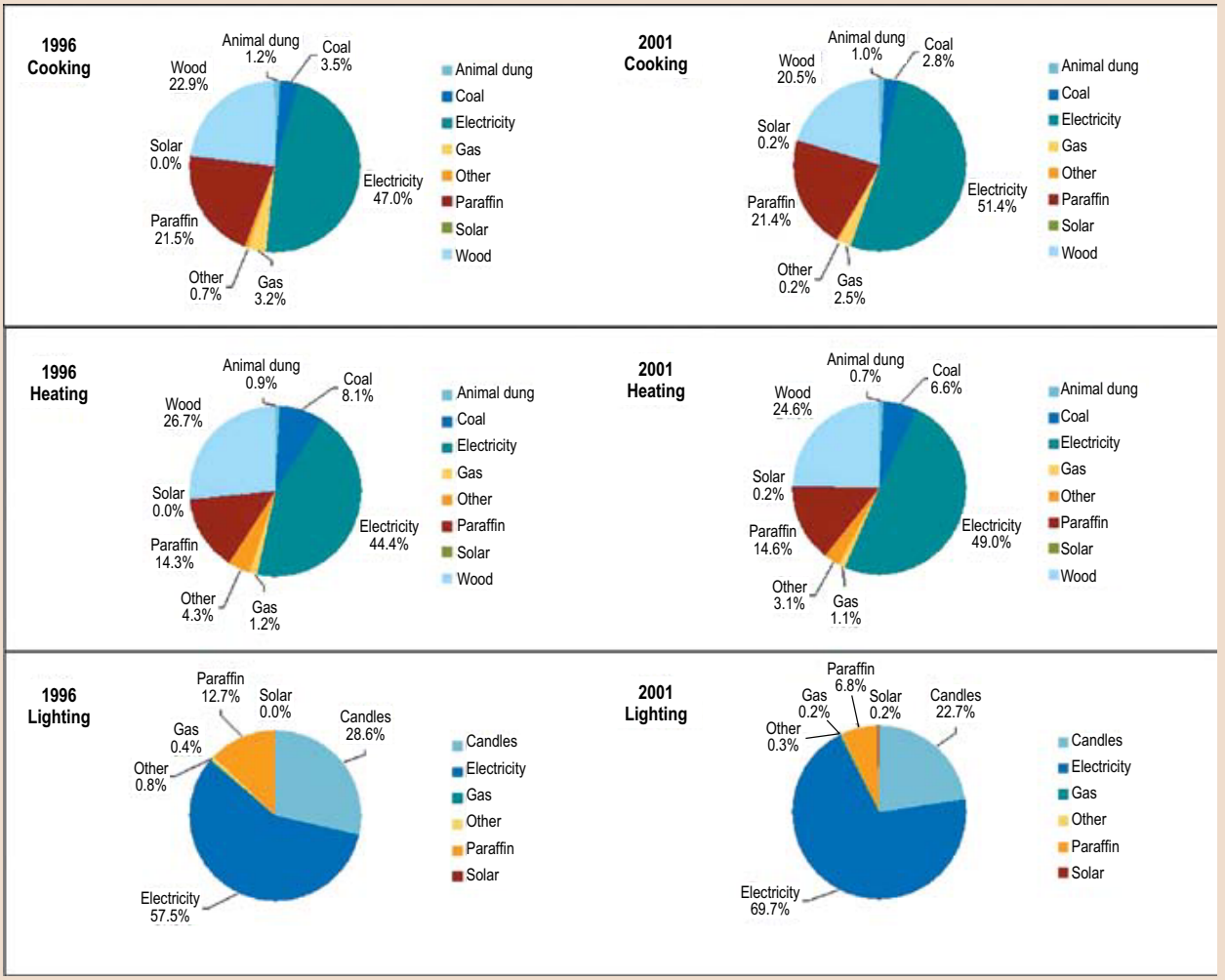


Figure 4.5: Percentage of type of household fuel used for cooking, heating and lighting for 1996 and 2001
Source: Statistics South Africa, 2002

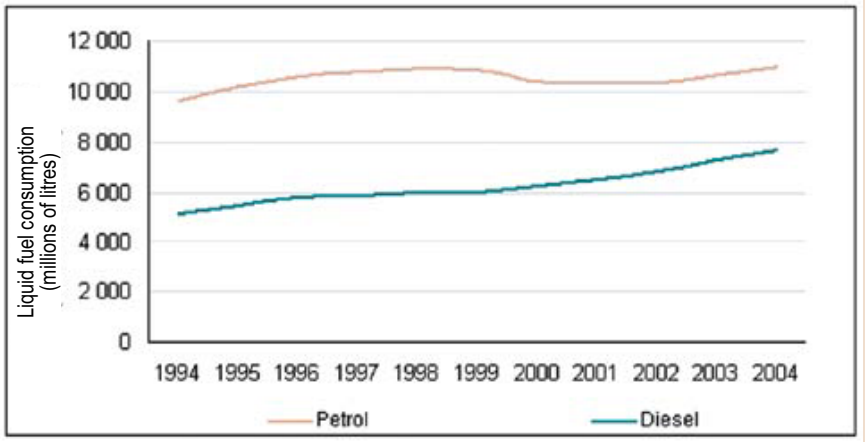


Figure 4.6: Trends in liquid fuel sales, 1994–2004
Source: South African Petroleum Industry Association (SAPIA), 2005

information made available by the Department of Minerals and Energy, March 2003).

Fuel-combustion-related air emissions around conurbations are linked to the following significant contributing commercial and industrial sub-sectors: chemical and petrochemical, textile manufacture, pulp and paper, food and tobacco (particularly sugar-refining and breweries), iron and steel and other metallurgical processes (ferro-alloy manufacture, precious metal refining, stainless steel manufacture), and non-metallurgical or ceramic processes (brick, cement, and refractory manufacture), as well as other commercial and institutional fuel-burning. Emission variations from these sectors are associated with (i) changes in demand for products, or change in their fuel-fired energy requirements; (ii) increase in fuel utilization efficiency,



(iii) fuel-switching (that is, reduction of emissions by changing from a 'dirty' fuel, such as coal, to a cleaner fuel such as oil or, better still, natural gas); and (iv) adoption of emission treatment technologies.

4.1.3 Household fuel-burning

The sustained use of coal and wood by a large section of the population is cause for concern in terms of air pollution and health risks. These fuels continue to be used mainly for two reasons: (i) rapid urbanization and the growth of informal settlements has exacerbated backlogs in the distribution of basic services such as electricity and waste removal; and (ii) many electrified households continue to use coal and wood for reasons of economy and efficacy, especially for space-heating and convenient multi-utility in cooking, heating, and lighting. Coal is cheaper, and easily accessible on the highveld because of the proximity of coal mines and well-developed local distribution networks. In coastal regions, such as Cape Town and eThekwini, which are further away from sources of coal, wood is preferred for domestic purposes.

The extent of household fuel combustion is affected by, amongst other things, population growth, availability of electricity, household income, degree of urbanization, cultural factors, and the proportion of informal (unserviced) households. Population growth, reduced household income levels, and increasing numbers of informal (unserviced) households are expected to exacerbate the adverse consequences of rising household fuel-burning emissions. Despite the extent of electrification, electricity accounted for only 38% of the total energy consumed by the residential sector during 2000, owing to the persistent use of other fuels for space-heating, cooking, and lighting (see Figure 4.3). Other sources of energy consumed included the combustion of wood (41%), coal (35%), paraffin (13.9%), liquified petroleum gas (2.9%), and the use of solar energy (0.3%) (ERI, 2001).

Coal-burning emits large quantities of gaseous and particulate pollutants, including SO_2, heavy metals, CO, polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene, and total and respirable particulates (including inorganic ash). Exposure to PAHs poses a cancer risk. Pollutants from the burning of wood include respirable particulates, nitrogen dioxide (NO_2), CO, PAHs, and formaldehyde. South African studies have shown that particulate emissions from wood contain about 50% elemental carbon and about 50% condensed hydrocarbons (HCs). The main pollutants emitted from combustion of paraffin are NO_2, particulates, CO, and PAHs. No comprehensive emission data exist for household fuel combustion[4].

4.1.4 Transportation sources

4.1.4.1 Vehicle emissions

Pollutants emitted by motor vehicle exhausts include CO_2, CO, HCs, SO_2, NO_x, and particulates. Secondary pollutants consequently formed in the atmosphere as a result of chemical reactions include NO_2, photochemical reaction products (such as ozone), HCs, sulphuric acid, and various oxides of nitrogen, giving nitric acid and nitrate aerosols.

The main factors affecting the demand for vehicle transport include economic trends, demographics, fuel accessibility and supply, spatial structure (for example, low-density urban development over large areas means that people have to travel relatively longer distances than in more compact, high-density cities), transport infrastructure (urban sprawl), lifestyle norms, and regulation. In the period 1994–2004, national petrol sales to the transport sector increased by 14% and diesel sales by 50% (see Figure 4.4). Across the country, the number of vehicles (including cars, trucks, motorcycles, buses, and taxis) increased by some 14% between 1998 and 2004. Based on vehicle registration information from the National Transportation Information System (NaTIS) database, as well as population statistics, for the year 2001, estimated car ownership in South Africa was about 129 vehicles per 1 000 population, slightly more than the world average of 120. Increased single-occupancy of travelling vehicles, greater average trip lengths, and a rise in the number of car owners have been cited in cities such as Cape Town as evidence of growing vehicle activity (City of Cape Town, 2002).

The chief measures recommended for mitigating vehicle emissions in the Implementation Strategy for the Control of Exhaust Emissions from Road-going Vehicles in South Africa (DEAT, 2004a) include the specification of EURO technology for controlling and

** Of significance is the fact that under conditions of poor household air-ventilation, especially where there is no fireplace and chimney, there is a risk of CO intoxication as, when oxygen supply is poor, the burning fuels listed here can generate lethally elevated concentrations of CO.*

Seasonal veld fires emit large quantities of pollutants into the atmosphere and contribute to regional pollution levels.

Photography: Janet Peace

reducing tail pipe emissions in new vehicles, as well as the reduction in sulphur, lead, and aromatic content of fuels. Were there to be no controls in future, it is expected that vehicle emissions would increase significantly, with various pollutants (specifically acetaldehyde) predicted to increase by 27% by 2007 and by up to 44% by 2011, relative to base-year 2002 (Scorgie *et al.* 2004a).

4.1.4.2 Airport emissions

There are various sources of atmospheric emissions that are typically related to airport activities, each with its own set of pollutants (see Table 4.3).

The extent of various pollutant emissions from an aircraft engine depends upon the mode of operation of the aircraft. Other than water vapour and CO_2, the greatest aircraft engine emission is NO_x, with CO as second largest; smaller amounts of volatile organic compounds (VOCs), SO_2, non-methane volatile organic compounds (NMVOCs), methane, and particulates are also emitted. The extent of the SO_2 emissions depends on the sulphur content of the fuel. Emissions of CO and HCs, which arise from incomplete combustion, are generally greater during taxi and idle operations. Production of NO_x, arising from the oxidation of atmospheric nitrogen during combustion processes, is greatest during take-off when the aircraft engine is at maximum power. Emissions of CO_2 relate directly to fuel consumption.

Table 4.3: Sources and pollutants related to airport activities

Source of emissions	Pollutants*
Tail pipe emissions from airport arrival-departure activities, airport ground-support service vehicles and equipment (such as aircraft and baggage tugs, fuel trucks, and maintenance vehicles), and airport access traffic routes	NO_x, CO, CO_2, HC, SO_2, Pb and particulates (primary pollutants); ozone, sulphuric and nitric acids, sulphate and nitrate aerosols (secondary pollutants)
Aircraft engine emissions, including emissions during aircraft operation in the idle, taxi, take-off, and landing modes	NO_x, CO, CO_2, H_2O, CH_x, NMVOC, VOC, (SO_x, depending on sulphur content of aircraft fuel)
Auxiliary power units (APUs) on the ground	VOCs, CO_2, SO_2, NO_x, HCs, and CO
Evaporative emissions during fuel handling and storage	VOCs, HCs

* The listing of pollutants in this table reflects the fact that they have been detectable by the analytical procedures used. Quantities can vary considerably.

Comprehensive emission inventories were undertaken in Cape Town and Johannesburg, for Cape Town and O.R. Tambo International Airports, respectively. At O.R. Tambo International, aircraft and vehicle emissions were found to constitute the most significant sources (Burger & Watson, 2003). Aircraft emissions during landing, taxiing, and take-off contributed 85–93% of the pollutants detected. The most abundant air pollutant, as expected, was CO_2 (143 kilotonnes/annum), with the largest contribution of CO_2 coming from aircraft (93%), followed by 5% from auxiliary power units (APUs), and 2% from vehicles. The second greatest air pollutant was CO (1.4-kilotonnes/annum) from aircraft (86%), vehicles (12%) (landside [10%], airside [2%]), and ground APUs (2%). Although these two pollutants comprise the most abundant emissions, however, oxides of nitrogen and total hydrocarbon emissions are regarded as having more significant adverse effects on human health. Aircraft contributions of oxides of nitrogen and total organic emissions were estimated to be 89% and 87%, respectively. The contribution of APUs to the NO_x emissions was about 6% (these formed the second largest source), but they added less than 2% to TOC emissions. The second largest contribution to hydrocarbon emissions was from motor vehicles and, more significantly, from emissions in the parking bays (about 7%). The 1,3-butadiene emissions were mostly from aircraft engines (98%), whereas most particulates (including entrained and diesel particulate matter) came from vehicle activities.

The air quality impact study for O.R. Tambo International Airport identified the most significant pollutants as NO_2 and 1,3-butadiene, with a likelihood of elevated concentrations of sulphur dioxide and inhalable particulates (Burger & Watson, 2003).

Industrial process emissions include those from a range of possible non-point sources, including evaporation of VOCs from the manufacture, transport, handling and storage of chemicals.

Photography: DEAT

4.1.4.3 Shipping emissions

Two types of emission from marine shipping are transit emissions, characteristic when the vessels enter or leave the harbour with their main engines running, and hotelling emissions, characteristic when the main engines are being shut down while the vessel is berthed and its power requirements are being provided by auxiliary ship-based generators. In addition to ocean-going vessels, additional emissions are released by tugs, dredgers, and other craft that are permanently confined to the region of the harbour (collectively referred to as 'harbour vessels').

Shipping-related emissions have been determined for Cape Town and for eThekwini (Wicking-Baird *et al.*, 1997; Ecoserv, 1998). Although the contribution of this sector to total emissions appears to be small, the localized nature of such sources justifies the inventory of emissions and the assessment of impacts arising from this source. The method developed by Ecoserv (1998) for quantifying shipping-related atmospheric releases could also be applied to other South African ports.

4.1.4.4 Rail-related emissions

Trains in operation include electric and diesel-powered locomotives. Pollutants associated with diesel-drawn rail-transport include CO_2, CO, VOCs, NO_x, particulates, SO_2, lead (Pb), N_2O, CH_4, NMVOCs, ammonia gas (NH_3), and hydrogen sulphide (H_2S).

Estimating the emissions from railway transport represents a relatively new area of study internationally, with emission estimates for railway networks in Europe having been made only since the late 1990s (Jorgensen & Sorenson, 1997). South African studies have been limited. Applying internationally developed emission factors to quantify railway transport emissions will necessitate the collation of a wide range of information. Important parameters include: inventory of train types (diesel, electric); passenger or cargo; average train speed; number of passengers per seat (0–100%); topography of the distance travelled; slopes and hills; wind speed; number of cold starts (for diesel-powered trains); average distance between train stations; and degree of reuse of braking energy.

4.2 INDUSTRIAL PROCESS EMISSIONS

Industrial process emissions include those from stacks and vents, as well as from a range of possible non-point sources, including evaporation of VOCs from the manufacture, transport, handling and storage of chemicals; fugitive dust releases from the handling of materials; vehicle entrainment; and wind erosion of stockpiles.



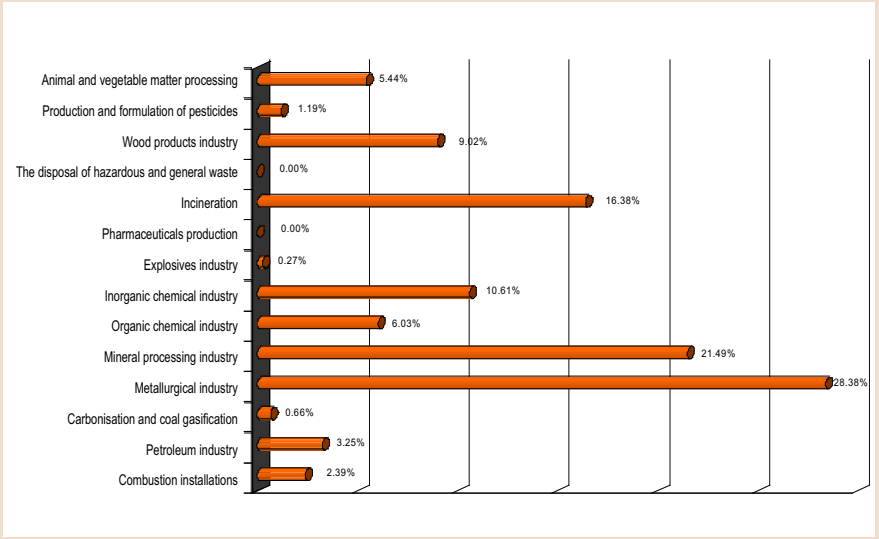


Figure 4.7: Classification by broad industry type of enterprises holding registration certificates (%)
Source: Baird et al., 2006

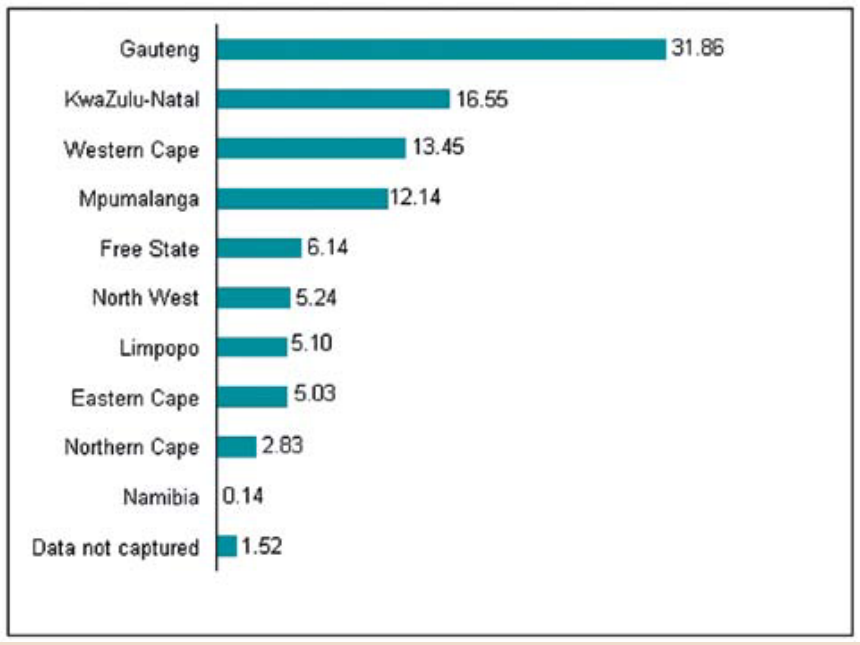


Figure 4.8: Enterprises holding registration certificates under the APPA situated in each province (%)
Source: Baird et al., 2006

An inventory of all enterprises undertaking Scheduled Processes – and, thereby, holding Registration Certificates under the APPA – was undertaken as part of the APPA Registration Certificate Review Project. In 2005, there were about 1 500 permitted operational industries in South Africa, approximately 28% of which fell within the metallurgical industry classification (see Figure 4.7, and Baird *et al.*, 2006). The mineral processing industry (21%) and incineration (16%) ranked next among the classifications. The large number of brickworks and medical waste incinerators accounted significantly for the mineral-processing and waste-incineration classifications, respectively. There were also numerous foundries and asphalt processors in operation, and, of the larger industries, relatively many coal-fired power stations and sawmills (34 coal-fired power stations, 109 sawmills) (Baird *et al.*, 2006).

Of the industries holding registration certificates under the APPA, approximately 32% were located in Gauteng, 16% in Kwazulu-Natal, 12% in Mpumalanga, and 12% in the Western Cape (see Figure 4.8).

Only 2% of registration certificate holders were based in the Northern Cape, with the remaining provinces each having about 5%. Most of the allocated permitted industries were situated within the major metropolitan areas, with 14% located in the Ekurhuleni

Table 4.4: Ten district and metropolitan municipalities with the greatest proportions of enterprises holding registration certificates under the APPA (Baird *et al.*, 2006)

District/Metropolitan Municipality	Proportion of permitted industries (%)
Ekurhuleni Metropolitan Municipality	14.2
eThekwini Metropolitan Municipality	6.9
City of Cape Town	6.4
City of Johannesburg	4.8
City of Tshwane Metropolitan Municipality	4.5
Nkangala District Municipality	4.1
Ehlanzeni District Municipality	3.7
Sedibeng District Municipality	3.4
Nelson Mandela Metropolitan Municipality	2.8
Northern Free State District Municipality	2.5
Unallocated*	6.8

* 'Unallocated' refers to enterprises on whose Registration Certificate no District or Metropolitan Municipality was specified



Metropolitan Municipality, 7% in eThekwini, 6% in Cape Town, 5% in Johannesburg, 4% in Tshwane, and about 3% in the Nelson Mandela Metropolitan Municipality (see Table 4.4). Of the district municipalities, Nkangala and Ehlanzeni (both in Mpumulanga) had 4% of the permitted industries situated within their jurisdictions, and Sedibeng District Municipality and Fezile Dabi District Municipality 3% each. This information highlights future capacity requirements for the fulfilment of future licensing functions under the Air Quality Act (AQA) (Act no. 39 of 2004) (Baird *et al.*, 2006).

Large-scale heavy industries with poorly managed processes and fugitive dust sources have a greater potential impact when they are located near residential settlements. Bulk storage of chemicals in tank farms in close proximity to where people live have similarly been identified as a source of unacceptable community exposure to VOCs such as benzene, toluene, and ethyl benzene.

Information about complaints received concerning enterprises holding registration certificates were gathered during the APPA Registration Certificate Review Project. Approximately 88% of these enterprises were identified as having given rise to infrequent or no complaints; about 10% of them were classified as generating "fairly frequent" to "frequent" complaints; and the remaining 2% were associated with "very frequent" complaints. Operations about which there had been very frequent complaints mainly comprised brickworks, pulp and paper manufacturers, iron and steel manufacturers, tanneries, cement manufacturers, and petrochemical and chemical industries (which included waste oil regeneration).

4.3 WASTE TREATMENT AND DISPOSAL SOURCES

Waste treatment and disposal methods of interest, in terms of both the toxicity and smell of their emissions, include incineration, landfilling, and liquid waste ponds used for the treatment, storage, and disposal of liquid wastes.

Given the range of hazardous pollutants emitted from waste disposal operations, and the difficulty of controlling emissions where there is a history of poor

The burning of old tyres to recover the metal is a common practice; however the emissions are dramatic and hazardous.
Photography: Zies van Zyl

management, such sites are typically classified internationally as potential 'toxic hotspots' for air quality management purposes. The influence of incinerator emissions generally extends more widely than that of landfills and wastewater treatment plants, owing to the higher elevation from which their more abundant emissions are released.

There are harmful emissions from all the waste disposal operations outlined in this section, and in some cases offensive odours as well. In terms of South Africa's constitution, everyone has the right to an environment that is not harmful to health and well-being, and it is recognized that unpleasant, malodorous (smelly) emissions affect one's well-being.

There are harmful emissions from all the waste disposal operations outlined in this section, and in some cases offensive odours as well

4.3.1 Incineration

The emission rate of an incinerator is a function of fuel usage, waste composition, incinerator design, and operating conditions. Emissions from incinerators may be grouped as follows:

- Criteria pollutants (SO_2, NO_x, CO, and particulates)
- Acid gases (hydrogen chloride [HCl], hydrogen bromide [HBr], hydrogen fluoride [HF])
- Metals (for example, chromium, arsenic, cadmium, lead, mercury, manganese)
- Dioxins and furans (for example, polychlorinated dibenzo-p-dioxins and dibenzo-furans).

The potential for emissions of VOCs during wastewater treatment is a cause for concern.

Heavy metal, dioxin, and furan emissions from medical waste incineration represent a considerable air quality and health-risk concern that is related to poorly managed operations.

4.3.2 Landfill operations

Sources of emissions of landfill gases include the closed portions of the landfill, work surfaces, trenches (applicable to co-disposal sites only), leachate drainage lines, ponds, and manholes. Landfill gases of concern associated with the general or co-disposal landfill options include a range of odiferous and toxic gases.

Landfill gas normally contains approximately equal parts of methane and carbon dioxide, and these two gases together constitute almost 100% of landfill gas composition. Other gases constitute only a small fraction of the total, and include inorganic products as well as a large number of organic compounds. Studies indicate that the presence of over 200 compounds can be detected in a landfill site, depending on the nature of the waste material that has been deposited there. Substances that most frequently contribute to malodours (bad smells) include H_2S, fatty acids, alkyl benzenes, limonene, mercaptans, bisulphides, and volatile amines. Carcinogenic substances frequently measured at waste disposal sites include methylene chloride, benzene, and carbon tetrachloride (CCl_4).

Air quality impact assessment conducted for large hazardous, as well as general landfill sites in South Africa have on the whole indicated that significant health risks, given good landfill facility management, are limited to within 500 m of the landfill boundary. Odour impact distances can vary from 200 m to 5 km, depending on management at the facility, with dust nuisance impacts generally restricted to within the immediate boundary of the facility.

4.3.3 Wastewater treatment

The potential for emissions of VOCs during wastewater treatment is a cause for concern. Chemicals measured at local wastewater treatment works have included hydrogen sulphide (H_2S), mercaptans, ammonia (NH_3), formaldehyde, acetone, toluene, ethyl benzene, xylenes, perchloroethylene, and volatile fatty acids. The most important sources of malodours include H_2S,

mercaptans, NH_3, and volatile fatty acids. Bad odours can lead to secondary effects such as nausea, vomiting, loss of appetite, sleeplessness, and the triggering of hypersensitive reactions, but there is no conclusive evidence that human health is seriously affected by odour. Unpleasant smells can, however, cause serious annoyance to the local community, and have been shown to affect property values and potential for development.

4.4 MINING OPERATIONS

Mining operations can be significant sources of fugitive dust emissions, from activities that include blasting and drilling operations, the handling of materials, vehicle-entrainment by haul vehicles, and wind-blown dust from tailings impoundments and stockpiles. Experience has shown that fugitive dust emissions arising from on-site operations typically have an impact only within 3 km of the mine boundary, but communities living close to mining operations and to poorly controlled tailings impoundments may well suffer adverse effects.

Gas emissions are associated with mining operations that include blasting, spontaneous combustion within coal discard dumps, and haulage vehicle tail pipe releases. Emission of reduced sulphur compounds and various VOCs from spontaneous combustion represents an area of concern and warrants investigation.

4.5 AGRICULTURAL BURNING

Lightning is the main natural initiator of vegetation fires in South Africa, but an estimated 70–90% of all vegetation fires are anthropogenic in origin (Helas & Pienaar, 1996). Sugarcane and crop-residue burning, as well as wild-fires (veld-fires), have been found to represent significant sources of combustion-related emissions associated with agricultural activity.

Reasons for agricultural fires include (i) burning off of unpalatable growth left over from previous seasons; (ii) stimulation of growth during seasons when there is little young forage available on the veld, thereby providing green feed for stock when it does not naturally occur; (iii) destruction of parasites, particularly ticks; and (iv) control of the encroachment of undesirable plants in the veld. Other reasons for the lighting of fires include arson (for purposes of hunting, to flush wild animals out of hiding), modification of land use, and negligence.

Biomass burning is an incomplete combustion process, emitting CO, CH_4, and NO_2. Only small amounts of SO_2 and sulphate aerosols are released – and it is the aerosol content that makes smoke plumes visible (Helas & Pienaar, 1996). Agricultural fires cause episodic peaks in ambient air pollutant concentrations, contributing in particular to the emission of fine particulates into the atmosphere. Savanna fires especially are associated with the release of significant percentages of very fine particulates.

Satellite imagery in the NEDLAC study helped to identify and quantify burn scar areas for the purpose of estimating emissions from crop-burning and veld-fires (Scorgie *et al.*, 2004a). The percentage of the total area within each region estimated to have been burnt during that half-decade is as follows: Johannesburg (28%), Vaal Triangle (25%), Mpumalanga Highveld (12%), Tshwane (24%), eThekwini (4%), and Cape Town (11%).

Cape Town experiences the greatest number of fires between January and April; eThekwini between June and August; and the highveld between July and September.

Burning off of unpalatable growth left over from previous seasons.
Photography: Otto Fobian



4.6 OTHER ANTHROPOGENIC SOURCES

Other sources of human-induced emissions include: vehicle-entrained dust from paved and unpaved roads, wind-blown dust from open areas, agricultural activities, informal refuse burning, and tyre-burning. The informal burning of refuse tips within former township areas and the burning of waste at local municipal landfill sites are cause for concern. Refuse tip combustion was, for example, found to contribute significantly to the total airborne particulate concentrations within Soweto. During a 1996–1997 source apportionment study conducted in Soweto, this source was estimated to be responsible for 10–25% of the $PM_{2.5}$ concentrations recorded (Annegarn & Grant, 1999).

Particulates released during tyre-burning have been found to contain aluminium, silicate, iron, and organic and elemental carbon. Detailed information as to the extent of the burning, and the consequent emissions, is not available.

4.7 REGIONALLY-TRANSPORTED POLLUTION

Regionally-transported, aged aerosols[5] contribute significantly to background air pollutant concentrations, particularly over the interior of South Africa. Source apportionment studies have identified four major contributing source types of regional significance to the atmospheric aerosol loading: (i) wind-borne crustal material consisting of mineral soil dust; (ii) marine aerosols from the two adjacent oceans; (iii) biomass burning particles occurring mainly north of 20°S; and (iv) aerosols from industrial emissions. Emissions from these four sources have been detected in the past at remote sites in South Africa (Annegarn, *et al.*, 1992; Piketh, 1995; Piketh *et al.*, 1996; Salma *et al.*, 1992; Maenhaut *et al.*, 1996).

Regionally-transported pollution contributes significantly to background air pollutant concentrations, particularly over the interior of South Africa

[5] Some aerosols stay in the atmosphere for extended periods, and during that time their composition and characteristics change; the longer they stay in the atmosphere the greater the changes.



Box 4.1 City of Cape Town: Source contributions to total emissions

Emissions from industrial/commercial/institutional fuel-burning contribute significantly to TSP, PM_{10}, and SO_2 emissions. This sector also contributes to NO_X and to greenhouse gas emissions (CO_2, N_2O). Vehicle emissions are the most significant source of NO_X, CO, TOC, NMTOC, benzene, formaldehyde, acetaldehyde, Pb, and 1,3-butadiene emissions. Vehicle emissions also contribute significantly to greenhouse gas emissions (CO_2, CH_4, and particularly N_2O), and contribute about 30% of total fine particulate and SO_2 emissions (Scorgie & Watson, 2004).

Shipping contributes marginally to NO_X and SO_2 levels, with emissions being more important in terms of their being localized within the harbour area (Wicking-Baird *et al.*, 1997). Airport emissions are also identified as a localized source of importance.

Domestic fuel-burning is a significant source of fine particulates and also contributes to greenhouse gas emissions (CO_2 and CH_4). Domestic fuel-burning emissions are relatively low compared with those from industry, but their impact is increased by the fact that they occur at ground level, within an urban structure, and at times when people are particularly exposed to them. The effect is often aggravated by local atmospheric inversion phenomena, which retain these emissions at ground level, rather than allowing them to disperse easily (for example, in winter evenings).

Biomass burning in the form of seasonal veld-fires contributes to fine particulate and CH_4 emissions, representing a potentially important localized source of episodic releases in Cape Town (Wicking-Baird *et al.*, 1997; Scorgie & Watson, 2004).

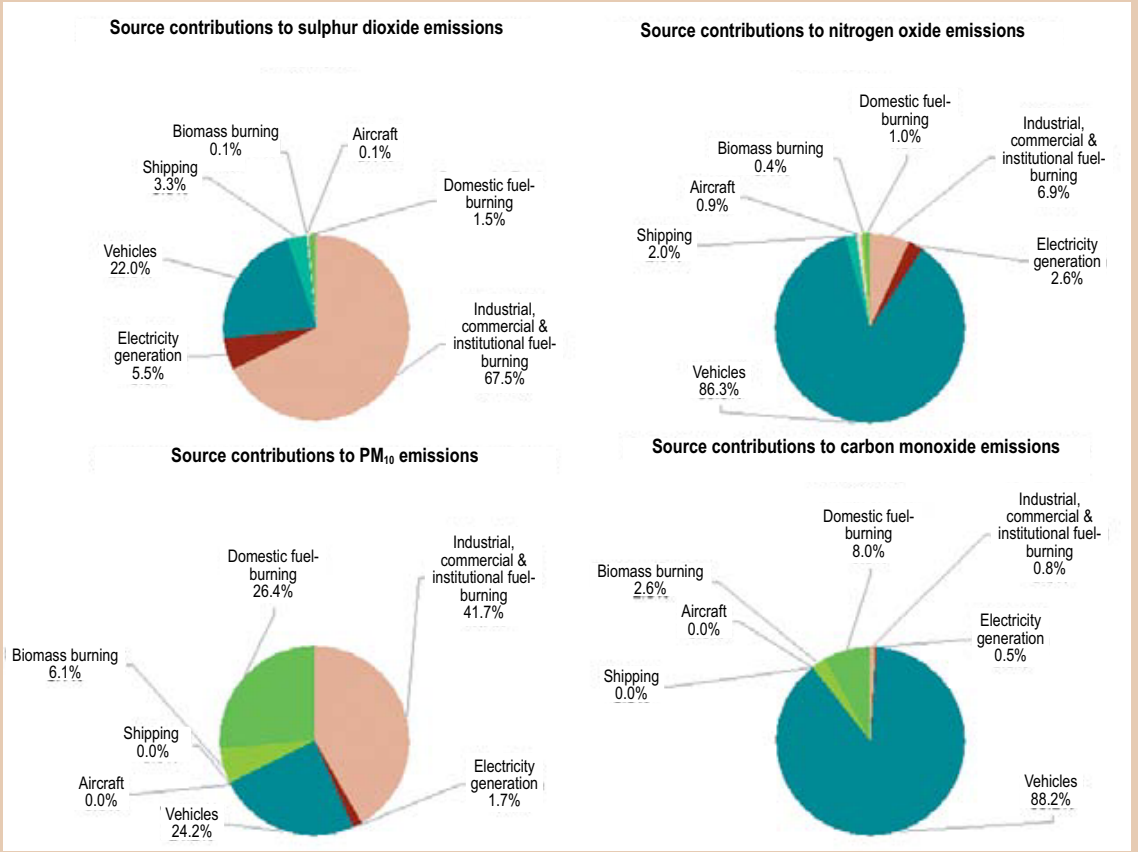


Figure 4.9: Contributions of different emission sources affecting Cape Town

ABBREVIATIONS: CO, carbon monoxide; CO_2, carbon dioxide; CH_4, methane; N_2O, nitrous oxide; NMTOC, non-methane total organic compound; NO_X, oxides of nitrogen; PM_{10}, particulate matter less than 10 μm in aerodynamic diameter; SO_2 , sulphur dioxide; TOC, total organic compound; TSP, total suspended particulate.

Chapter 5

Indoor air quality

At a glance

Household fuel-burning is a significant contributor to both ambient and indoor air pollutant concentrations. Suspended particulate concentrations were found to be orders of magnitude above recommended health limits, and concentrations of fine particulates were even higher in dwellings where wood was burned as a fuel. Ample evidence from local and international studies reveals that household fuel-burning of coal and wood can have serious adverse effects on health. Indoor air pollution from coal-burning has been established as one of the risk factors for the development of acute respiratory illnesses (ARIs). Additional sources of indoor air pollution include building materials and furnishings, deteriorated asbestos-containing insulation; wet or damp carpets; cabinetry or furniture made of specific pressed wood products; central heating and cooling systems and humidification devices; pesticides; solvents and cleaning agents, paints; animals; moulds, dust mites, and other biological sources; and environmental (third party) tobacco smoke.



5.1 INDOOR AIR QUALITY WITHIN FUEL-BURNING HOUSEHOLDS

Household fuel-burning is a significant contributor to ambient air pollutant concentrations, as well as to high concentrations indoors that have been associated with significant adverse impacts on people's health.

Several studies have been conducted to quantify indoor air pollutant concentrations within fuel-burning households (Terblanche *et al.*, 1993; Terblanche & Pols, 1994; Terblanche *et al.*, 1995; Taljaard, 1998; van Niekerk & van Niekerk, 1999; van Niekerk & Swanepoel, 1999). Ranges in air pollutants recorded within coal-burning households are summarized in Table 5.1. Suspended particulate concentrations were found to be orders of magnitude above recommended health limits, and concentrations of fine particulates were even higher in wood-burning dwellings. Although outdoor sulphur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2) concentrations within fuel-burning residential areas have not generally been found to exceed ambient air quality guidelines of the past, violations of health standards occur from indoor exposures to these pollutants[1].

Indoor volatile organic compound (VOC) monitoring programmes have also been undertaken. In the same way as criteria pollutants, indoor VOC concentrations varied substantially, depending on the households' fuel-burning practices, with concentrations of various compounds found to exceed recommended health limits (Scorgie *et al.*, 2001; Taljaard, 1998).

Table 5.1: Ranges of air pollutant concentrations recorded indoors within South African households during coal-burning for cooking and/or space-heating
(Terblanche *et al.* 1994; Taljaard, 1998; van Niekerk & van Niekerk 1999; van Niekerk & Swanepoel, 1999)

Pollutant	Air quality limits[a]	Synopsis of range of indoor air pollutant concentrations measured within households during coal burning (over 1–24-hour averaging periods)
CO	30 mg/m³ for 1-hour exposure 10 mg/m³ for 8-hour exposure	25–50 mg/m³
NO_2	0.2 mg/m³ for 1-hour exposure	0.01–5 mg/m³
SO_2	0.125 mg/m³ for 24-hour exposure	1–3 mg/m³
Total particulate matter	0.075 mg/m³ for 24-hour exposure (given by SANS 1929:2005 for PM_{10})	0.1–4.2 mg/m³

ABBREVIATIONS: CO, carbon monoxide; NO_2, nitrogen dioxide; SO_2, sulphur dioxide; PM_{10}, particulate matter less than 10 μm in diameter.

[a] These air quality limits, issued by the World Health Organization (2000), were recommended for adoption in South Africa by Standards South Africa (SANS 1929:2005).

The burning of wood and coal indoors is of concern due to the high exposure to pollutants emitted by these fuels.
Photography: Hot Tomato Communications

Ample evidence from local and international studies reveals that, when coal and wood are burned indoors other than in structured fireplaces with adequate smoke extraction, household fuel-burning can have serious adverse effects on health (Terblanche *et al.*, 1992; Terblanche & Pols, 1994; Mathee & von Schirnding, 2003; Ehrlich and Kalkoff, 1998; Taljaard, 1998; Scorgie *et al.*, 2001). Indoor air pollution from coal-burning has been established as one of the risk factors for the development of acute respiratory illnesses (ARI). Epidemiological data indicate that ARIs are a leading cause of death among black South African children, and their mortality rate from ARI is reported to be 270 times greater than for children in western Europe (Terblanche *et al.*, 1993). When correlated for socio-economic status, age, and gender, the risk of upper respiratory infection (URI) in winter among rural populations exposed to coal and/or wood cooking and heating fires was found to be four times higher than the risk among electricity users (Terblanche *et al.*, 1992).

Exposures to indoor CO concentrations were found to be up to 180% higher in coal-burning households compared to wood-burning ones within the Vaal Triangle (Terblanche *et al.*, 1995). Data collection and exposure analysis during indoor air pollution studies (in the Qalabotjha Synthesis study [Scorgie *et al.*, 2001]) indicated that CO (which can be lethal in high concentrations) contributed significantly to acute

1. Indoor exposures depend on factors that include the size of the dwelling, the size of the fire, the way in which the fire is made and fed, the type of stove used, the composition of the material being burnt, and ventilation.



health risk, and that chronic health problems were a likely consequence of particulates in the air, as well as volatile compounds such as benzene, hexane, carbon tetrachloride, and tetrachloroethylene (Taljaard, 1998).

The "Birth to Ten" research project, initiated by the Medical Research Council in 1990, aimed to assess the environmental, economic, psycho-social, and biological determinants of health, development, and well-being in a cohort of 3 275 children from birth to the age of ten years in Soweto and parts of Johannesburg (von Schirnding & Mokoetle, 1993). The study found that 50% of children who lived in homes with an open fire experienced respiratory symptoms such as sneezing or a runny/stuffy nose, in contrast to 24% of children who lived in homes without open fires. Over half (54%) of the respondents reported that children had experienced colds and chest illness with high frequency since birth. Runny noses (53%), sneezing (38%), and a productive cough[2] (28%) were among the most frequently reported symptoms of ill health. Ear infections (8%), bronchitis/bronchiolitis (5%), pneumonia (4%), and allergies (4%) were among the most frequently reported health problems diagnosed by a doctor since the birth of the child. By about the age of 14 months, 4% of the children in the study had been admitted to hospital for a chest illness.

Health risks associated with exposure to household coal-burning were quantified in the Qalabotjha Synthesis study (Scorgie *et al.*, 2001). The risks were calculated for each individual fuel-appliance combination considered by South Africa's Atomic Energy Corporation (AEC) (Britton, 1998), based on predicted ambient air pollutant concentrations (that is, using dispersion simulations and the AEC's 1998 emission factors as a basis). Health risks have also been calculated for actual above-normal as well as normal coal combustion periods, based on ambient air quality data measured by the AEC during the Qalabotjha macro-scale experiment (Sowden, 1998) and indoor air quality measurements made by the CSIR during the same study (Taljaard, 1998). Cancer risks arising from bituminous coal-burning in both braziers and stoves were calculated to be greater than 1:10 000 for the haematopoietic, hepatic, and pulmonary systems, and were therefore considered to pose unacceptable health risks. In assessing irritation associated with organic compounds, effects on the eyes, dermal system, and pulmonary system were taken into account. Particulate matter, rather than organic compounds, were found to be primarily responsible for irritation in the pulmonary system. Potential irritation to the eyes and dermal system were associated with exposures to organic compounds,[3] and health risks associated with the eyes and the pulmonary-cardiovascular systems occurred as a result of exposures to SO_2.

5.2 INDOOR POLLUTANT SOURCES (OTHER THAN FUEL-BURNING)

Many researchers who study indoor air quality believe that – even in households that do not burn fuel – overall exposure to air pollutants is greater indoors than outdoors (EPA, 1998), the reason being that there are various other sources of indoor emission and many people spend most of their time indoors (in houses, offices, schools, and shops, for example). Inadequate ventilation can raise indoor pollutant levels by not allowing the entry of outdoor air, which would dilute emissions from indoor sources, and by not allowing

2. A productive cough is one that produces phlegm, as opposed to a dry cough which does not.

3. 'Organic compound' defines material in terms of chemistry; 'particulate' and 'aerosol' defines material in terms of its physical state.

the pollutants to escape out of doors. Elevated temperatures and humidity levels can also increase indoor pollutant emissions.

Sources of indoor air pollution include building materials and furnishings, as diverse as deteriorated asbestos-containing insulation; wet or damp carpets; cabinetry or furniture made of specific pressed wood products (a significant source of formaldehyde emissions); central heating and cooling systems and humidification devices; (radon gas from uranium in soil or rock on which buildings may be constructed); pesticides; solvents and cleaning agents, paints; animals, moulds, dust mites, and other biological sources; and environmental (third party) tobacco smoke.

It is hoped that the risk of exposure to environmental tobacco smoke in South Africa has been dramatically reduced as a result of legislation that restricted smoking in public places

Environmental tobacco smoke (ETS) – or 'passive smoking' – has received considerable public attention in recent years. Tobacco smoke comprises a complex mixture of over 4 000 chemical compounds, and includes respirable particles, CO, NO_2, nicotine, formaldehyde, ammonia, and hydrogen cyanide. Many of these are listed as toxins or carcinogens. The US Environmental Protection Agency (EPA, 1992) has classified ETS as a known human (Group A) carcinogen and estimates that it accounts for about 3 000 lung cancer deaths per year among non-smokers in the USA. Comparable statistics are unavailable for South Africa.

It is hoped that the risk of exposure to ETS in South Africa has been dramatically reduced as a result of legislation that restricted smoking in public places, confining it to purpose-designed smoking rooms with independent ventilation to the outside (Tobacco Products Control Amendment Act, [No. 12 of 1999]). A survey by the Department of Health in 1998 showed that 42% of men (over the age of 15) and 11% of woman (over the age of 15), 10% of adolescents aged 15–19 years were smokers (Department of Health, 1998). The total annual consumption of cigarettes in the country has decreased since the 1990s.

Asbestos contributes to both indoor and ambient air pollution. Asbestos mining has ceased, but exposure to airborne asbestos fibres continues, primarily by non-occupational exposure of communities using asbestos material for affordable housing, and persistent exposure in the vicinity of abandoned and unrehabilitated asbestos mine works. A study for the Department of Housing in 2001 found that asbestos materials are still widely used in affordable housing, particularly in KwaZulu-Natal, and the Eastern and Western Cape (Fridge, 2002). Problems are also associated with the use of asbestos-containing minerals for road construction. Inhalation exposure to asbestos fibres is associated with a range of pulmonary diseases, primarily asbestosis (mesothelioma-type lung cancer).

Asbestos deteriorates over time, leading to the possibility of inhalation of asbestos fibres which could lead to a range of pulmonary diseases such as asbestosis.

Chapter 6

Ambient air quality monitoring and data availability

At a glance

Air quality monitoring networks have been established by several provincial and local governments and by non-governmental parties, including those from industries, research agencies, and higher education institutions. Data from these networks have formed an important information resource in air quality management planning. The most commonly monitored compounds are sulphur dioxide, nitrogen oxides, ozone, particulate matter, lead, carbon monoxide, and some volatile organic compounds. Air quality monitoring stations can be classified into categories according to the chief characteristics of the sources and/or environments being monitored. These categories include: background stations, industrial areas, residential areas affected by industrial pollution, informal settlements, urban areas affected by commercial and traffic pollution, and waste disposal sites. Data coverage has been insufficient to identify all potential priority areas accurately, or to quantify impacts of air pollution on human health and the environment. The spatial distribution of monitoring stations and the range of pollutants measured need to be extended.



The successful implementation of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004) depends on characterizing air quality effectively, and identifying areas where air pollutants exceed air quality limits. The characterization of air quality across the country is hindered, however, by the limited availability of high-quality, long-duration air pollution monitoring datasets. This is largely because government officials were not tasked with air quality monitoring under the Atmospheric Pollution Prevention Act (APPA) (Act no. 45 of 1965), and because monitoring guidelines were not published for use by those government departments undertaking voluntary monitoring campaigns. A few air quality monitoring networks were established by several provincial and local governments and by non-governmental parties including those from industries, research agencies, and higher education institutions. Data from these networks have formed an important information resource in subsequent air quality management planning.

The status of air quality monitoring in South Africa was assessed by the CSIR as part of the Phase II Transition Project (DEAT, 2006b). Air quality monitoring data over a 10-year period (1994–2004) were further assessed in order to characterize trends in air pollution concentrations and to determine compliance with APPA standards. (The findings are documented in the Appendix at the end of this report.)

This chapter gives an overview of the status of ambient air quality monitoring for the year 2004, with reference to the Standards South Africa guidelines for monitoring published in 2005 (SANS 1929:2005). Amongst other things, SANS 1929 specifies macro- and micro-scale siting criteria, data quality objectives, and the minimum number of monitoring stations required within urban areas. The status of monitoring is therefore evaluated in the present report on the basis of the number of stations in operation and the integrity of the data produced. A synopsis is given of the major conclusions drawn by the National Air Quality Information Review (DEAT, 2006b).

6.1 OVERVIEW OF AIR QUALITY MONITORING

6.1.1 Monitoring agencies and pollutants measured

Ambient air quality monitoring has been conducted by 35 different agencies using a range of monitoring methods and approaches. For the most part, air quality monitoring activities have been conducted by metropolitan councils and by industry[1]. Air quality associations, consultants, and scientific bodies have also collected data (see Table 6.1).

Air quality monitoring activities take on a variety of forms, ranging from continuous ambient monitoring to *ad hoc* diesel vehicle emission testing, shown above.

1. Because of the implementation of the Air Quality Act, much change has occurred in monitoring activities since 2004, and, in most cases, monitoring networks at local authorities have been expanding and improving.



Table 6.1: Monitoring by different organizations (major pollutants, 2004)

	Organization	Parameters
Metropolitan	City of Johannesburg	SO_2, PM, NO_X, O_3, CO, met.
	City of Tshwane Metropolitan Municipality	SO_2, PM, O_3, CO, met.
	Ekurhuleni Metro	SO_2, PM, NO_X, O_3, CO, met.
	City of Cape Town	SO_2, PM, NO_X, O_3, CO, H_2S, met.
	eThekwini Municipality	SO_2, PM, NO_X, O_3, CO, other*, met.
	Nelson Mandela Metropolitan Municipality	SO_2, PM, NO_X, O_3, smoke
Air quality organizations	Air Pollution Liaison Committee (APOLCOM)	NO_X, PM, SO_2
	Annegarn Environmental Research (AER)	116 dust fallout monitoring sites at Anglo Coal mines
	East London Regional Waste Disposal Site	PM, VOCs, met.
	Msunduzi Air Quality Forum	NO_X, O_3, SO_2, met.
	Richards Bay Clean Air Association	SO_2
	C & M Consulting Engineers	Pb, smoke, SO_2
	Kiepersol Joint Venture	Acid rain
Scientific data holdings	North-West University (DEBITS programme)	NO_X, O_3, SO_2, other*
	South African Weather Service	O_3, NO_X, VOCs, other*, met.
Industrial holdings	African Explosives Limited	PM, SO_2, met.
	Chrome International South Africa (Pty) Ltd	PM, other*
	Columbus Stainless Air Quality Station	PM, SO_2
	East London Industrial Development Zone Corporation	PM, SO_2, VOCs
	Eskom	SO_2, PM, O_3, NO_X, met.
	Mittal Steel	SO_2, PM, NO_X, CO, VOCs, O_3, other*, met.
	Mondi Packaging	SO_2, PM, other*
	Natref	Other*
	Phalaborwa Mining Company	NO_X, O_3, PM, SO_2
	PetroSA Environmental Department	NO_X, O_3, PM, SO_2, VOCs, Mn, Pb
	Sappi Saiccor	SO_2
	Sasol Synfuels	CO, NO_X, SO_2, PM, O_3, VOCs, other*, met.
	Lonmin	PM, SO_2, met.
	Coega Development Corporation	SO_2, NO_X, PM
	Eskom (for AngloPlatinum)	SO_2, PM, met.

ABBREVIATIONS: CO, carbon monoxide; met., meteorological measurements (such as wind speed, direction); Mn, manganese; NO_X, nitrogen oxides; O3, ozone; Pb, lead; PM, particulate matter; SO2, sulphur dioxide; VOCs, volatile organic compounds.

* "Other" refers to a non-criteria pollutant that is measured at one station on the network, but not elsewhere.

Table 6.2: Number of air quality datasets per parameter per province

Parameter	Province									
	EC	FS	GAU	KZN	LMP	MP	NC	NWP	WC	Total
SO_2	8	6	8	35	1	20		21	7	106
Dust	6			1				48		55
O_3	2	4	13	4	1	12	1	1	5	43
NO_2	2	4	11	7	1	11		1	7	44
PM_{10}	4	1	10	6		2		3	6	32
Pb	1		7	17					1	26
Smoke	4			16						20
NO		1	7	6		6			5	25
CO			9	2		1			4	16
H_2S		3	5			5			1	14
NO_X		3	4	3		5				15
TSP	2		1	4						7
BTEX	6									6
Hazing*		1				5				6
Benzene		1	3							4
Cr				4						4
Cr^{6+}				4						4
Methane			3						1	4
$PM_{2.5}$			2			2				4
Toluene		1	3							4
Xylene		1	3							4
Mn							2			2
TRS				3						3
CO_2									1	1
N_2O									1	1
Total	**35**	**26**	**89**	**112**	**3**	**69**	**3**	**74**	**39**	**450**

ABBREVIATIONS: BTEX, benzene, toluene, ethylbenzene, xylene; CO, carbon monoxide; CO_2, carbon dioxide; Cr, chromium; EC, Eastern Cape; FS, Free State; GAU, Gauteng; H_2S, hydrogen sulphide; KZN, KwaZulu-Natal; LMP, Limpopo; Mn, manganese; MP, Mpumalanga; NO_X, nitrogen oxides; NWP, North West Province; NO, nitric oxide; N_2O, nitrogen dioxide; NO_X, nitrogen dioxide; O_3, ozone; Pb, lead; $PM_{2.5}$, particulates with an aerodynamic diameter of less than 2.5 μm; PM_{10}, particulates with an aerodynamic diameter of less than 10 μm; SO_2, sulphur dioxide; TRS, total reduced sulphur; TSP, total suspended particulates; WC, Western Cape.

* Hazing is largely attributed to the backscattering of light by small airborne particles. The degree of hazing can therefore be related to the concentration of such particles through an index, namely a hazing index. In Mpumalanga the hazing index is used to assess the impact of air pollution ($PM_{2.5}$) on visibility.

The most commonly monitored compounds are sulphur dioxide (SO_2), NO_X (NO_2 and NO), ozone, and particulate matter (ambient PM_{10} concentrations and dust deposition). The other pollutants measured include Pb, CO, TSP, VOCs (BTEX [benzene, toluene, ethylbenzene, xylene] components or just benzene), $PM_{2.5}$, hazing index, Cr and Cr^{6+}, Mn, greenhouse gases (CH_4, CO_2, and N_2O), H_2S, and total reduced sulphur (TRS). Historical data from smoke and SO_2 bubbler sampling stations and recent SO_2 data from passive diffusive monitoring networks is also available.

6.1.2 Geographical distribution of monitoring

A detailed description of available monitoring for each pollutant, including maps showing station locations, is available in the *Technical Compilation to Inform the State of Air Report* (DEAT, 2006a), reproduced in the Appendix (at the end of this report). The number of datasets for each pollutant in each province (sorted in descending order) is shown in Table 6.2.

Emissions from a tall stack at an industrial plant.
Photography: John Ledger

The objectives of ambient air quality monitoring are to provide data on

- The areas within zones and agglomerations where the highest concentrations of pollutants occur, to which people are likely to be directly or indirectly exposed
- Pollutant concentrations to which the general population and ecological systems are exposed, in order to determine impacts
- Transboundary pollution and resultant effects.

To achieve their goals, the monitoring stations need to be correctly located and must meet certain location criteria in the immediate vicinity of the monitoring station. The macro- and microscale location criteria detailed in SANS 1929:2005 are available for this purpose. In addition, a minimum number of sampling points is required in zones and agglomerations to assess compliance with air pollutant limit values (see Tables 6.3 and 6.4).

A mobile air quality monitoring station, used most often for once-off research campaigns.

Table 6.3: Minimum number of sampling points required for fixed measurements to assess compliance with SO_2, NO_2, PM_{10}, CO, benzene and Pb limit values (SANS 1929:2005)

Human population of agglomeration or zone (thousands)	Minimum number of sampling points required		
	Where concentrations exceed the upper assessment threshold[a]	Where maximum concentrations are between the upper and lower assessment thresholds[b]	For SO_2 and NO_2 in agglomerations where maximum concentrations are below the lower assessment threshold[c]
0 – 250	1	1	not applicable
250 – 499	2	1	1
500 – 749	2	1	1
750 – 999	3	1	1
1 000 – 1 499	4	2	1
1 500 – 1 999	5	2	1
2 000 – 2 749	6	3	2
2 750 – 3 749	7	3	2
3 750 – 4 749	8	4	2
4 750 – 5 999	9	4	2
>6 000	10	5	3

[a] Areas in which the 99th percentile pollutant levels represent a value exceeding 70% of a limit value (taking into account limit values for all periods used to derive averages).

[b] Areas in which the 99th percentile pollutant levels represent a value between 50% and 70% of a limit value (taking into account limit values for all periods used to derive averages).

[c] Agglomerations where the 99th percentile pollution levels are below 50% of all limit values (taking into account limit values for all specified averaged periods).

Table 6.4: Minimum number of sampling points required for fixed measurements to assess compliance with O_3 limit values (SANS 1929:2005)

Human population of agglomeration or zone (thousands)	Agglomerations (urban and suburban)[a]	Other zones (suburban and rural)[a]	Rural areas
0 – 250	–	1	1 station per 50 000 km^2 as an average density over sparsely populated zones in the country[b]
250 – 499	1	2	
500 – 999	2	2	
1 000 – 1 499	3	3	
1 500 – 1 999	3	4	
2 000 – 2 749	4	5	
2 750 – 3 749	5	6	
>3 750	1 additional station per 2 million inhabitants	1 additional station per 2 million inhabitants	

[a] At least one station in suburban areas, where the highest exposure of the population is likely to occur. In agglomerations, at least 50% of the stations should be located in suburban areas.

[b] For complex terrain, 1 station per 25 000 km^2 is recommended.



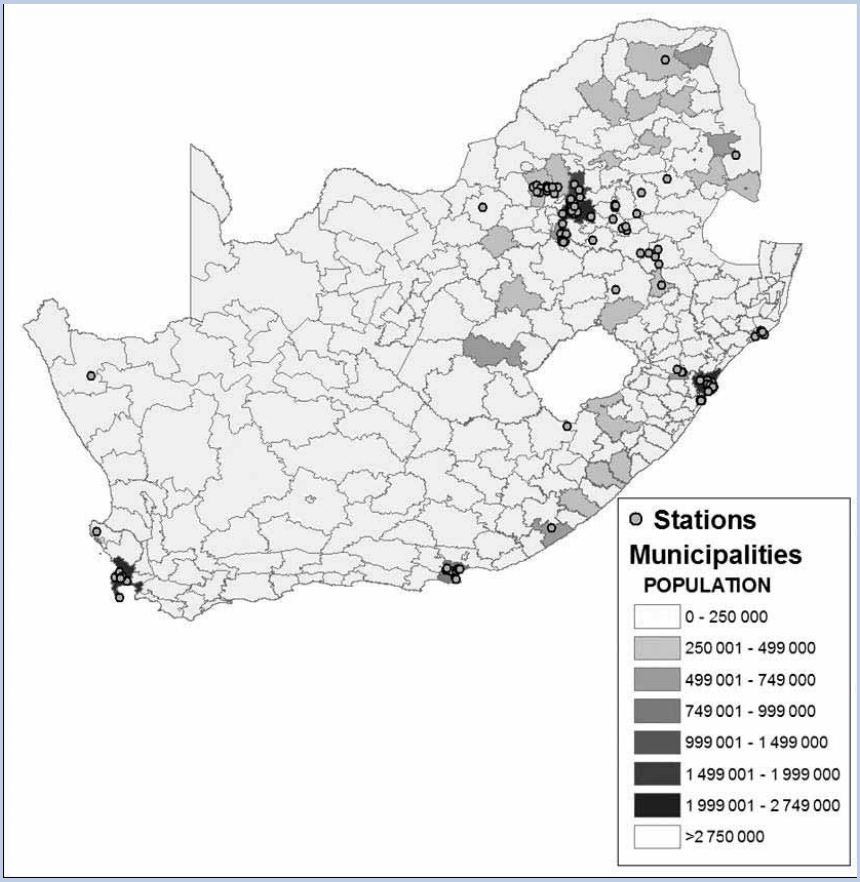


Figure 6.1: South African population distributions and the relative location of ambient air quality monitoring stations

Table 6.5: Number of stations required per metropolitan municipality

Local authority	Human population (millions)	Number of monitoring stations in 2004*	Minimum number of stations required by SANS 1929:2005
eThekwini Metropolitan Municipality	2.75	23	2–6
City of Johannesburg	2.64	8	2–6
City of Cape Town	2.56	11	2–6
Ekurhuleni Metropolitan Municipality	2.03	1	2–6
Tshwane Metropolitan Municipality [Pretoria]	1.68	1	1–5
Nelson Mandela Metropolitan Municipality [Port Elizabeth]	0.97	4	1–3

* Number of stations from which data have been obtained (including smoke and SO_2 bubbler sampling stations that provided historical data).

The location of ambient air quality monitoring stations in relation to population distribution is illustrated across the country in Figure 6.1, demarcated by municipal boundaries and using the population bins defined by SANS 1929:2005. The same information is used to summarize the number of monitoring stations required for the largest metropolitan centres (see Table 6.5), given that no South African municipality has a population that exceeds 2.75 million. When comparing the minimum requirements of SANS 1929:2005 concerning the number of stations needed, it is evident that sufficient are in operation in the major metropolitan areas and industrial development zones. It does not necessarily follow, however, that the monitoring network meets the criteria required for identifying impacts from major pollution sources. Furthermore, little attention is placed on air quality monitoring in areas where population is more widely dispersed.

6.1.3 Characterization of pollution sources

Air quality monitoring stations were classified as follows to establish the chief characteristics of the sources and/or environments being monitored:

- background station (B) (one where no specific source of pollution is being monitored)
- industrial area (I)
- a station likely to be impacted by emissions from power generation (P)
- residential (R)
- residential affected by industrial pollution (RI)
- informal settlement (T)
- urban, affected by commercial and traffic pollution (U)
- waste disposal site (W).

The number of monitoring stations is given in Table 6.6 (per class) for the pollutants for which more than 10 stations are operated nationally. Many of them are situated in industrial areas and residential sites exposed to industrial pollution. Relatively less monitoring is conducted in townships and around waste disposal sites.



Table 6.6: Number of datasets representing station types for main pollutants
(excluding the additional 84 pollutant datasets listed in Table 6.2)

Parameter	B	I	P	R	RI	T	U	W	Total
SO_2	8	34	13	13	20	7	8	0	103
Dust	0	34	0	0	12	2	0	6	54
O_3	9	8	7	6	4	2	4	1	41
NO_2	7	9	7	3	7	1	3	1	38
PM_{10}	0	8	1	4	5	5	4	2	29
Pb	1	2	0	2	5	0	14	0	24
Smoke	1	3	0	4	6	1	4	0	19
NO	0	3	5	2	5	0	3	1	19
CO	1	3	0	1	2	1	4	0	12
H_2S	0	5	0	0	8	0	1	0	14
NO_X	0	2	3	1	4	0	3	0	13
Total	**27**	**111**	**36**	**36**	**78**	**19**	**48**	**11**	**366**

ABBREVIATIONS: CO, carbon monoxide; B, background station; H_2S, hydrogen sulphide; I, industrial area; NO, nitric oxide; NO_2, nitrogen dioxide; NO_x, nitrogen oxides; O_3, ozone; P, impacted by power generation; Pb, lead; PM_{10}, particulates with an aerodynamic diameter of less than 10 μm; R, residential; RI, residential affected by industrial pollution; SO_2, sulphur dioxide; T, informal settlement; U, urban affected by commercial and traffic pollution; W, waste disposal site.

6.1.4 Characterization of air quality in areas remote from pollution sources

South Africa has 30 datasets that represent remote environments and representing regional air quality (that is, pollution levels due to the influence of large sources within the region, from neighbouring countries, such as extensive biomass burning or veld fires at specific times of year). Here, the term 'datasets' refers to discrete monitoring periods at the monitoring locations listed – in other words, if monitoring at a particular station took place six times over a three-year period, it would give six datasets – and 'remote environments' are locations isolated from the influence of specific sources of air pollution (for example, Ben McDhui is in the Drakensberg mountains, on the border with Lesotho). Greenhouse gases are measured at Cape Point (CO_2, N_2O, and CH_4) in addition to the 27 background-station datasets listed in Table 6.6.

There are only nine background stations in seven provinces (excluding Gauteng), which is clearly inadequate given the large number of protected and environmentally-sensitive areas and the diversity of climates across the country. The background stations are located across the provinces as follows: Ben McDhui (Eastern Cape); Cedara and Cowies Hill (KwaZulu-Natal); Houtbosrand and Skukuza (Mpumalanga); Lichtenburg (North West); Louis Trichardt (Limpopo); Springbok Weather Office (Northern Cape); and Cape Point (Western Cape).

Ozone (O_3) affords the largest number of datasets from available measurements. There are two types of O_3 measurements: the monitoring of ground-level O_3 concentrations (measured in ppb or $\mu g/m^3$); and the measurement of total column O_3 (using Dobson Units [DU]). The latter gives the amount of O_3 in the atmospheric column extending from the Earth's surface to the top of the atmosphere.

Total column O_3 data are relatively homogeneous on a regional scale, generally decreasing slowly with decreasing latitude. Total column O_3 also varies relatively little during an annual period. Measurements are conducted at Springbok and Irene, and, separated by some 6 degrees of latitude, are considered adequate to represent total column O_3 over South Africa.

Continuous monitoring of background concentrations has been supplemented in certain regions by passive diffusive sampling. Through a joint venture between the University of Johannesburg, the University of the Witwatersrand, parties from the North West Province, and the Council for Scientific and Industrial Research (CSIR), a regional-scale passive diffusive monitoring network has, for example, been established. It comprises 37 passive sampling monitoring sites situated in four provinces (in Mpumalanga, Limpopo, northern KwaZulu-Natal, and the eastern Free State). (For more information on this network, see Chapter 9.)

6.1.5 Data quality

All aspects of air quality monitoring are subjected to recognized procedures to ensure standardization and conformity of approach, so that the resultant data are representative and comparable. These procedures relate to the siting of stations; site and equipment operations; routine equipment performance tests and calibration processes; site and equipment auditing; inter-laboratory testing; data processing; and storage. Standard site operating procedures have been detailed by organizations such as the United States Environmental Protection Agency (1994), World Health Organization (2000), and Standards South Africa (SANS 1929:2005). Different aspects of data quality, such as quality control (QC), quality assurance (QA), data validation, data ratification, and accreditation of monitoring are explained in the Appendix (at the end of this report).

The key components of an air quality monitoring programme include QA and QC. Data ratification is a further step that can be undertaken to ensure long-term sustainability of data acquisition. The agencies that collect data from monitoring programmes in South Africa were asked to report on their QA and QC for the *National Air Quality Information Review* (DEAT, 2006b) (for a synthesis of their responses, see Table 6.7). Only a few agencies provided information on their QA and QC procedures, and even fewer reported having utilized accredited laboratories for calibration. There is a high level of confidence in data obtained from audited networks.

Photography: John Ledger

Monitoring stations that form part of international networks, such as the North-West University's DEBITS programme and the South African Weather Service Climate Systems Global Atmosphere Watch (GAW), are conducted under strict international QC procedures, and QA is achieved through site and laboratory audits and inter-laboratory calibration testing. There is a high level of confidence in data that originate from these stations. There is a low level of confidence in data from air quality monitoring stations where limited or no QC or QA are applied.

No norms and standards are in place in South Africa for storing, sharing, and distributing ambient air quality data. Several organizations have well developed data management and archiving systems (for example, the City of Cape Town, eThekwini Metropolitan Municipality, Eskom Holdings). These conditions imply that data are fragmented and are held as the property of the collecting agencies. Access to data for provincial- and national-scale assessment and reporting is therefore limited, and the problem is exacerbated by differing data-sharing policies.

In preparing this report, the underlying assumption on data quality was that all data received had undergone a QC process by the respective data-holding agencies. Closer inspection of the data revealed, however, that the data from a few of the contributing organizations contained spurious points, including negative concentrations. Such data points have been excluded from this assessment. Some unrealistically high values were also excluded after the spikes had been checked with the relevant agency.

6.2 RECOMMENDATIONS AND CONCLUSIONS

6.2.1 *National Air Quality Information Review* conclusions

The main conclusions drawn in the *National Air Quality Information Review* (DEAT, 2006b) were as follows.

- Air quality monitoring was occurring mostly in industrial areas and central urban areas. Air quality was often unmonitored in high-density low-income residential areas, with pollution arising from coal combustion for cooking and space heating, and from unpaved roads. The data coverage was not sufficient to identify all potential

Table 6.7: Synthesis of QA/QC reported by agencies collecting South African data (DEAT, 2006b)

Agency	QC procedures in place	QA procedures in place	Calibration laboratory used
African Explosives Limited	No	No	
Air Pollution Liaison Committee (APOLCOM)	No	No	
Air Quality Monitoring Laboratory, City of Cape Town	Yes	Yes	Air Quality Monitoring, City of Cape Town
Anglo Coal	No info	No info	
Annegarn Environmental Research (AER)	Yes	Yes	AER
City of Johannesburg	No info	Yes	Eskom TSI (Technology Services International)
City of Tshwane Metropolitan Municipality	No info	No	
C & M Consulting Engineers	No info	No info	
Columbus Stainless Ambient Air Quality Station	No info	No	
Coega Development Corporation	Yes	Yes	Scientific Services, Grant Ravenscroft
Chrome International South Africa (Pty) Ltd	Yes	No info	
East London Industrial Development Zone Corporation (ELIDZC)	No info	No	
East London Regional Waste Disposal Site	No	Yes	Ecoserv (Pty) Ltd
Ekurhuleni Metro: Eastern Region	No info	No info	
Eskom	Yes	Yes	Eskom Calibration Laboratory (SANAS No. 1503)
Eskom (for AngloPlat)	Yes	Yes	Eskom TSI
eThekwini Municipality	No info	Yes	Eskom TSI
Lonmin	No info	No info	
Mittal Steel	Yes	Yes	Technischen Überwachungsvereine (Technical Inspections Organizations) (TÜV) & National Occupational Safety Association (NOSA) for SO_2; no information for NO_x, CO, and O_3
Mondi Packaging	No info	No info	
Msunduzi Air Quality Forum	Yes	No info	
Nelson Mandela Metropolitan Municipality	Yes	No info	
North-West University (DEBITS programme)	Yes	No	
Phalaborwa Mining Company	Yes	Yes	C & M Consulting Engineers
PetroSA Environmental Department	Yes	Yes	Gaschrom Analytical Services cc
Richards Bay Clean Air Association	Yes	Yes	Eskom TSI
Sappi Saiccor	Yes	Yes	Internal/ SANAS Audit Laboratory
Sasol Synfuels	Yes	Yes	CSIR
South African Weather Service Climate Systems Global Atmosphere Watch (GAW)	Yes	Yes	UBA, Germany (NO_x); EMPA, Zurich, Switzerland (CO and O_3)

ABBREVIATIONS: CO, carbon monoxide; SO_2, sulphur dioxide; NO_x, nitrogen oxides; O_3, ozone; TSI, Technology Services International.



priority areas (and had not been supplemented by an emissions inventory or by air dispersion modelling).

- At a provincial and local government level:
  - Data coverage in all provinces other than Gauteng was inadequate to facilitate effective air quality management
  - Monitoring had generally been limited to central urban and industrial areas, without extending to rural areas. Effective air quality monitoring was being conducted by a few local governments, including eThekwini, Richards Bay, the City of Cape Town, Johannesburg, and the Nelson Mandela Metropolitan Municipality
  - Monitoring had generally been limited to a few pollutants (typically SO_2, NO_x, and PM), while key urban pollutants such as ozone, $PM_{2.5}$, and benzene had not been widely monitored
  - Not all local government monitoring networks had the required quality systems in place, nor were they audited by SANAS accredited calibration laboratories.
- To assess air quality impacts on human health, existing air pollution monitoring data were inadequate, specifically with respect to the following:
  - Air quality monitoring focused mostly on metropolitan and industrial areas: monitoring in high-density low-income residential areas, particularly those in rural or semi-rural areas, were often excluded
  - Carcinogens that typically occur within urban environments, such as benzene and 1,3-butadiene, were not commonly monitored.
- National monitoring needed to be expanded beyond urbanized and industrial areas in order to improve understanding of background levels of air pollutants and to provide insights into transboundary transport of pollutants.
- The data may have been inadequate for assessing the impacts on the ecological environment, specifically:
  - Ozone is a common pollutant that poses the highest risk to vegetation. Most ozone monitoring was conducted in urban environments and bore no relevance to agricultural or natural environments
  - Wet-deposition monitoring was limited to the northeastern parts of South Africa
  - Limited dry-deposition work was conducted in research programmes, and was limited to sulphate and ozone.

6.2.2 Extension and optimization of the available air quality information

Data coverage has been insufficient to identify all potential priority areas accurately, or to quantify impacts of air pollution on human health and the environment.

The city of Cape Town on a clear day.



An ambient air quality monitoring station measuring pollution concentrations in Vereeniging.
Photography: DEAT

The spatial distribution of monitoring stations and the range of pollutants measured should be extended. Some issues need to be addressed through monitoring campaigns (that is, scientific projects with a limited measuring time, generally focusing on a specific issue). For example, the impacts of wild and controlled fires have been studied in a few research studies, but need to be extended to cover volatile organic compound (VOC) pollution from smouldering mine dumps. (For these issues, see Chapter 9.)

Automated continuous monitoring needs to be supplemented by additional air quality monitoring and characterization techniques.

- Passive sampling should be used for spatial screening of regional pollution and for baseline characterization in small municipalities and less polluted areas.
- Remote sensing is an important emerging tool for spatial screening and regional characterization.
- Emissions inventories and atmospheric dispersion modelling are critical components of cost-effective, ongoing air quality characterization.

These techniques supplement monitoring by assisting in the prediction of spatial variations in air pollutant concentrations. Furthermore, dispersion modelling also allows the projection of air quality changes related to new building or industrial developments, for example, and the implementation of planned emission-reduction strategies.

6.3 STATION SELECTION FOR BASELINE AIR QUALITY CHARACTERIZATION

All monitoring datasets obtained during the *National Air Quality Information Review* are documented in the Appendix (at the end of this report). Datasets were selected from suitable stations for more detailed data processing to characterize the baseline status of the air quality in various South African environments, including areas where there is residential fuel-burning, dense traffic, heavy industry, one or more power stations, and mining, as well as remote sites, far from such sources of pollution. When selecting datasets, use was made of stations with the longest-term and most comprehensive data (that is, data with the highest level of confidence). (For results from the analysis of these datasets, see Chapter 7.)

Chapter 7

Ambient air quality - current status and recent trends

At a glance

South Africa faces the challenge of addressing a range of persistent air pollution problems, including emissions from industrial activity and power generation, as well as high levels of ambient sulphur dioxide and fine particulates resulting from coal- and wood-burning within households. Emerging air pollution issues are closely associated with transport, particularly on the roads. Rising traffic levels and the ageing of the nation's vehicles are projected to compromise planned and proposed national emission reduction measures. To highlight South Africa's air quality challenges, the status of air pollution concentrations and trends for six types of environment were analyzed, namely residential household fuel-burning areas, dense traffic areas, heavily industrialized areas, power station locations, mining areas, and remote sites. Air pollution concentrations from certain source types follow distinct diurnal and seasonal trends, which are a function of meteorological variations and activity at the source. These variations have implications for people's potential exposure to pollutants.



In addition to having to deal proactively with emerging issues, South Africa also faces the challenge of addressing a range of persistent air pollution problems. These include pollution from industrial activity and power generation. They also include high levels of ambient sulphur dioxide (SO_2) and fine particulate concentrations, which come mainly from coal- and wood-burning within households, with impacts on human health that remain the country's most serious and pressing air pollution problem. The location of heavy industries near places where communities live presents a continuing source of health risks and conflict, exacerbated by increased pressure to allow residential areas to develop within former industrial buffer zones. Further questions arise concerning potential environmental impacts and transboundary transportation of pollutants generated by elevated stack emissions from petrochemical, metallurgical, and mineral processing, and from coal-fired power stations.

Emerging air pollution issues are closely associated with transport, particularly on the roads. Rising traffic levels and the ageing of the nation's vehicles are projected to compromise planned and proposed national emission reduction measures aimed at regulating fuel composition and new vehicle technology. Although air quality limits for nitrogen dioxide (NO_2) and ozone (O_3) – aimed at protecting people against acute adverse effects on their health – have been exceeded only relatively infrequently within South African cities, the concentrations of these pollutants have been increasing. Volatile organic compound (VOC) releases from fuel filling stations, and NO_2 and hydrocarbon releases from major airports, have also underscored the air quality implications of transportation policies. Furthermore, the contribution of the transport sector to greenhouse gas emissions has increased significantly (World Bank, 2006). Transport was responsible for 27% of South Africa's total energy demand in 2000 (DME, 2005), and this contribution is increasing, particularly in urban areas. Within the six largest metropolitan areas in 2004, for example, transport accounted for 56% of energy consumption (SEA, 2006).

To highlight South Africa's air quality challenges, this report presents the status of air quality and trends in air pollution concentrations for six types of environment:

- Residential household fuel-burning areas
- Dense traffic sites
- Heavy industrial areas
- Power station locations
- Remote sites
- Mining areas.

Selected air pollution monitoring stations in this study (see Appendix), aimed at demonstrating typical air pollution concentrations within the above environments, are discussed in Chapter 6. (For the definition of 'high pollution days' as the term is used in this report, see §3.3.)

7.1 COMPLIANCE OF COMMON POLLUTANTS WITH AIR QUALITY LIMITS

Data were obtained for years between 2002 and 2005 from 136 ambient air pollution-monitoring stations, and summary statistics were calculated to highlight current air quality challenges (see Tables 7.1–7.4). Preference was given to information from monitoring stations with the most current, comprehensive, and reliable data. Emphasis was also placed on stations expected to continue operation in the foreseeable future, to lay the groundwork for subsequent comparison. Stations were categorized to demonstrate typical air pollution concentrations within domestic fuel-burning, industrial, dense-traffic areas, as well as in the urban 'background'[1]. This chapter provides a snapshot of air quality in South Africa. For details, refer to the *Technical Compilation to Inform the State of Air Report* (DEAT, 2006a), reproduced in the Appendix.

These air pollution data highlighted the following air quality conditions requiring attention.

- *Elevated concentrations of PM_{10}* (particulate matter with an aerodynamic diameter of less than 10 micrometres) occurred across the country, with exceedances of maximum 24-h South African National Standard (SANS) air quality limits

1. A 'background' monitoring station is one that does not have any particular source of emissions in its vicinity, but that assesses general pollution in the area. The station in Delta Park, for example, monitors the City of Johannesburg's 'background' air pollution.



Table 7.1: Ambient air pollutant concentrations recorded at sites in residential household fuel-burning areas

Location	Data year	Pollutant	% Data availability	Highest hourly (µg/m³)	Highest daily (µg/m³)	Annual average (µg/m³)	Exceedances per year (hourly limit, as hours/year)	Exceedances per year (daily limit, as days/year)	Annual/ period average as ratio to annual limit
Johannesburg (Orange Farm) (primarily coal-burning; wood to a lesser extent)	2004/5	PM_{10}	73.6	1 016	400	67	NG	94	1.67
	2004/5	SO_2	70.3	530	107	18	9	0	0.35
Cape Town (Khayelitsha) (primarily wood and paraffin burning)	2003	PM_{10}	65.0	497	165	51	NG	137	1.28
	2003	SO_2	73.0	92	51	14	0	0	0.28

ABBREVIATIONS: NG, no guideline; PM_{10}, particulate matter with an aerodynamic diameter of less than 10 micrometres; SO_2, sulphur dioxide.
Sources: City of Cape Town, City of Johannesburg

Table 7.2: Air pollutant concentrations at sites affected by multiple source types

Location	Year	Pollutant	% Data availability	Highest hourly (µg/m³)	Highest daily (µg/m³)	Annual average (µg/m³)	Exceedances per year (hourly limit, as hours/year)	Exceedances per year (daily limit, as days/year)	Annual/ period average as ratio to annual limit
Johannesburg (Kempton Park)[a]	2002	PM_{10}	62	NC	333	41	NG	243	1.03
	2002	SO_2	67	903	66	12	5	0	0.24
	2002	NO_2	58	263	187	37	54	NG	0.93

ABBREVIATIONS: NA, not applicable; NC, no concentrations; ND, no data; NG, no guideline; NO_2, nitrogen dioxide; PM_{10}, particulate matter with an aerodynamic diameter of less than 10 micrometres; SO_2, sulphur dioxide.
[a] Site near heavy industry, busy traffic routes, domestic coal-burning, and international airport.
Source: Airkem

The contribution of vehicle emissions, particularly in urban areas, to ambient air pollution levels is increasing.
Photography: Janet Peace

and international best practice standards (European Commission [EC] limits) at many sites for which PM_{10} data were available. Annual limits were also exceeded at various stations.

- *SANS and EC daily PM_{10} thresholds* were exceeded at all 10 stations reported on in Tables 7.1–7.4, as is evident from the comparison of their highest daily PM_{10} concentrations, and the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004) threshold was exceeded at four of them[2]. At 6 of the 10 stations, the RSA SANS annual average limit of 40 ug/m^3 was exceeded. More comprehensive data, included in the Appendix (DEAT, 2006a), indicate that almost 44% (43/96) of annual averages obtained from the stations exceeded the SANS annual average limit, with almost 22% (21/96) exceeding the AQA threshold.

- *Significantly high concentrations of fine particulates in fuel-burning residential areas* were recorded, specifically coal- and wood-burning areas. Both daily (on 20–40% of days) and annual health limits were frequently exceeded.

- *Sulphur dioxide concentrations in domestic coal-burning areas* exceeded short-term (10-minute as well as hourly) air quality limits, but did so relatively infrequently, with annual averages comprising only 30% of the annual limit set for the protection of human health. Sulphur dioxide

Table 7.3: Air pollutant concentrations recorded at road-traffic-related monitoring sites

Location	Year	Pollutant	% Data availability	Highest hourly (µg/m³)	Highest daily (µg/m³)	Annual average (µg/m³)	Exceedances per year (hourly limit, as hours/ year)	Exceedances per year (daily limit, as days/year)	Annual/ period average as ratio to annual limit
eThekwini (City Hall)	2004	PM_{10}	78.8	NC	160	38	NG	21	0.95
	2004	SO_2	26.5	101	22	6	0	0	0.12
	2004	NO_2	78.6	196	NC	20	6	NG	0.50
	2004	Benzene		NC	NC	8	NG	NG	1.60
eThekwini (Warwick)	2004	NO_2	74.6	147	NC	24	3	NG	0.60
	2004	CO	69.0	18	7	2	0	0	NG
	2004	Benzene		NC	NC	9	NG	NG	1.80
Johannesburg (Buccleuch Interchange)	2004	PM_{10}[a]	57.0	268	134	75	NG	96[a]	1.88[a]
	2004	$PM_{2.5}$	57.0	187	97	55	NG	NG	NG
	2004	SO_2	54.0	171	40	16	0	0	0.32
	2004	NO_2	57.0	220	64	33	1	NG	0.83
	2004	CO	57.0	17	10	6	0	NG	NG
	2004	O_3	57.0	265	259	38	304	NG	NG
	2004	Benzene	19.0	14	8	2	NG	NG	0.40
	2004	Toluene	19.0	32	20	5	NG	NG	NG
	2004	Xylene	19.0	27	3	0.3	NG	NG	NG
Cape Town (City Hall)	2003	PM_{10}	99.0	365	76	23	NG	11	0.58
	2003	SO_2	97.0	163	62	16	0	0	0.32
	2003	NO_2	99.0	446	131	45	28	NG	1.13
	2003	CO	99.0	23 712	9 274	2 195	0	NG	NG

ABBREVIATIONS: CO, carbon monoxide; NA, not applicable; NC, no concentrations; ND, no data; NG, no guideline; NO_2, nitrogen dioxide; O_3, ozone; $PM_{2.5}$, particulate matter with an aerodynamic diameter of less than 2.5 micrometres; PM_{10}, particulate matter with an aerodynamic diameter of less than 10 micrometres; SO_2, sulphur dioxide.

[a] PM_{10} concentrations particularly elevated, owing to contributions from the coal-burning residential area of Alexandra.

Sources: eThekwini Municipality, City of Johannesburg, City of Cape Town

2. Daily average PM_{10} concentrations were not calculated for the more comprehensive list of stations considered in the Technical Compilation (DEAT, 2006a, reproduced in the Appendix), as such an exercise was outside the scope of this report. Given the indication of the potential that exists for exceedance of daily limits from the sub-set of stations included in the current report, it is recommended that daily average concentrations be considered in all future standard reports.

concentrations within wood-burning residential areas such as Khayelitsha were within permissible limits.

- *Air quality limit exceedances (PM_{10}, NO_2, and benzene concentrations) at road-traffic-related sites* were recorded. Exceedances of NO_2 air quality limits were limited to short-term averaging periods, but NO_2 levels along busy traffic routes in metropolitan areas have been increasing since the mid-1990s (Scorgie *et al.*, 2005). The SANS annual limit for benzene was exceeded at all traffic-related sites for which data were presented, with the exception of the Johannesburg Buccleuch station (where there were poor data availabilities [19%] for the dataset obtained from this station). Although PM_{10} concentrations recorded at traffic sites exceeded air quality limits, there are indications that only about 30% of the PM_{10} concentrations may be related to vehicle exhaust

Table 7.4: Ambient air pollutant concentrations recorded at industry-related monitoring stations

Location	Year	Pollutant	% Data availability	Highest 10-min (µg/m³)	Highest hourly (µg/m³)	Highest daily (µg/m³)	Annual average (µg/m³)	Exceedances per year (10-min limit)	Exceedances per year (hourly limit, as hours/year)	Exceedances per year (daily limit, as days/ year)	Annual/ period average as ratio to annual limit
eThekwini (Wentworth)	2004	PM_{10}	75.5		NC	143	39	NG	NG	27	0.98
	2004	SO_2	76.8	605	NC	61	16	58	NC	7	0.32
	2004	NO_2	79.9		108	NC	12.9	NG	3	NG	0.32
	2004	O_3	72.4		118	70	15	NG	3	2	NG
eThekwini (Settlers School)	2004	SO_2	75.8	685	NC	125	13	149	NC	7	0.26
	2004	Benzene			NC	NC	9	NG	NG	NG	1.80
Rustenburg (industrial)	2003	PM_{10}	50.0		499	158	57	NG	NG	18	1.43
	2003	SO_2	99.0	ND	3 214	785	205	NC	1 337[a]	219	4.10
Cape Town (Belville South)	2003	PM_{10}	58.0		362	97	33	NG	NG	27	0.83
	2003	SO_2	57.0	ND	278	71	19	NC	0	0	0.38
Tshwane (Rosslyn)	2003/2004	SO_2	22.0	ND	966	569	18	NC	10	1	0.36
	2003/2004	NO_2	26.0		223	78	31	NG	2	NG	0.78
	2003/2004	O_3	16.0		160	111	37	0	NG	NG	NG
Richards Bay (Arboretum)	2004	SO_2	84.0	752	262	70	12	2	NA	0	0.24
Richards Bay– (Arboretum Ext.)	2004	SO_2	95.0	2 511	1 150	120	7	18	NA	0	0.14
Sasolburg (residential)	2002/2003	SO_2	84.0	ND	937	404	44		113	10	0.88
Boiketlong (residential coal-burning area close to industry)	2002/2003	H_2S	48.0		351	142	17		1 959[a]	NG	NG
Sasolburg (industrial)	2002/2003	PM_{10}	52.0		870	520	63	NG	NG	198	1.58
	2002/2003	SO_2	90.0	ND	1 065	267	79	NC	161	38	1.58
	2002/2003	O_3	93.0		380	77	29	NG	3	NG	NG
	2002/2003	H_2S	89.0		370	140	18	NG	7 164[a]	NG	NG

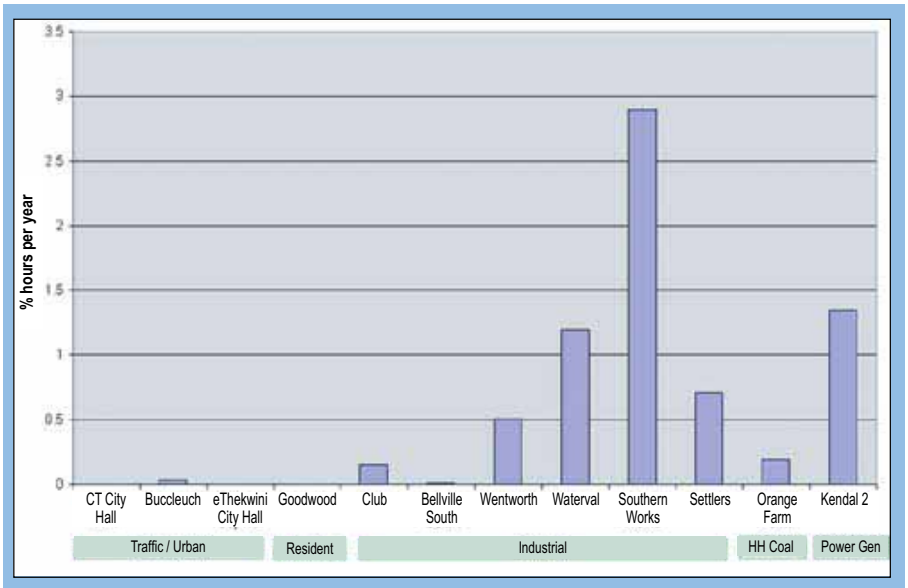
ABBREVIATIONS: H_2S, hydrogen sulphide; NA, not applicable; NC, no concentrations; ND, no data; NG, no guideline; NO_2, nitrogen dioxide; O_3, ozone; PM_{10}, particulate matter with an aerodynamic diameter of less than 10 micrometres; SO_2, sulphur dioxide.

[a] Number of odour threshold exceedances.

Sources: eThekwini Municipality, Richards Bay Clean Air Association, Tshwane Metropolitan Municipality, City of Johannesburg, City of Cape Town, Anglo Platinum, Sasol

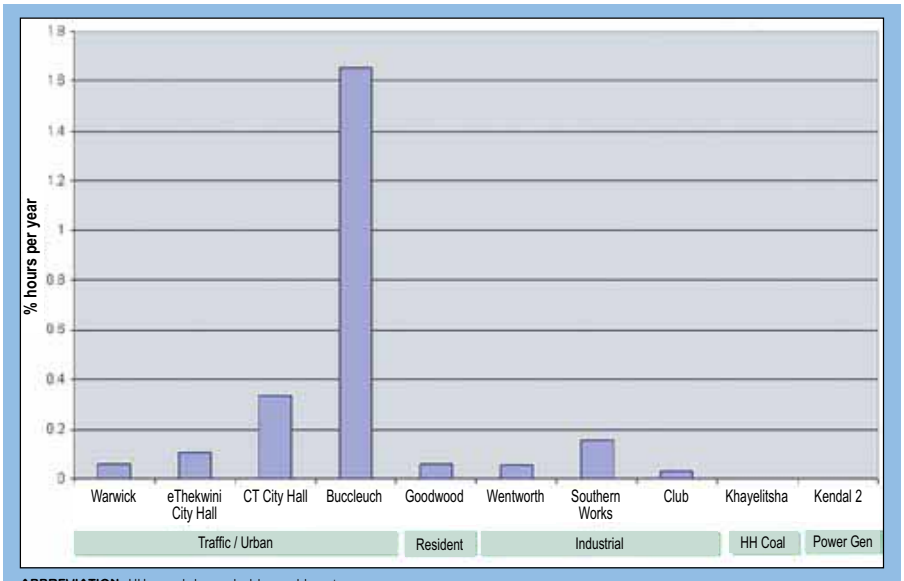


emissions, with the remainder arising from other sources such as domestic fuel-burning in nearby residential areas or construction activities and road works (Burger & Thomas, 2002).



ABBREVIATIONS: CT, Cape Town; HH coal, household coal-burning.

Figure 7.1: Frequency of exceedance (% hours per year) of the SO_2 limit of 350 µg/m³ at selected sites, 2004



ABBREVIATION: HH wood, household wood-burning.

Figure 7.2: Frequency of exceedance (% hours per year) of the NO_2 limit of 200 µg/m³ at selected sites, 2004

- Elevated industry-related PM_{10}, SO_2, NO_2, and benzene concentrations exceeding air quality limits have been recorded. Although data from various monitoring stations presented here reflected contributions from petrochemical, chemical, and mineral processing industries, other industries could similarly be adding to air quality limit exceedances – for example, those involved in pulp and paper, metallurgical, and textile manufacture, as well as ceramic processes (brick, cement, and refractory manufacture).

- Frequent exceedances of hydrogen sulphide (H_2S) odour thresholds were related to petrochemical operations and wastewater treatment works.

Exceedances of SO_2 and NO_2 limits for 2004 at stations characteristic of specific environments are illustrated in Figures 7.1 and 7.2; the percentage of high-pollution days for the same year, due to fine particulate concentrations and calculated using the UK's banding approach, is illustrated in Figure 7.3.

Typically, ambient SO_2 concentrations were relatively low at traffic sites and in residential areas where no fuel-burning takes place, provided no other sources played a part (see Figure 7.1). Although elevated SO_2 concentrations were recorded in household coal-burning areas (such as Orange Farm), air quality limit exceedances were relatively infrequent. Peak SO_2 concentrations were typically associated with particular industrial and power generation activities, and recorded, for example, in the vicinity of coal-fired power stations (such as Kendal 2 monitoring station), refineries (such as Southern Works monitoring station), and platinum smelting operations (for example, Waterval monitoring station). Located in an area frequently affected by Kendal Power Station emission plumes, Kendal 2 air quality monitoring station provides data that illustrate peak ground-level concentrations from coal-fired power generation. Many coal-fired power stations are located at more remote sites, however, and these have lower exposure potentials. Potential exposure of people to SO_2 is higher when large industrial emitters are situated close to residential areas (in Durban South, for example), where there is a greater need to reduce the frequency of air quality limit exceedances.



The highest NO_2 concentrations in the 2004 data occurred in areas affected by high traffic densities, including those adjacent to busy highways (such as Johannesburg's Buccleuch Interchange), within central business districts (CBDs) (such as eThekwini and Cape Town City Hall), and in residential areas with significant vehicle activity (see Figure 7.2). Elevated NO_2 concentrations also occurred in some industrial areas, and were primarily caused by activities related to fuel-burning.

High PM_{10} concentrations, characteristic of residential coal-burning areas, were recorded at the Diepsloot and Orange Farm monitoring stations (see Figure 7.3), and frequent pollution days occurred at Johannesburg's Buccleuch traffic station. Investigation of air pollution trends at this station indicated that elevated particulate concentrations occurred at night and in winter, mainly from household coal-burning in the Alexandra residential area nearby, and were channelled down the Jukskei valley to the Buccleuch Interchange. Other pollutants measured at this station, including nitrogen oxides (NO_x) and BTEX (the benzene, toluene, ethylbenzene, and xylene group of VOCs), peaked during daytime, with diurnal trends that followed traffic flow patterns (see §7.2.2 below).

Annual averages of benzene for 2004 for Durban are given in Figure 7.4 (eThekwini Health Department, 2004). According to the eThekwini 2004 Annual Report, the highest annual benzene concentration of 8.1 $\mu g/m^3$ was measured at Settlers, exceeding the SANS air quality limits of 5 $\mu g/m^3$. This station is affected by pollution from refineries. Warwick, a station affected by traffic pollution, was second highest with an annual average of 7 $\mu g/m^3$. These annual averages are comparable to values measured in similar conditions in Gauteng and the Free State.

7.2 DIURNAL AND SEASONAL TRENDS CHARACTERISTIC OF DIFFERENT SOURCE TYPES

Air pollution concentrations from certain source types follow distinct diurnal and seasonal trends, which are a function of meteorological variations and activity at the source. These variations have significant implications for people's potential exposure to pollutants.

7.2.1 Household fuel-burning

To derive diurnal trends in emissions from domestic coal-burning, reference was made to aerosol black carbon (BC) concentrations measured during a monitoring study conducted in Soweto (Annegarn & Grant, 1999) (see Figure 7.5 on next page). Time-series analysis of aerosol BC concentrations, used as a tracer of domestic coal-burning emissions,

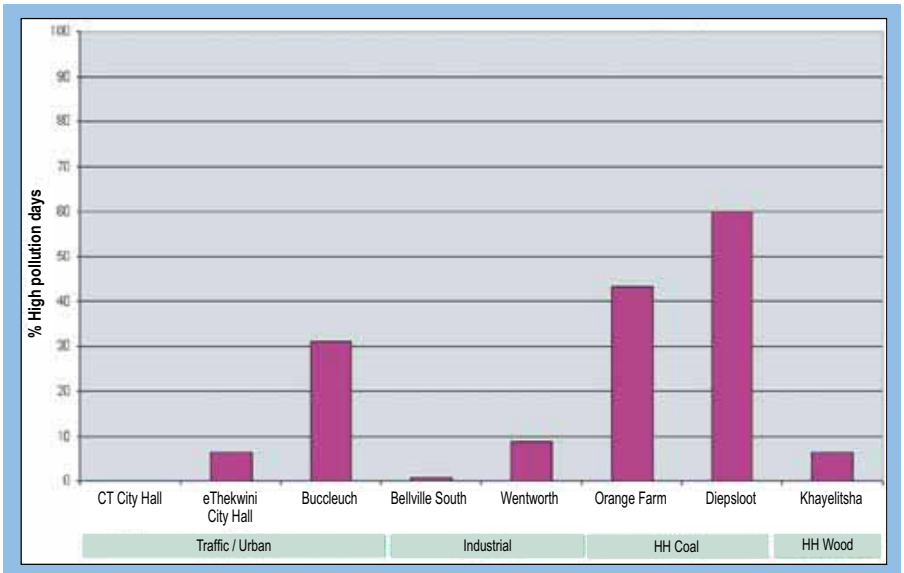


Figure 7.3: Frequency of occurrence of high pollution days due to fine inhalable particulate concentrations of PM_{10} at selected sites, 2004

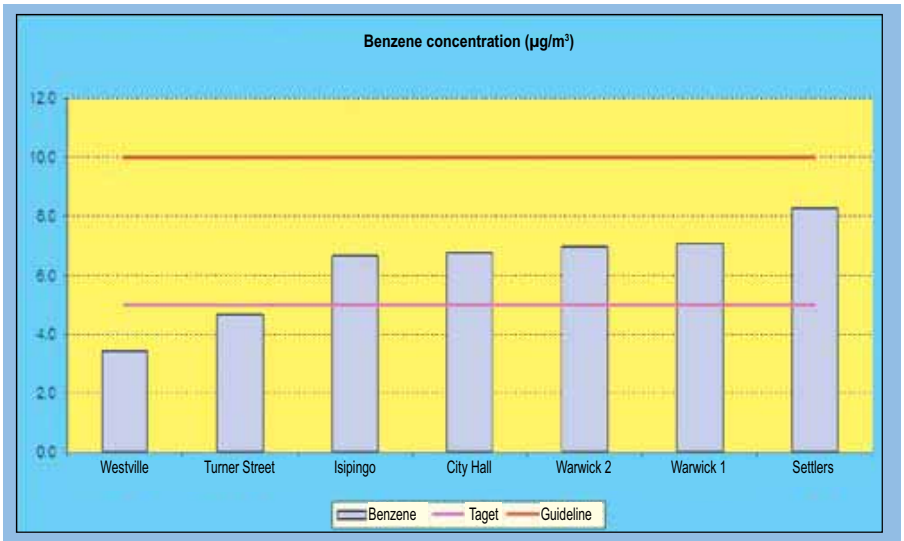


Figure 7.4: Benzene concentrations in Durban, 2004
Source: eThekwini Annual Report, 2004

revealed maximum concentrations in the mornings and evenings, and very low concentrations in the afternoons. Average BC concentrations were observed as low (2–3 $\mu g/m^3$) between 12h00 and 16h00. A sharp increase commenced at 17h00, with concentrations peaking typically in the range 30–50 $\mu g/m^3$ by 18h00. A secondary, smaller peak was observed at about 21h00 or 22h00, representing the impact of a final evening addition of coal to the stoves. After that, concentrations decreased gradually until about 06h00, and then increased again to reach a maximum of some 20–30 $\mu g/m^3$ at about 08h00.

The evening peak came from the lighting of night-time fires for cooking and space heating. The slow fall in concentrations was due to fires left to smoulder, and to the stability of the atmosphere that created a tendency for pollution to accumulate close to the source. The morning peak came from the lighting of household fires for cooking, and the rapid reduction in atmospheric BC after the morning peak occurred because morning fires were extinguished more quickly than at night, and because a rapid atmospheric clearing rate follows the dissipation of the nocturnal inversion about two hours after sunrise and the onset of convective mixing. Air pollution related to residential fuel-burning peaks during winter months was due mainly to increased burning of fuel for heating space, and to increased accumulation of air pollution due to more intense surface-based inversions and stable atmospheric conditions (see Figure 7.6).

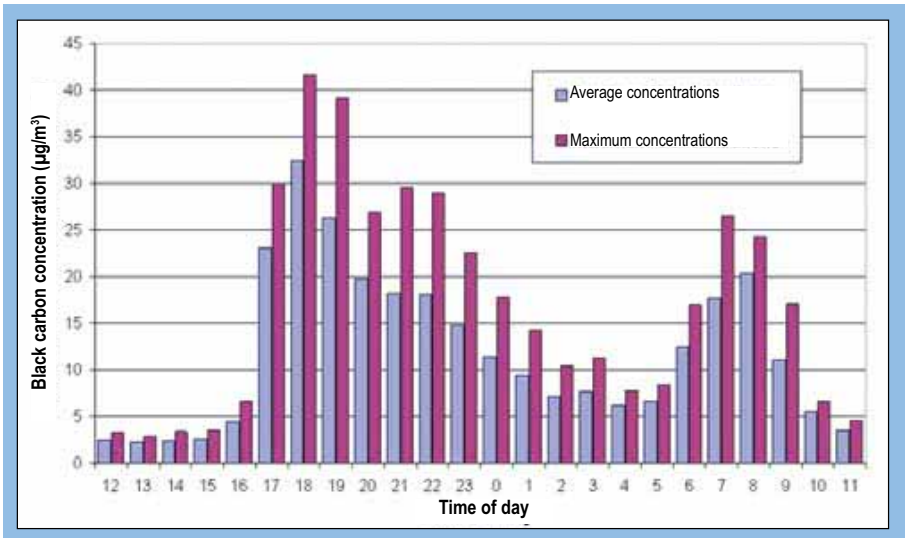


Figure 7.5: Diurnal variations in mean $PM_{2.5}$ black carbon concentrations, as observed in Soweto 1–20 June 1997 (Annegarn & Grant, 1999)

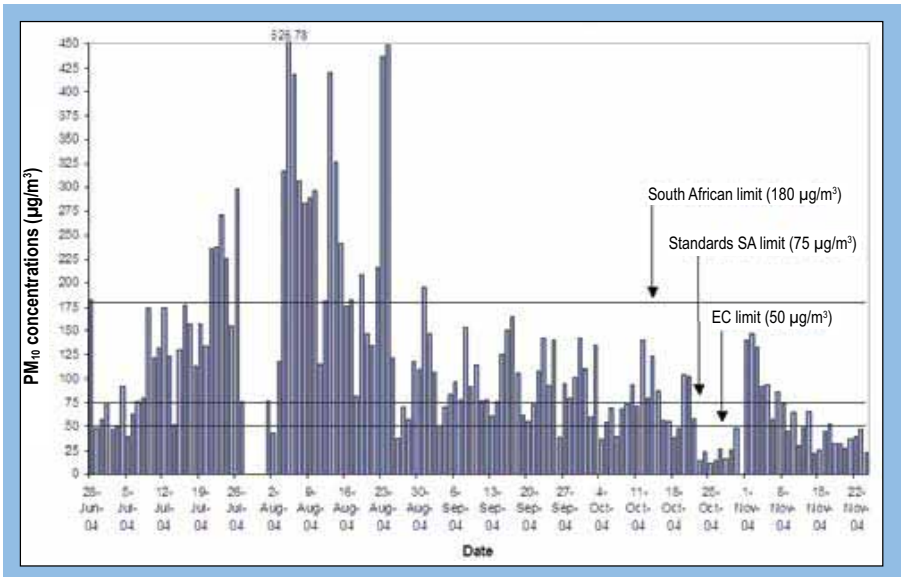
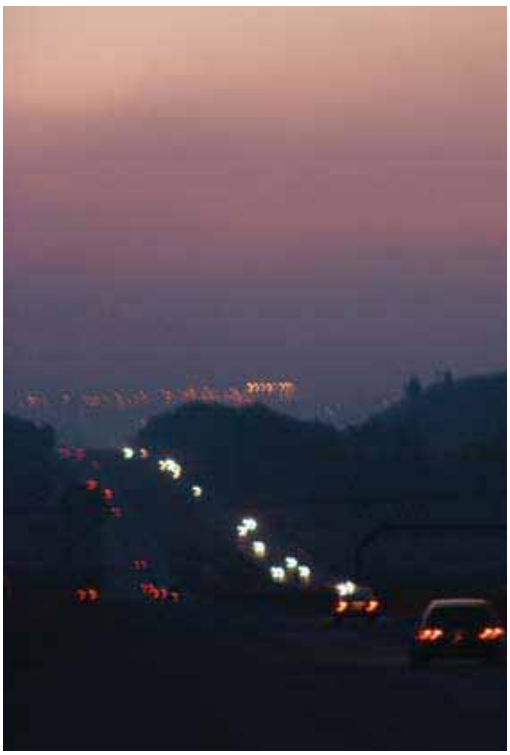


Figure 7.6: Daily average PM_{10} concentrations recorded by the City of Johannesburg at the Oliver Tambo Clinic, Diepsloot, 28 June–24 November 2004



Topography and meteorology play a key role in the dispersion of atmospheric emissions.

Photography: Hot Tomato Communications

7.2.2 Vehicle traffic

Diurnal trends in air pollutant concentrations at sites of high traffic activity are evident from eThekwini's Warwick monitoring station. Figure 7.7 illustrates such trends in hourly-average nitric oxide (NO), emitted as a primary pollutant, and NO_2, which predominantly occurs as a secondary pollutant formed through chemical conversion of NO in the atmosphere. The evidence reveals sharp, distinctive morning peaks and lower diffuse evening peaks typical of rush-hour patterns.

Seasonal trends have not typically been recorded in vehicle-emission-related air pollutant concentrations, apart from marginally higher or lower concentrations during the holiday months, depending on the location of the monitoring station.

7.2.3 Elevated stack emissions

Peak ground-level concentrations of air pollution that result from elevated stack releases typically occur during the late morning, as the dissipation of the nocturnal surface-based inversion and the onset of convective mixing bring the plume 'to ground' at this time. The exact time of day and location of ground-level maxima are a function of the height of the stack and the prevailing meteorology. By way of illustration, Figure 7.8 shows diurnal trends in ground-level ambient SO_2 concentrations recorded by Anglo Platinum at its Hex Complex monitoring station, located in relative proximity to the company's Waterval Smelter operation in Rustenburg.

Stack emissions from a large industrial plant.

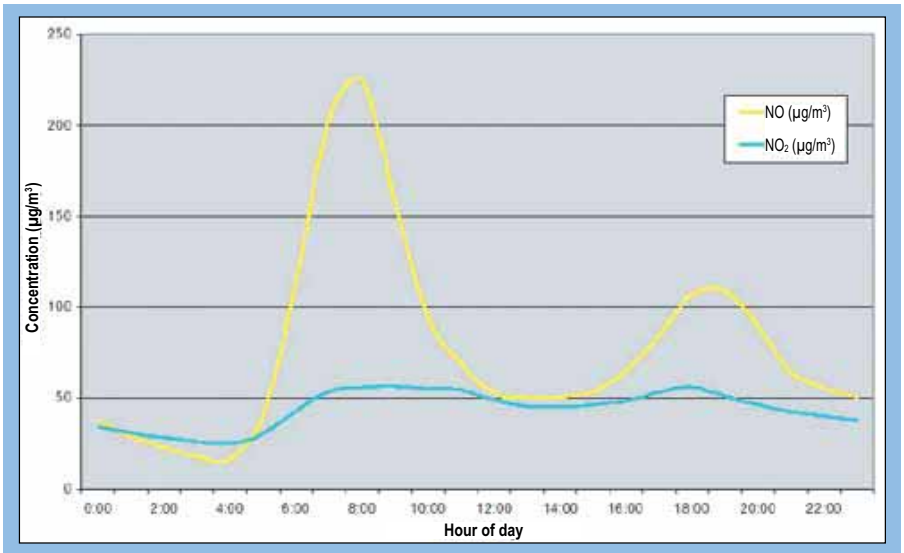


Figure 7.7: Diurnal variations in hourly average NO_x and NO_2 concentrations recorded by eThekwini Metropolitan Municipality at its Warwick Station, 2004
Source: eThekwini Health Department, 2004

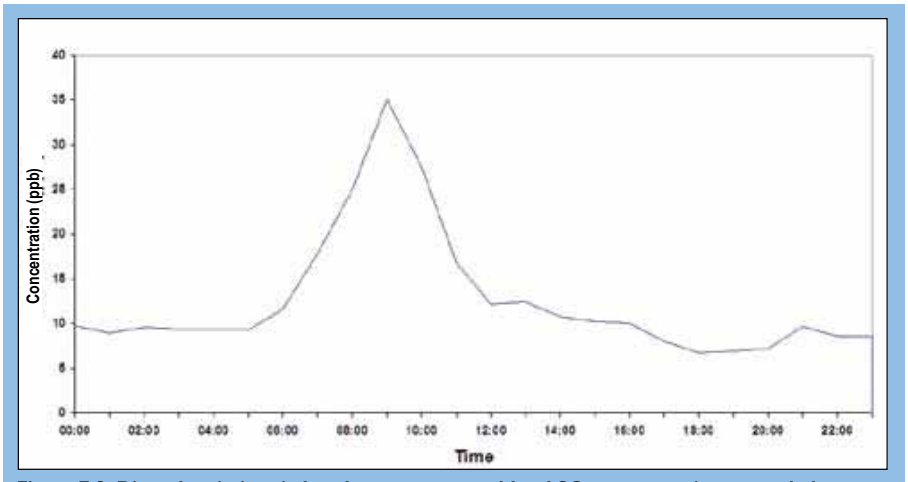


Figure 7.8: Diurnal variations in hourly average ground-level SO_2 concentrations recorded at Anglo Platinum's Hex Complex monitoring station

7.3 CENTRAL WITWATERSRAND DUSTFALL TRENDS

Wind-blown dust from mine tailings impoundments has historically been a source of concern. Trends in dust deposition for the Central Witwatersrand are illustrated through reference to dustfall sampling information.

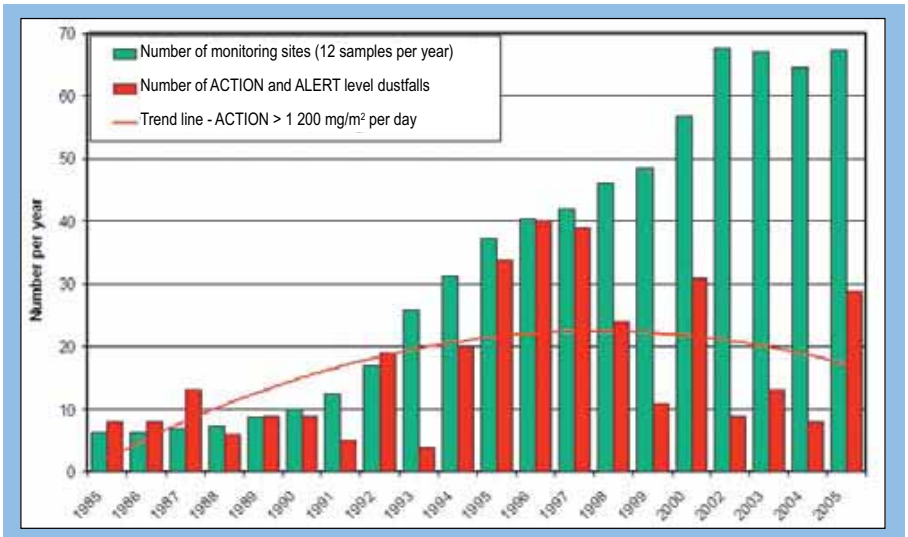


Figure 7.9: Number of installed dustfall monitoring sites on the Central Witwatersrand and total number of monthly dustfall values in the 'action' and 'alert' bands

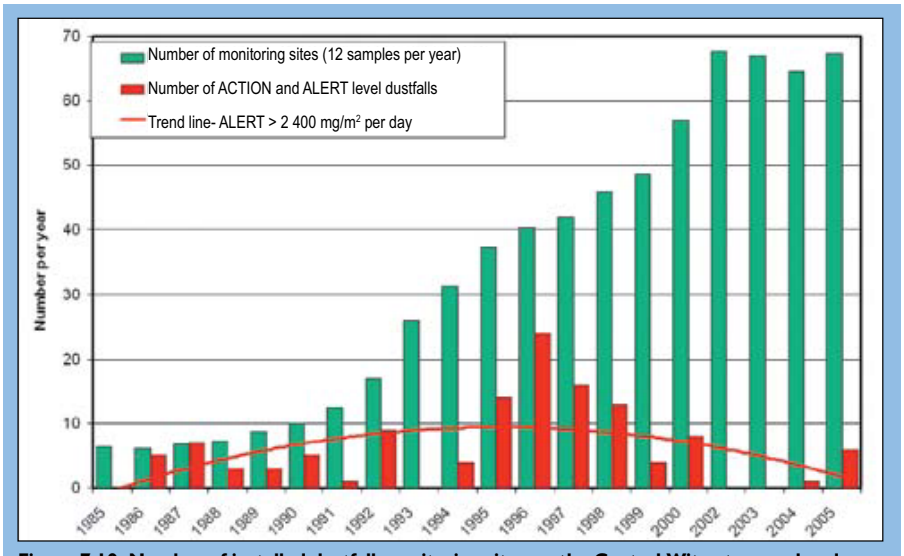


Figure 7.10: Number of installed dustfall monitoring sites on the Central Witwatersrand and total number of monthly dustfall values in the 'alert' bands

In 1985, dustfall monitoring using the ASTM (American Society for Testing and Materials) open bucket dust deposition method commenced, with six monitoring sites. By the end of 2006, this monitoring network had expanded to about 65 sites as the number of gold-mine reclamation sites increased. Dustfall values were evaluated historically on the Department of Environmental Affairs and Tourism (DEAT) dustfall categories: 'Slight' (<300 mg/m² per day); 'moderate' (300–500 mg/m² per day); 'heavy' (500–1 200 mg/m² per day) and 'very heavy' (>1 200 mg/m² per day). Dustfalls are evaluated in four bands, in terms of the Standards South Africa air quality limits (SANS 1929:2005), which specify permissible frequencies of exceedances and action that needs to be taken. The bands are: 'residential' (<600 mg/m² per day); 'industrial' (600–1 200 mg/m² per day); 'action' (1 200–2 400 mg/m² per day); and 'alert' (>2 400 mg/m² per day) (see §3.1.7).

Figure 7.9 shows the number of installed monitoring sites on the Central Witwatersrand, and the total number of monthly dustfall values in the 'action' and 'alert' bands during the period 1985–2005. The

Fugitive emissions from an open-pit coal mining operation.

number of dustfall incidents in these two bands peaked in the years 1994–1998 and fell significantly thereafter, owing to an intensification of dust mitigation activities. (This graph does not indicate conditions on the West Witwatersrand and Boksburg, where dust mitigation measures and monitoring were not carried out with equivalent intensity.)

Figure 7.10 indicates the number of monitoring sites and the number of monthly dustfall values in the 'alert' band on the Central Witwatersrand. The 'alert' levels during the period 1996–1998 were recorded at two well documented sites, where satisfactory dust control procedures had not been implemented. Both occurrences resulted in legal actions. Following mitigation, 'alert' level dust emissions did not recur.

The percentage of 'action' and 'alert' dustfall incidents as a fraction of the total number of installed dust monitoring sites is given in Figure 7.11. Since most of the monitoring sites are located in the vicinity of active mining sites, the relative reduction of high dustfall incidents, indicated by the trend lines, indicates the progress in managing and reducing dust impacts associated with surface mining on the Central Witwatersrand.

Dustfall on the Witwatersrand is strongly affected by influences of weather on exposed surfaces of gold-mine sand dumps and dried-out slime dams. Higher wind speeds during spring and summer have the potential to generate dust. Frequent rains from November until March keep the surfaces moist and

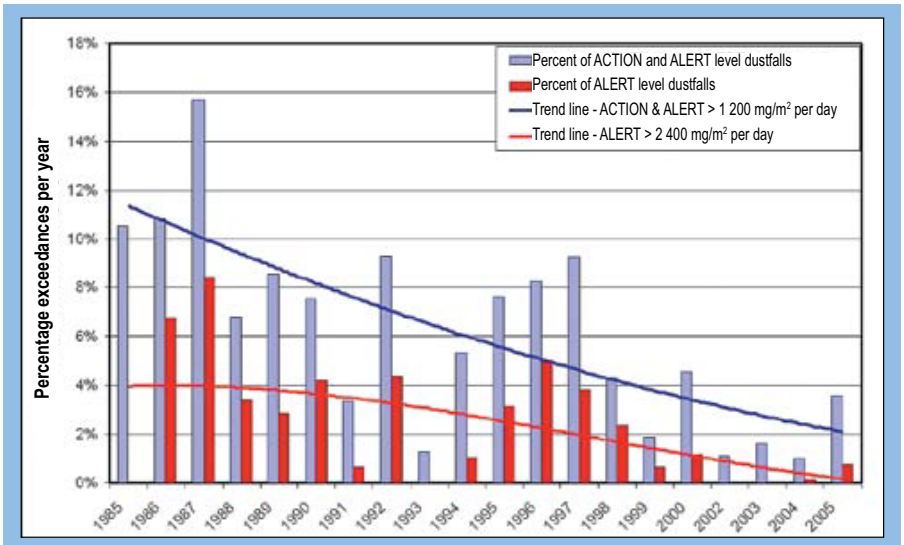


Figure 7.11: Percentage of 'action' and 'alert' dustfall incidents as a fraction of the total number of installed dust monitoring sites

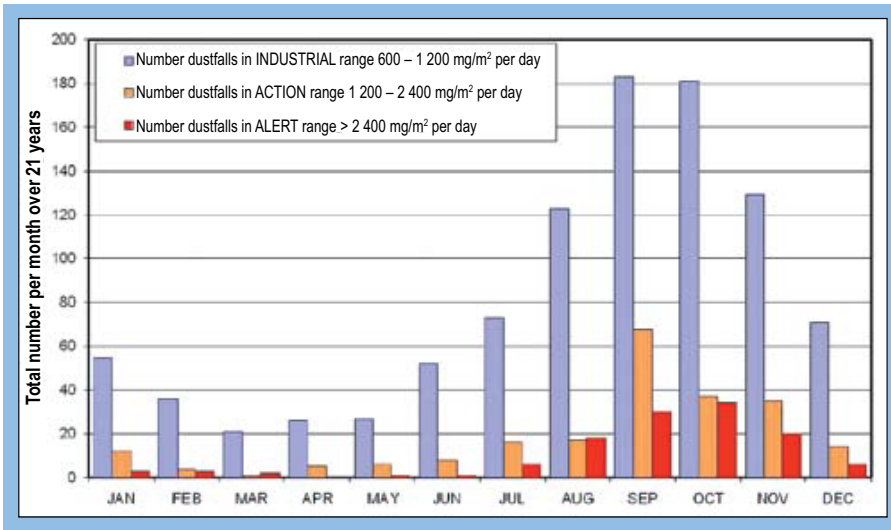


Figure 7.12: Number of dustfall measurements recorded on the Central Witwatersrand during the period 1985–2005 that are in 'industrial', 'action' and 'alert' ranges



limit dust generation. During drier autumn and winter months (from April until mid-July), winds are calm and rarely disturb dried-out surfaces. In early spring (mid-July until mid-October), higher wind speeds act on dry surfaces, creating the greatest amount of dust, as is evident from the fact that the maximum number of dustfall incidents are recorded in these months (see Figure 7.12 on previous page).

7.4 NON-CRITERIA POLLUTANTS AND MONITORING PROGRAMMES

Human-induced emissions are responsible in certain areas for elevated concentrations of VOCs and heavy metals. Typical sources of such pollutants include vehicle traffic, household fuel-burning, waste disposal activities, and certain industrial operations. Many pollutants are not typically monitored on a continuous basis, but several monitoring programmes have been undertaken to determine concentrations within specific environments.

7.4.1 VOC concentrations in the City of Johannesburg

Volatile organic compound concentrations were recorded for a range of sites throughout the Johannesburg metropolitan area during a six-week programme undertaken in 1998. Elevated concentrations were found in industrial areas (Industria and Selby), in the CBD, and in Soweto. From their study of these concentrations, John *et al*. (1998) concluded that industry and vehicle exhausts were the main sources at most sites. This was not established quantitatively but on the basis of qualitative assessment of sources located close to sites as well as records of maximum concentrations. Furthermore, although none of the individual compounds detected were suspected to pose a health risk at the concentrations observed, the potential for synergistic effects and minor health irritations was taken into consideration.

Further VOC monitoring was undertaken by the Council for Scientific and Industrial Research (CSIR) and the Swedish Environmental Research Institute (IVL) as part of the passive diffusive sampling programme conducted in July 1999 at the request of the City of Johannesburg. Sampling was carried out indoors and outdoors in Soweto, and indoor VOC concentrations varied substantially depending on the households' fuel-burning practices, with indoor pollutant concentrations being generally higher than outdoor levels. The benzene concentrations measured exceeded 5 $\mu g/m^3$. On the basis of this study, it was strongly recommended that the elevated indoor VOC concentrations be further investigated, given their potential health risks.

7.4.2 VOC and SVOC concentrations in household fuel-burning areas

Target VOCs and semi-volatile organic compounds (SVOCs) were measured at hourly intervals both indoors and outdoors within Qalabotjha, a coal-burning residential area situated in the Free State, during a large-scale low-smoke fuel experiment conducted by the Department of Minerals and Energy (DME) in 1997. Measurements

The cumulative impact of emissions from a number of sources result in hazy conditions over the City of Johannesburg.

Photography: Janet Peace



were undertaken both during normal coal-burning practices and during periods of experimental low-smoke fuel-burning. The Atomic Energy Corporation (AEC) was responsible for ambient measurements (Sowden, 1998), and Mintek for the indoor monitoring (Taljaard, 1998). In addition, VOC and SVOC concentrations were simulated, based on AEC emission factors and meteorological data recorded during the Qalabotjha macro-scale experiment (Britton, 1998; Scorgie *et al.*, 2001).

Based on the predicted and measured VOC and SVOC concentrations, the cancer risk due to normal coal-burning in braziers and stoves was calculated to be 1:10 000 for the haematopoietic, hepatic, and pulmonary systems, and therefore considered "potentially unacceptable" (Scorgie *et al.*, 2001). The measured volatile and semi-volatile organic compounds were found to result in relatively low systemic health risks, with more emphasis placed on exposures to fine particulates for such risks (van Niekerk, 1998).

7.4.3 VOC concentrations in the Sasolburg region

The concentrations of about 40 VOC species have been measured in the Sasolburg region. Sasol initiated the monitoring, with chemical analysis at the School of Chemistry of the North-West University (formerly the University of Potchefstroom for CHE)[3], and the results were based on data from eight sampling sites, including industrial, commercial, and residential sites within Sasolburg, collected between November 2001 and July 2002.

Residents burn coal or wood in and around their homes for cooking purposes and as a means of social interaction.

Photography: Hot Tomato Communications

In many instances, industrial operations continue through the night contributing to elevated night time concentrations of pollution due to stable meteorological conditions.

Photography: GDACE

Organic solvents that were flagged as exceeding health-effect screening levels at one or more sites were as follows (Scorgie, 2004): carbon tetrachloride (at AJ Jacobs); benzene (at all the monitoring sites); chloroform (at AJ Jacobs, Boiketlong, Vaal Park, and Sasol Industrial Station); and 1,2,4-trimethylbenzene (at West Gate).

Carbon tetrachloride concentrations measured at the AJ Jacobs site exceeded the World Health Organization (WHO) tolerance concentration and Integrated Risk Information System (IRIS) sub-chronic inhalation reference concentrations for this compound (see §3.2). Chloroform concentrations exceeded long- and short-term effect screening levels, indicating health-risk potential and the need for a more comprehensive health-risk assessment. Whether or not people's health is affected depends on what (if any) exposure to the pollutant occurs at the time and place of the exceedance.

The air quality limit for benzene published by Standards South Africa (SANS 1929:2005) is 5 $\mu g/m^3$ for an annual averaging period (see Chapter 3). This

3. All the data were collected by canisters, with 8-hour flow controllers (producing an 8-hour concentration), and analyzed chemically according to accredited US-EPA method TO-14A.

Indoor air pollution concentration levels in the workplace are regulated by the Occupational Health and Safety Act (Act no. 85 of 1993).

is in line with the European Commission (EC) limit value for benzene, also given as 5 $\mu g/m^3$, to be met by 1 January 2010[4]. The benzene concentrations recorded in the Sasolburg region made it clear that benzene emissions would need to be addressed to meet air quality limits at the AJ Jacobs, Boiketlong, and Vaal Park sites. Benzene is a human carcinogen, and cancer risks were estimated by conservatively assuming 24-hour exposures, over a 70-year lifetime, to the period-average concentrations recorded at the various ambient sites. Based on the concentrations recorded at Boiketlong, cancer risks were estimated to be greater than 1:10 000, which is cause for concern.

High levels of benzene concentrations identified by Sasol at the Boiketlong Community Hall monitoring site were reported to the Sasolburg Community, and discussed during the Air Quality Monitoring Feedback brief issued in March 2002 as well as in an Environmental Brief released in August 2002. These briefs indicated that possible contributors to these elevated benzene levels included industrial pollution, traffic, petrol retailers, and residential fuel use such as the burning of rubber, coal, and plastic bags. Sasol began investigating the contribution of these sources, and undertook a programme to measure benzene emissions from Sasol operations. The introduction of natural petroleum gas by Sasol was expected to bring reductions in benzene emissions in the region. Monitoring will validate or disprove this expectation.

7.4.4 Roadside concentrations of criteria and non-criteria pollutants

A monitoring programme was conducted in Gauteng in 2002 by Environmental Management Services (EMS) on behalf of Sasol Oil to establish typical air concentrations of pollutants from vehicle emissions, and to determine concentrations in areas where high concentrations and continual exposures were expected. This exercise specifically targeted high-throughput filling stations on major highways and roads; high throughput filling stations in residential areas; filling stations next to busy roads; and toll plazas. Pollutants included in the investigation were criteria pollutants (SO_2, NO_X, PM, O_3, CO), various metals (lead, manganese, aluminium, silicon, iron, copper, zinc), and organic emissions (methane, non-methane hydrocarbons, and various aromatics including benzene, toluene, ethylbenzene, xylene, styrene, and 1,2,4-trimethylbenzene) (Burger & Thomas, 2002).

The monitoring programme identified three pollutants as potentially significant: inhalable particulate matter (PM_{10}) and its constituents, oxides of nitrogen, and benzene. The relative contribution of vehicle exhaust emissions to measured PM_{10} concentrations across all monitoring sites was estimated to be in the order of 20%, with the remainder coming from industrial activities, soil (wind entrainment), and coal-burning. It was noted that particulates emitted from diesel engines were likely to include a higher proportion of fine and ultrafine particulates than those fuelled by petrol and to contain a variety of toxicologically active organic compounds (Burger & Thomas, 2002).

Nitrogen oxides were clearly shown to be a function of vehicle traffic volumes. The WHO NO_2 guidelines were exceeded only at some of the monitoring stations. Although other sources, such as household fuel-burning and industry, were identified as potential contributors to the NO_X concentrations at certain sites, vehicles were nevertheless seen as the main cause for high peak concentration values (Burger & Thomas, 2002).

4. The margin of tolerance for the EC limit of 5 $\mu g/m^3$ was based on an initial historical threshold of 10 $\mu g/m^3$. This margin was reduced by 1 $\mu g/m^3$ on 1 January 2006, and the level of reduction was to continue by a further 1 $\mu g/m^3$ every 12 months thereafter, to ensure that the value of 5 $\mu g/m^3$ would be reached by 2010.

The daily average benzene levels were considered to be fairly high at some of the Johannesburg monitoring stations (for example, in Sandton and along the Ben Schoeman Highway), and fell into the upper range of levels normally observed in urban areas in the USA. Based on typical vehicle traffic flow, it was estimated that the peak hourly traffic exposures along the Ben Schoeman Highway could be as high as 80–180 ppb. Using the observed concentration levels and assuming two hours of exposure at peak traffic periods per day, it was estimated that a person travelling along the Ben Schoeman Highway for 250 days of the year (that is, five days a week for 50 weeks of the year) could be exposed to an annual average level of 0.6 ppb (1.8 $\mu g/m^3$) and a maximum of 1.3 ppb (3.9 $\mu g/m^3$). Using the WHO unit cancer risk factors of between 1:4 400 000 and 1:7 500 000 (that is, between 4.4×10^{-6} $(\mu g/m^3)^{-1}$ and 7.5×10^{-6} $(\mu g/m^3)^{-1}$), the incremental cancer risk was estimated to be between about 8 and 29 chances per million. Although this may not be regarded as a serious health risk, it nevertheless merits further investigation (Burger & Thomas, 2002).

7.5 REGIONS KNOWN TO BE CHARACTERIZED BY POOR AIR QUALITY

Elevated air pollution concentrations have been noted in various regions of South Africa. The inventory of such sites is limited to the ambient air quality monitoring information available. Most data are for areas within the large metropolitan municipalities, supplemented by monitoring conducted on the highveld by industries such as Eskom and Sasol. Regions of recorded air pollutant concentrations in excess of health thresholds are illustrated in Figure 7.13, with indications of the relevant pollutants. (The areas and pollutants shown are not exhaustive; they merely offer an overview of the nature and extent of the air quality challenges being faced, as revealed by the information to hand.)

Flaring, to burn off excess gas, is common practice in the industrial sector.

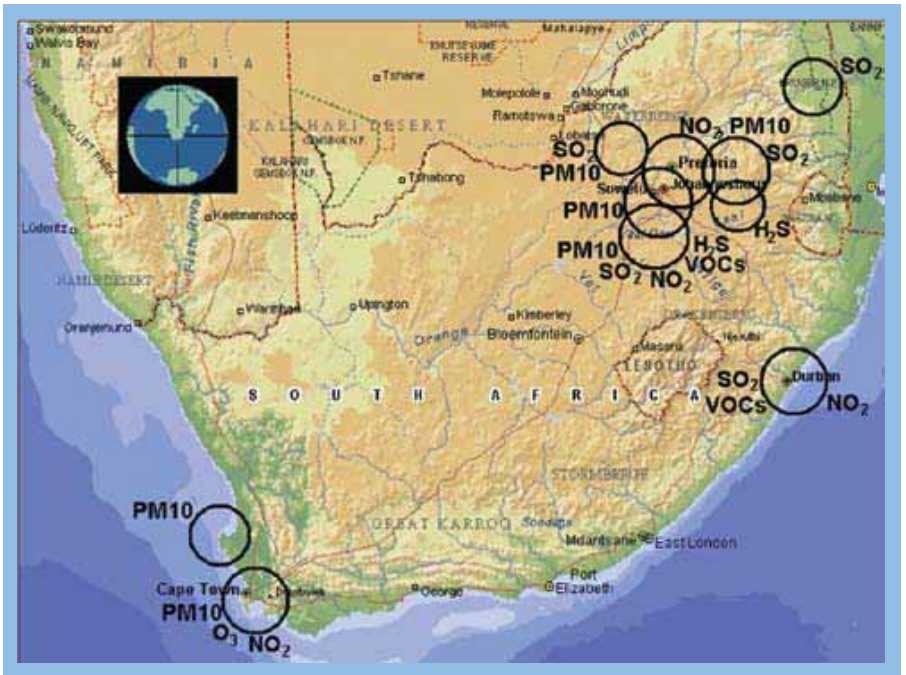


Figure 7.13: Some of the regions where elevated air pollutant concentrations exceeding health thresholds have been recorded

Chapter 8

Regional and global air pollution challenges

At a glance

Several air pollution challenges face South Africa on a global and regional scale. The global issues include climate change, driven by increased concentrations of greenhouse gases (GHGs), and controlled by the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol; stratospheric ozone depletion driven by the use of chlorofluorocarbons and controlled by the Montreal Protocol; and persistent organic pollutants (POPs), which are carbon-containing chemical compounds that resist photochemical, biological, and chemical degradation. The Stockholm Convention requires the control of the twelve POPs identified by the United Nations Environmental Programme. On a regional scale, industrial emissions and veld fires have the greatest potential for inducing environmental and climatic change. Air pollutants carried in air masses that are either recirculated over the highveld or imported from neighbouring regions have been found to contribute significantly to local atmospheric concentrations of fine particulates.



8.1 CLIMATE CHANGE

Greenhouse gases (GHGs) are transparent to short-wavelength radiation from the Sun (in other words, they allow short-wavelength radiation from the Sun to pass through them), but they absorb and reflect the long-wavelength radiation (heat) emitted from the Earth, thereby warming the planet's atmosphere. Water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs) are examples of GHGs – considered to be contributors to climate change, which includes gradual increases in ambient temperature and more frequent extreme climate-related events such as droughts and floods (see Figure 8.1).

Climate change is an international concern, and has led to the UNFCCC as well as the associated Kyoto Protocol, which schedules GHG reductions for 'developed' countries.

South Africa's per capita GHG emissions are estimated to be above the global average, being higher than that of most developing nations, and equivalent to certain developed nations. The country's emissions expressed in 'per capita' and 'per GDP' terms are almost 20 times higher than the value for the USA (Bond, 2007).

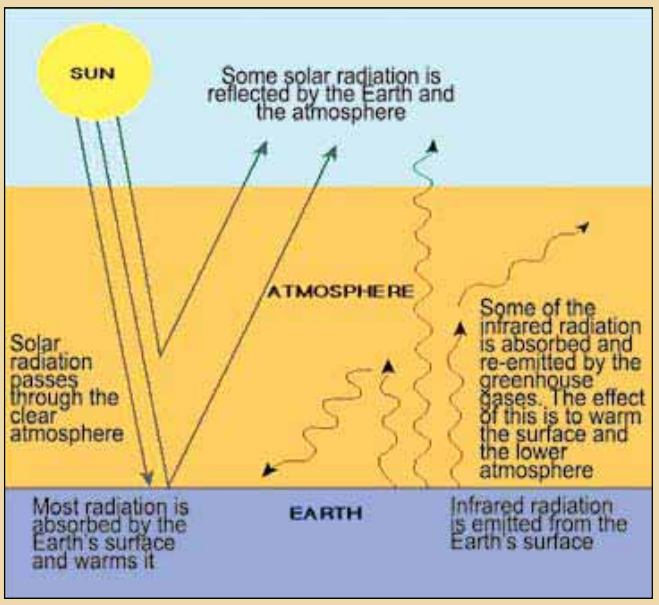


Figure 8.1: The greenhouse effect
Source: DEAT, 2006d

Given the importance of South Africa's commercial agricultural sector and the location of human settlements close to rivers and beaches, there is concern about the consequent vulnerability of people and infrastructure to climate change and abnormal climatic events. The country has signed and ratified the UNFCCC but, having been classified as a 'developing' country in terms of the convention, is not required to reduce its GHG emissions. Its responsibilities are largely confined to reporting its GHG emissions on a sectoral basis, and formulating adaptation strategies.

South Africa's climate is highly variable, both temporally and spatially. Global warming is expected to exacerbate this variability, increasing the frequency and intensity of droughts and floods. Projected climate changes in South Africa, based on integrated findings from simulations that used a range of climate models, are summarized as follows (Scholes & Biggs, 2004; personal communication, B. Hewitson, University of Cape Town, 26 May 2005).

- Most climate models indicate a net drying on the western two-thirds of the sub-continent, south of about 10°S.
- East-coast regions, where topography plays a significant role in rainfall formation, are likely to become wetter, although it is not certain how far this wetting might extend into the interior.
- The Western Cape is thought to be facing a shorter rainfall season, with the eastern interior portions of the province likely to have an increased late summer rainfall.
- Ambient air temperature is predicted to rise across the country, with the interior experiencing the greatest increases. Maximum warming for the interior is likely to be in the range of 3–4 °C above current levels.

The potential impact of climate change on the health of South Africa's population has not been modelled, as has been done in other countries such as the USA. Possible indirect consequences on people's health in South Africa have been identified as including (Terblanche, 1994):



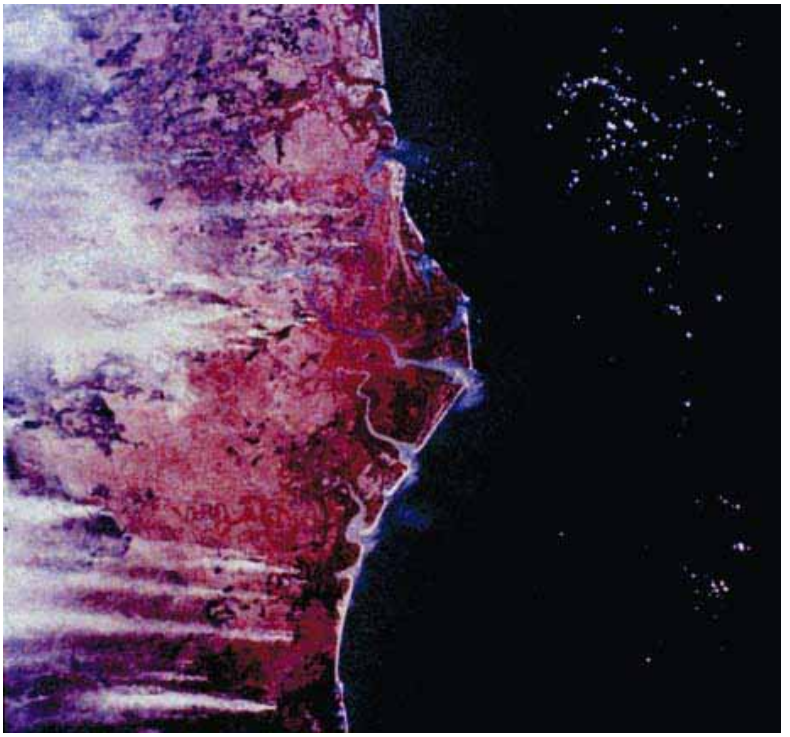
- Rising mortality, adverse effects on infant growth and development, and more infectious diseases and respiratory disorders arising from higher surface temperatures - the likely occurrence of epidemic infectious diseases is linked to changes in the distribution of disease vectors, as well as to reduced cellular immunity in humans as a result of exposure to elevated ultraviolet (UV) radiation levels, which is also expected to bring about increased incidence of skin cancer and eye diseases[1]

- Increases in ambient air pollution - higher ambient temperatures are likely to result in rising ozone levels in the lower atmosphere, with longer-lasting peaks predicted to occur in urban areas early in the day.

Indirect effects on human welfare due to global climate change are related to the potential impacts on biodiversity, ecosystems, and the availability of arable land and water for irrigation. The potential for crowding, malnutrition and starvation, allergic diseases, and suffering due to weather extremes has been noted (Terblanche, 1994). Further potential impacts of climate change and some estimates of potential damage have been described in a number of documents (for the most recent summary, consult the Department of Science and Technology's climate change strategy discussion document [DST, 2006]).

Drivers of climate change need to be closely monitored, particularly levels of CO_2, which, as measured at Cape Point, increased almost linearly by about 20 ppm between 1993 and 2004 (see Figure 8.2).

More detailed information on climate change, associated international agreements and protocols, and South Africa's response to climate change are documented in the Department of Environmental Affairs and Tourism's general publication series, specifically Publication Series 4: Book 6, *Climate Change and International Agreements* (DEAT, 2006d).



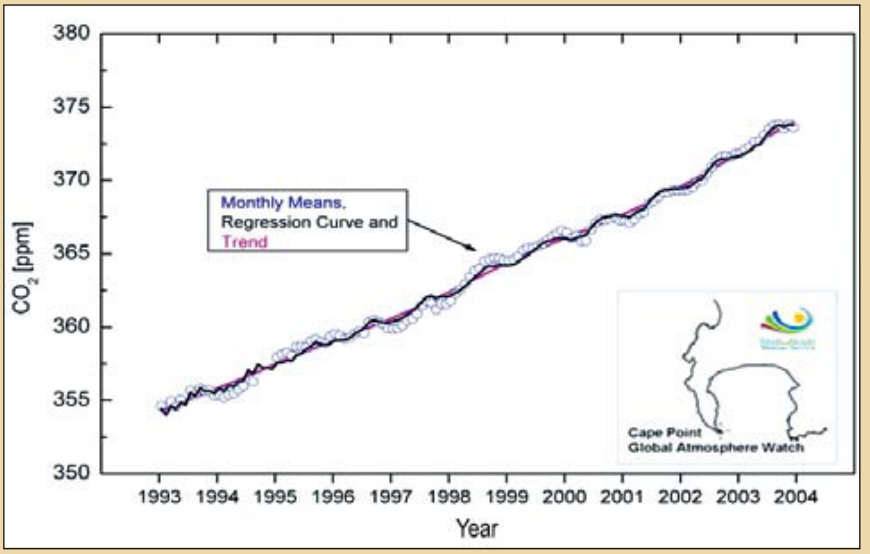


Figure 8.2: Trend in atmospheric concentrations of CO_2 as measured at Cape Point (1993–2003)
Source: Ernst Brunke, Cape Point Global Atmosphere Watch station, South African Weather Service

1. Although the Sun is a strong emitter of UV radiation, the wavelengths most harmful to people (those below 290 nanometres) are normally absorbed by the ozone layer of the atmosphere. The three classifications of UV radiation are: UV-A (the longest-wavelength range; not harmful in normal doses); UV-B (excessive exposure can cause severe blistering); UV-C (the shortest-wavelength range). Short-wavelength UV radiation is thought to cause skin cancer, and the risk of people contracting it has been increased by the depletion of the ozone layer.

8.2 STRATOSPHERIC OZONE DEPLETION

The depletion of stratospheric ozone is believed to result in increased levels of harmful UV-B radiation reaching ground level. Although stratospheric ozone depletion is a global issue, its impacts are likely to be significant on a local scale. These include increased incidence of skin cancer, eye cataracts, and immune-system-related health risks in humans. The UV-B radiation also affects vegetation by damaging the photosynthetic pathways and genetic structure of plants.

The Montreal Protocol, which reached consensus in 1987, aims to protect the stratospheric ozone layer. South Africa became a signatory in 1990 and, in 1992, also ratified the subsequent London Amendments that restricted the use of chlorofluorocarbons (CFCs) and halons. South Africa's use of ozone-depleting substances (including CFC-11, 12, 113, 114, and 115) has diminished substantially following its signing of the protocol and ratification of the related amendments. The country's industries ceased using the above-listed CFCs as propellants in July 1992. South Africa is required to collect data every year on the consumption of ozone-depleting substances (ODS) for submission to the Ozone Secretariat.

8.3 PERSISTENT ORGANIC POLLUTANTS

Persistent organic pollutants (POPs) are carbon-containing chemical compounds that, to a varying degree, resist photochemical, biological, and chemical degradation. They remain intact in the environment for long periods[2], become widely distributed geographically, accumulate in the fatty tissue of living organisms, and are toxic to humans and wildlife. Their sources are both natural and anthropogenic and, although many different chemicals may be defined as POPs, twelve have been identified as priority pollutants by the United Nations Environmental Programme (UNEP)

Crop-spraying with non-ozone depleting substances is a safe and sustainable alternative to using methyl bromide as a pesticide.

2. In the Stockholm Convention on the management of persistent organic pollutants, 'persistence' is determined by evidence of a half-life of the chemical in water greater than two months, or a half-life in soil greater than six months, or a half-life in sediment greater than six months (Resource Futures International, 2001).

because of their impact on human health and environment: polychlorinated biphenyls (PCBs), dioxins, furans, aldrin, dieldrin, DDT, endrin, chlordane, hexachlorobenzene, mirex, toxaphene, and heptachlor.

The Stockholm Convention on Persistent Organic Pollutants, a global treaty to protect human health and the environment from POPs, was signed in 2001 by 100 countries including South Africa, and requires the control of the twelve POPs listed above, also referred to as the 'dirty dozen'.

Emissions of POPs, varying from point to diffuse sources[3], have not been quantified nationally in South Africa. Measurements of POPs' concentrations in the ambient atmosphere are currently experimental, and data are not readily available. Given the widespread occurrence of POPs and increasing international emphasis on regulating them, it would be beneficial to quantify their emissions annually and establish environmental concentrations of the most important ones.

Plants may become physically damaged as a result of high levels of acid deposition.

8.4 TRANSBOUNDARY TRANSPORTATION OF AIR POLLUTANTS[4]

Industrial emissions and biomass burning in the form of wild-fires (that is, uncontrolled veld or forest fires) have the greatest potential for inducing environmental and climatic change that has effects on a regional scale (Charlson *et al.*, 1990; Andreae, 1991; Schimel *et al.*, 1996).

Four major atmospheric transport pathways carry air towards the highveld (see Figure 8.3). Air masses from the south and central Atlantic are most likely to be free of industrial emissions, although there are indications that this pathway can transport products of wild-fires – in particular, carbon monoxide (CO) – from South America to southern Africa. Air masses from the Indian Ocean are also relatively free of industrial pollutants. The African transport plume, however, can carry industrial pollutants from central southern Africa towards South Africa. Major industrial sources for these pollutants are copper smelters in northern Zambia and Botswana. Although production has declined in recent years, emissions from the Zambian copperbelt remain a significant source of

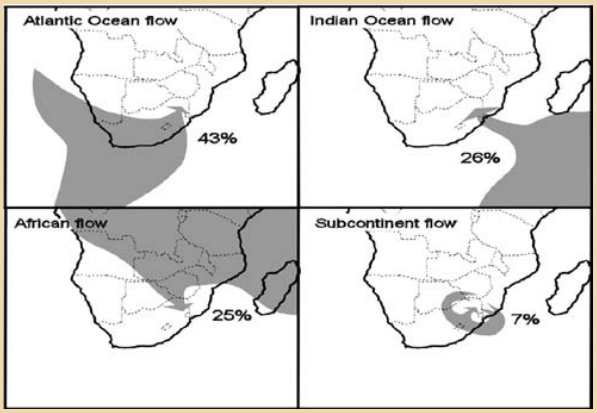


Figure 8.3: Transport pathways advecting air to the Mpumalanga Highveld region. The shaded arrows indicate an ensemble of trajectories between 850 and 500 hectopascals (hPa). The frequency of occurrence of each group is given as a percentage of the total number of trajectories evaluated

3. Point sources refer to single, identifiable sources of pollution; emissions from diffuse sources are likely to arise from less well-defined points, such as chemical spills and area sources.

4. Information contributed by Stuart Piketh, Climatology Research Group, University of the Witwatersrand.



airborne fine particulates and acidic aerosols (Meter *et al.*, 1999; Meter, 1999). Intermittently, from August to October, the African transport plume also imports large quantities of emissions over South Africa from wild-fires in the Democratic Republic of Congo, Angola, and western Zambia.

There are five main pathways of transportation of air-masses away from the highveld, namely: the Indian Ocean plume, the recirculation plume, the Atlantic Ocean plume, the African plume, and the Southern Ocean plume (see Figure 8.4). The most frequently occurring of the five types is the Indian Ocean plume (48%) by means of which material is transported directly to the Indian Ocean from the highveld, or to the Indian Ocean via the highveld, initially moving westward before recurving over Lesotho to exit over the southeast coast. The recirculation plume is the second most frequent (32%). Together, the Indian Ocean and the recirculation plumes eventually transport 80% of airborne pollutants off the southeastern continental margin and towards Australasia.

Air pollutants carried in air masses that are either recirculated over the highveld or imported from neighbouring regions have been found to contribute significantly to local atmospheric concentrations of fine particulates. Veld-fire biomass burning and aged pollution-laden air (that is, air laden with pollution from distant sources) have been found to be responsible for 20–40% of inhalable particulates recorded in the Vaal Triangle and Johannesburg. It is therefore evident that local authorities tasked with air quality management need to concern themselves not only with local sources, but also with air quality within their own and adjacent provinces as well as neighbouring countries. Local and provincial air quality management, if carried out in isolation from national and regional air quality planning and management initiatives, will have only limited success.

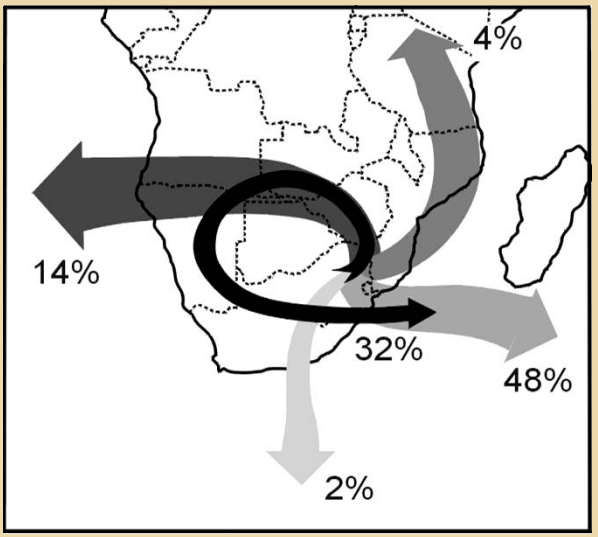
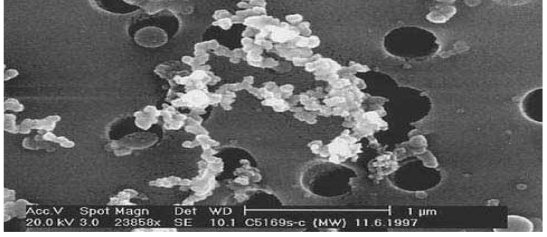


Figure 8.4: Five transport pathways identified from the forward trajectory analysis for the five-year period 1990–1994. The percentages represent the frequency of occurrence relative to all the calculated trajectories between 850 and 500 hPa

8.5 ACID DEPOSITION

Sulphur dioxide (SO_2) and nitric oxide (NO) are primary acidifying pollutants emitted as gases from combustion processes. These gases can be deposited onto surfaces from the gas phase, or they can be converted by chemical processes in the atmosphere into sulphuric acid (H_2SO_4) and nitric acid (HNO_3). These acids condense into aerosols (that is, microscopic droplets or particles suspended in the atmosphere), which may be deposited directly onto surfaces (dry deposition), including vegetation and soil, resulting in an accumulation of acidity within soils. Alternatively, the droplets may efficiently be removed from the air by rainfall or dew-fall (wet deposition), resulting in 'acid rain'. Given South Africa's relatively dry atmosphere, particularly during winter months, dry deposition of acidifying species, by both gas-phase and aerosols, accounts for a significant proportion of acid deposition.

A natural buffer for acids is provided by soils, which show only a very gradual decrease in pH (that is, potential of hydrogen, which is a measure of acidity or alkalinity) from atmospheric acid pollution over several decades. Plant growth may initially even be enhanced through the fertilizing effect of the nitrogen and sulphur. If the rate of acid deposition exceeds the natural buffering capacity of the soil, however, the soil becomes acidic and less able to support plant growth. Acidity problems first become evident in rivers and lakes, occurring when the absorptive capacity of the ecosystem has been saturated, with the excess acidity entering aquatic systems. Leaching of aluminium into bodies of water occurs, and this is toxic to aquatic life. The amelioration of acid impacts on ecosystems, by treating rivers with lime, for instance, is extremely costly and may itself cause harm.




Wet deposition and rain chemistry have been monitored continuously by Eskom since 1985 (Turner *et al.*, 1996). Monitoring has been undertaken at Louis Trichardt (characteristic of rural environments) and Amersfoort (indicative of environments affected by industrial emissions, for example from coal-fired power stations concentrated in the eastern highlands, each of which can burn as much as 1 000 tonnes of coal per hour). Data from these sites, based on precipitation analysis over 13 years, show that concentrations of non-sea-salt sulphate and nitrate at Amersfoort are as high as those in the northeastern USA and in central Europe, and typical of regions affected by acid-forming emissions. Soil buffering capacity has fortunately given rise to an average soil pH of only 4.35. At Louis Trichardt, concentrations of non-sea-salt sulphate and nitrate were found to be comparable with those at sites in western Africa. Fossil-fuel sources were found to be the greatest contributors to acidic precipitation at Amersfoort, while at Louis Trichardt, emissions from veld-burning have been predominant (Mphepya *et al.*, 2004).

Chapter 9

Scientific advances

At a glance

Considerable research on air quality is conducted in South Africa through scientific research campaigns designed to address specific research questions or hypotheses, and their purpose is to add to the existing body of knowledge. These campaigns take place on a number of temporal and spatial scales. On a local level, the two Cape Town Brown Haze studies focused on the characterization of pollution contributing to the local brown haze dominant in Cape Town between April and September, and ongoing acid deposition research takes place in Mpumalanga. Nationally, passive monitoring of sulphur dioxide, nitrogen oxides, and ozone takes places in four provinces, and the South African Mercury Assessment is ongoing. Regional-scale projects include the Southern Africa Regional Science Initiative (SAFARI 2000), an aircraft monitoring programme; the Cross-Border Air Pollution Impact Assessment (CAPIA) project; and the estimation of biogenic volatile organic compound emissions.



9.1 INTRODUCTION

Considerable research on air quality is conducted in South Africa through scientific research campaigns. Studies are normally designed to address specific research questions or hypotheses, and their purpose is to add to the existing body of knowledge. They range from regional-scale scientific investigations such as the Southern African Fire-Atmosphere Research Initiative, or SAFARI-92 (www.igac.noaa.gov/newsletter/15/safari-2000.php) and the subsequent Southern Africa Regional Science Initiative, SAFARI 2000, which involved local and international research groups, and urban-scale projects such as the Cape Town Brown Haze Study (Wicking-Baird *et al.*, 1997), to a host of smaller scale research projects contributing towards master's and doctoral dissertations.

Unlike routine monitoring exercises, research campaigns

- Last a relatively short time and are designed to answer specific questions rather than to monitor compliance and the state of the air
- Are typically driven by university and other research groups
- Present the data and the findings in scientific publications and postgraduate theses, or at scientific conferences.

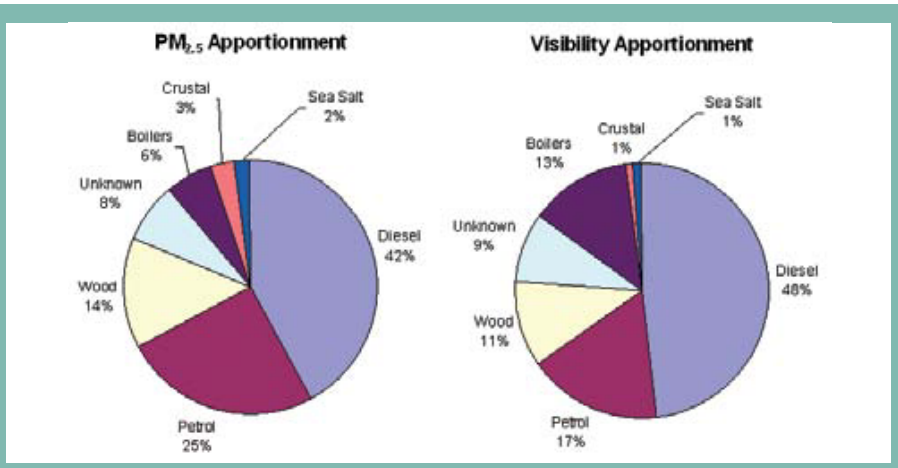


Figure 9.1: To gather information about the quality required for satisfactory modelling, data for six brown haze episodes were used in the Chemical Mass Balance Model to determine the contribution of various sources to Cape Town's brown haze. This figure shows $PM_{2.5}$ apportionments (left) and the contribution of each source to impairment of visibility (right) (Wicking-Baird *et al.*, 1997).

These campaigns are diverse in scope and too numerous to be comprehensively covered here. Rather, the main findings of selected scientific campaign studies conducted during the period 1994–2006 are discussed, providing insights into the state of air on a regional scale and further insights into urban air quality. An inventory of the research outputs (theses, research reports, journal articles, and conference papers) of other campaign studies is available in the DEAT's air quality research database (DEAT, 2006d).

9.2 CAPE TOWN BROWN HAZE

The brown haze over Cape Town occurs mostly from April to September. It is caused by strong temperature inversions and windless conditions that can occur during these months, leading to the build-up of pollutants emitted into the atmosphere.

Brown haze is not unique to Cape Town, however. It is found in many cities and on a much larger scale. The Asian Brown Cloud, for instance, develops over the South Asian region and the tropical Indian Ocean, Arabian Sea, and Bay of Bengal (Srinivasan, 2002; Ramanathan, 2001). But the brown haze in winter over Cape Town is often regarded as the city's most obvious and pervasive air quality issue, particularly at that time of year.

The first Cape Town Brown Haze Study, whose findings are summarized in this section, was conducted by the Energy Research Institute in 1997 (Wicking-Baird *et al.*, 1997). Its main objective was to determine the main sources of the brown haze and the mechanisms that form it. It is most intense in the mornings, and then lifts and disperses. The single largest cause of visibility impairment is recognized to be $PM_{2.5}$ (that is, particulate matter with a diameter less than 2.5 micrometres – in contrast to a human hair, for example, which is typically 60 micrometres in diameter). For this reason, $PM_{2.5}$ was sampled at four sites in Cape Town in 29 brown haze episodes during the period July 1995–June 1996. The chief contributor to the brown haze was shown to be emissions from diesel vehicles, with further significant contributions from petrol vehicles, wood-burning, and industrial boilers.

The second Cape Town Brown Haze Study was undertaken during July and August 2003 over a period of five weeks, using both ground-based and



The Brown Haze over Cape Town at certain times of he year has been extensively researched through two scientific campaigns conducted in 1997 and 2003.

airborne measurements. It was led by the Climatology Research Group from the University of the Witwatersrand, working in collaboration with the City of Cape Town and the South African Weather Service.

The main aims of this second study were to characterize accurately the physical and chemical nature of brown haze fine particles and clouds. The work involved quantifying the concentrations in both the horizontal and vertical dimensions, and examining the potential effects on health, especially in disadvantaged residential areas that had not previously been examined.

Airborne measurements included those taken from instruments – fitted to aeroplanes – that had been designed specifically to measure trace gases such as sulphur dioxide (SO_2), ozone (O_3), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and aerosols.

Including VOC measurements was a new departure, and one of the main differences between this and the first Brown Haze Study. Volatile organic compounds are vapour-phase atmospheric organics (excluding carbon monoxide [CO] and carbon dioxide [CO_2]). They consist of a wide variety of chemicals that can be emitted into the atmosphere, where they react with other compounds. These reactions have significant consequences for the chemical composition of the air. Important also is the fact that VOCs produce photochemical oxidants by reacting with oxides of nitrogen in the presence of sunlight, and are thereby the precursors to the formation of ozone (Wicking-Baird *et al.*, 1997; Hakami *et al.*, 2004).

The second Brown Haze Study reported a variety of findings in the air and near the ground (Piketh *et al.*, 2004).

- Visual brown haze episodes did not always correspond to elevated (that is, higher than

Hazy conditions are attributed to the cumulative impact of atmospheric pollution from a wide range of sources.
Photography: Janet Peace

normal) concentrations of atmospheric pollutants, and significant pollutant concentrations were also present during non-brown haze episodes (see Figure 9.2).

- Ground-based concentrations of pollutants generally rose sharply in the mornings and evenings of brown haze days (see Figure 9.2).

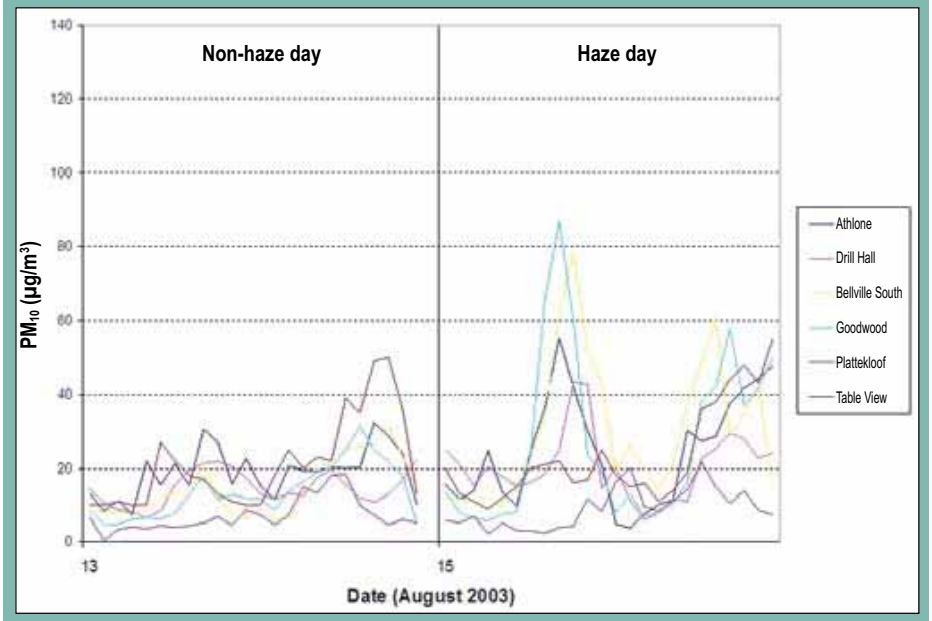


Figure 9.2: Comparison of ground-based PM_{10} measurements between a non-haze day (13 August 2003) (left) and a haze day (15 August 2003) (right). The data are represented on a time series starting at midnight

- Far higher concentrations of nitrous oxide (NO) were recorded over the city of Cape Town on brown haze days, with high concentrations measured by both ground-based and airborne instruments for all flights conducted over the Cape Town metropolitan area.

- High concentrations of aerosols were found in the same areas as sources of pollution, southeast of the city in the Cape Town Metropolitan area.

- Aerosol and nitrogen dioxide (NO_2) concentrations typically get diluted and mixed vertically[1] in the atmosphere towards the afternoon. Some of the NO_2 probably also gets converted to O_3 towards the afternoon, which results in raised O_3 levels at around 750 m above sea level over the Strand area.

- The species of VOC pollutants were found to vary significantly at selected sites over the area studied, and were present in considerable concentrations. In some locations, for example, up to 23 different types were identified. The process of measuring VOCs involves drawing air from the atmosphere into sealed canisters; then, since each VOC has a unique 'signature', those present in the sample are 'identified' by means of gas chromatography. The nature and potential impact of the VOC species identified in the sample will need further evaluation.

1. Vertical mixing means that instead of pollution being mixed, and therefore diluted, only in the horizontal plane, it is also mixed, and therefore diluted, in the vertical.

- To determine the impact on visibility of a particular combination of pollutants in the atmosphere, visibility modelling is undertaken. The model – in this case PLUVUE II – is used to calculate the visual impact (reduction of visual range as well as atmospheric discoloration) of plumes that result from the emissions of sulphur oxides, nitrogen oxides, and particulate matter from a specific point or source area. The model predicts the transport, dispersion, chemical reactions, optical effects, and surface deposition of point or area source emissions (EPA, 1992). Visibility modelling showed that the direct emission of aerosols into the atmosphere was the most important factor in the development of brown haze over the city of Cape Town.

- The model showed little impact from NO_2 on the brown haze, but the presence of a prevalent layer of NO_2 was not reproduced by the model, so its contribution to the brown haze was probably underestimated.

- This campaign identified motor vehicle emissions, industrial emissions, and domestic fuel-burning as the main sources of air pollution in the city of Cape Town.

9.3 SAFARI 2000

The Southern Africa Regional Science Initiative (SAFARI 2000) was a large-scale international field campaign conducted at ground level, in the air, and using information from satellites. It was carried out between 1999 and 2001, with intensive field campaigns in 1999 (August–September), 2000 (February–March, August–September, and November–December), and 2001 (February–March). It involved scientists from 19 countries – from Africa, Europe, and the United States – and examined a broad range of phenomena related to land–atmosphere interactions and the biogeochemical functioning of southern Africa. The SAFARI 2000 activities characterized surface emissions from the level of the ground; aerosols and trace gases from samples taken from aircraft; and regional haze and trace gas composition and concentrations. They also took measurements of incoming solar radiation from surface, aircraft, and remote sensing 'platforms' (that is, surfaces or bases to which measuring instruments are fitted) (see Swap *et al.*, 2003).

Box 9.1 El Niño-Southern Oscillation

The El Niño-Southern Oscillation (ENSO) is a global event arising from large-scale interaction between the ocean and the atmosphere. The Southern Oscillation refers to a fluctuation in the surface pressure (atmospheric mass) between the southeastern tropical Pacific and the Australian–Indonesian regions. When the waters of the eastern Pacific are abnormally warm (an El Niño event), sea-level pressure decreases in the eastern Pacific and rises in the western Pacific. The reduction in the pressure gradient is accompanied by a weakening of the low-latitude easterly trade winds. Since ocean currents are greatly influenced by the winds blowing above them, this easing of the trade winds also warms surface ocean currents, particularly the Peruvian Current.

The Peruvian Current is normally a cold current that moves northward along the coast of South America, causing an upwelling of cold, nutrient- and oxygen-rich water that is conducive to dense concentrations of marine life. During an El Niño, however, the relaxation of the trade winds may allow warm water to appear at the water surface along the coastline of South America affected by the Peruvian Current. This warm water not only kills off marine life, but also raises the temperature of the atmosphere directly above it to cause convection, which can bring intense rainfall to a region that is normally dry. In addition, rainfall follows the warm water eastward, resulting in flooding in Peru and drought in Indonesia and Australia. During an El Niño event, South Africa may experience below-normal rainfall, or droughts.

The possible interrelationship between El Niño and global weather patterns – especially the simultaneous droughts in the Soviet Union, Africa, Australia, and Central America – was first recognized in 1972–1973. Relationships between El Niño and other global weather anomalies are known as teleconnections.

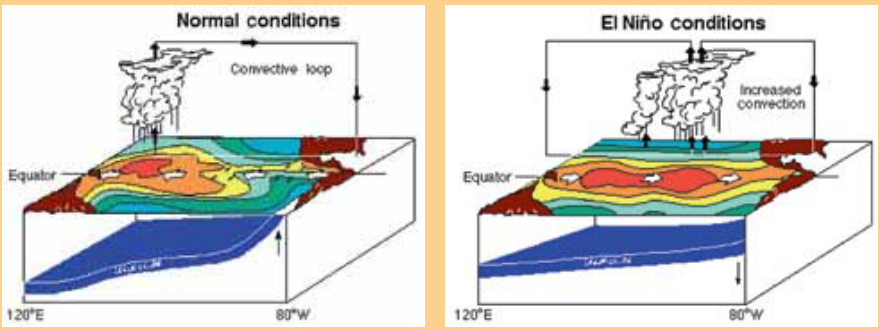


Figure 9.3: Ocean–atmosphere interactions, and their consequent impacts on the weather of the Pacific region during normal conditions (left) and El Niño conditions (right) of the ENSO cycle



Sea-spray, generated by wave action along South Africa's coast, gives rise to maritime aerosols.

Although SAFARI 2000 investigated southern Africa, with samples covering the region as far north as Zambia, some of the findings were relevant to South Africa and to this report (for the full suite of findings from the intensive field campaign conducted in August and September 2000, see the special issue of the *Journal of Geophysical Research*, SAFARI 2000-Southern African Regional Science Initiative, 2003). Some of the main findings are summarized below.

- The higher regional biomass fuel loads associated with the moist La Niña phase of the El Niño-Southern Oscillation (ENSO) cycle produced above-average emissions from biomass burning (in the sense of veld-fires and crop-burning), which dominated all other aerosol and trace gas emissions during the dry season that followed, contributing more to the overall pollution load in the region than other sources.

- The southward transport of a broad plume of smoke that originated over equatorial Africa and exited off the east coast towards the Indian Ocean was attributed to the unusual synoptic flow associated with the ENSO phase (the ENSO cycle fluctuates between the La Niña and the El Niño phases)[2].

- Fire scars (that is, the 'scars' on the land left by fires), visible on satellite images, were used to determine the volume of biomass burnt and the area of land burnt. They showed that the biomass fire season starts in May, peaks in June and July, and ends in October. In June 2000, more than 340 000 km^2 was burned in southern Africa.

9.4 REGIONAL-SCALE AIRCRAFT MONITORING PROGRAMME

Aircraft provide mobile monitoring platforms able to provide continuous spatial coverage and to measure the vertical distribution of pollutants in the troposphere (that is, the layer of the atmosphere directly above the Earth's surface). Flights can be designed to investigate atmospheric processes such as the transport of pollution and plume evolution, and to characterize the main pollution sources.

2. 'Synoptic flow' in this context refers to the weather patterns resulting from the high-pressure and low-pressure systems that affect South Africa. La Niña is the phase of the ENSO cycle in which conditions are opposite to those that dominate during El Niño.



Box 9.2 Cloud microphysical processes in South Africa

In the Aerosol Recirculation and Rainfall Experiment (ARREX) project, levels of cloud condensation nuclei (CCN, that is, the subset of aerosols that may be activated to form cloud droplets) were measured for the first time in South Africa (Terblanche *et al.*, 2000; Ross, 2003; Ross *et al.*, 2003).

It was found that CCN levels were significantly elevated by anthropogenic aerosol emissions, particularly downwind of the industrialized highveld (see Figure 9.4). From July to September, aerosol and CCN concentrations over the subcontinent reflected the north–south gradient in biomass burning emissions, with concentrations increasing towards the north.

Most CCN were contained within what is called the mixing layer (that is, the layer of air within which pollutants are mixed by turbulence), which typically extends 1 500–2 500 m above ground level over the plateau that makes up the Mpumalanga and Gauteng highveld, and is capped by a temperature inversion* at the 700 hectopascal (hPa) level. Concentrations of CCN are lowered by rainout (also known as washout, that is, the removal of pollution particles from the atmosphere by precipitation, usually rain), and by the advection (or horizontal transport) of clean maritime air over the subcontinent. Aerosols and CCN are often found in distinct layers, due to the presence of absolutely stable layers and, occasionally, of convection in clouds (Ross, 2003; Ross *et al.*, 2003).

Measurements of cloud-droplet size distributions show that anthropogenic aerosol emissions do indeed affect cloud formation. Clouds forming in coastal environments have low droplet concentrations and a broad cloud-droplet spectrum skewed towards large droplets (see Figure 9.5).

Since the highveld is the major source of anthropogenic aerosols and of CCN in southern Africa, the concentration of aerosols and CCN generally decreases with distance from the highveld. As a result, clouds forming above it are more 'continental' in nature (that is, they have higher concentrations of smaller droplets) than clouds forming further away. Consequently, clouds over the highveld are expected to be more reflective; and they normally need to extend beyond freezing level, and for ice processes to come into play, before precipitation forms.

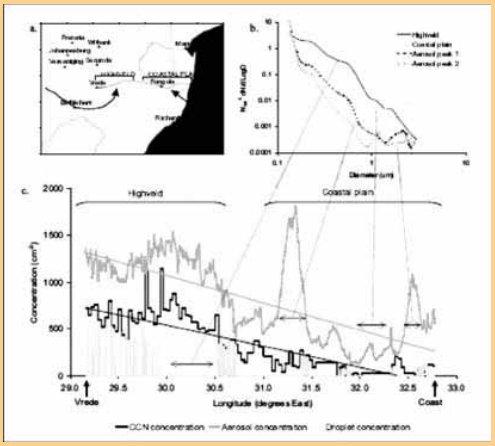


Figure 9.4: a. West–east flight path in a straight line from Vrede on the highveld, to the northern KwaZulu-Natal coast; b. A graph showing aerosol size distribution of the highveld airmass and the coastal plain airmass; c. Decreasing aerosol and CCN concentrations from the highveld to the coast (Ross *et al.*, 2003)

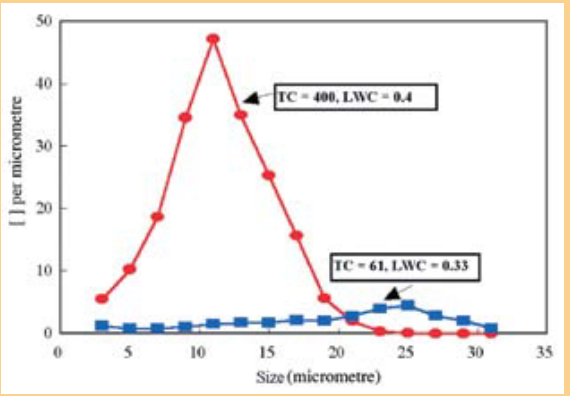


Figure 9.5: Cloud-droplet spectra recorded in a continental cloud over the highveld (red line) and in a maritime cloud recorded off the KwaZulu-Natal coast (blue line) (Terblanche *et al.*, 2000)

* Under non-inversion conditions atmospheric temperature decreases with height, whereas under inversion conditions atmospheric temperature increases with height.

By 2004, two important projects had been conducted in South Africa: the Aerosol Recirculation and Rainfall Experiment (ARREX), and a project commissioned by the Department of Environmental Affairs and Tourism (DEAT) to assess air quality over industrial and urban areas. Both made use of the South African Weather Service's Aerocommanders 690A. The two twin turbine aircraft were modified to carry instruments for sampling the air. The VOC samples were collected and analyzed later; all the other pollutants were measured on board, in real-time, during the flights. These projects were collaborations, involving the South African Weather Service and the Climatology Research Group at the University of the Witwatersrand.

ARREX was initiated in December 1997, to investigate the prevalent transport pathways of atmospheric constituents over South Africa, and to evaluate the effects of industrial aerosols on cloud microphysical processes (Piketh *et al.*, 2002; 2003).

Natural veld-fires occur seasonally throughout South Africa and contribute to elevated levels of particulate matter during the period August to October each year.

Photography: Otto Fobian

What happens is that industrial aerosols increase the number of particles onto which water droplets preferentially condense, to form clouds. Before the campaign started, it was suspected that, when this process occurs, clouds develop but rain does not fall as the droplets remain too small. The project was co-funded by Eskom and the Water Research Commission. Wet season campaigns, focusing on aerosol–cloud interactions, were conducted in December 1997, January/February 1999, and March 2001. Dry season flights, focusing on the characterization of atmospheric aerosols and their sources, were conducted in May 1998, September 1999, and August/September 2000 (the latter campaign was conducted as part of the SAFARI 2000 intensive dry season campaign). This research has been ongoing, but for some specific findings from this project, see Box 9.2.

The DEAT commissioned approximately 250 hours of flying, conducted between August 2003 and March 2006, to establish baseline atmospheric pollution levels, identify pollution 'hotspots' (that is, areas of significant air pollution), and characterize important sources. Flights focused on the major industrial areas on the highveld, in Durban and Richards Bay, in Cape Town, and in Port Elizabeth. The study measured concentrations of aerosols with diameter less than 3 μm, SO_2, hydrogen sulphide (H_2S), O_3, NO_x, CO, and CO_2 continuously during each flight, as well as various state parameters (that is, temperature, pressure, and humidity); VOCs were collected in canisters, whose contents were later analyzed for VOC concentrations.

9.5 CROSS-BORDER AIR POLLUTION IMPACT ASSESSMENT (CAPIA) PROJECT

Ozone is commonly regarded as the pollutant that poses the greatest risk to vegetation, with damage possible at ambient concentrations as low as 40 ppb (parts per billion). With abundant sunshine and significant sources of precursors of O_3 (typically VOCs, for example), the objective of the Cross-Border Air Pollution Impact Assessment (CAPIA) project from 2001 onwards was to estimate the deposition rates and ambient concentrations of O_3 in southern Africa so as to assess the potential risk to agricultural crops.

In the Southern African Development Community (SADC) region, the CAPIA project (conducted by a multinational project team led by the Council for Scientific and Industrial Research [CSIR]) used maize as an indicator crop to assess O_3 damage. The research indicated that the O_3 concentrations that were both monitored and modelled exceeded values at which maize is at risk, and covered large areas, particularly over Zimbabwe and the northeastern parts of South Africa (see Figure 9.6) (van Tienhoven *et al.*, 2006). Furthermore, anthropogenic and biogenic emissions of O_3 precursors were found to contribute collectively to the formation of O_3 across the region (Zunckel *et al.*, 2006).

9.6 ACID DEPOSITION

Acid deposition is the process by which trace gases such as nitrogen and sulphur oxides are removed from the atmosphere and deposited on the ground. Nitrogen is removed from the troposphere as dilute nitric acid in precipitation (wet deposition) and as ammonium in aerosol fallout (dry deposition), whereas sulphur is precipitated from the atmosphere as dilute sulphuric acid in rain, snow, fog, and dew as well as in aerosol deposition (Tyson & Preston-Whyte, 2000).

Since 1985, wet deposition and acid rain monitoring have been conducted by Eskom, mostly in Mpumalanga. The network started with seven monitoring stations, expanding later to thirteen. The Kiepersol Joint Venture between Eskom, the CSIR, and industry intended to expand the network across the country during the period 1994–1997, but the finances were not available. Instead, the network was expanded to 15 stations, and remained concentrated in the northeastern parts of the country. Eskom maintains two core wet deposition monitoring sites at Amersfoort and Louis Trichardt.

Galpin and Turner (1999a; 1999b) conducted a comprehensive trend assessment of rain quality data. They evaluated seven rain sites, managed by Eskom, where data were collected for seven or more rain seasons between 1985 and 1995. They concluded that the rain quality was inconsistent, and that South African rainfall is highly seasonal, with considerable variability from year to year. Their main findings were as follows:

- No significant trend was observed in the sulphates, which indicated that acidity derived from fossil fuels did not increase substantially during the period 1985–1995.
- Significant downward trends observed in organic acid anions were related to drought during the period, as these anions are indicators of the contribution of biomass burning to rain quality. In other words, the emissions from biomass burning – detected as organic acid anions that

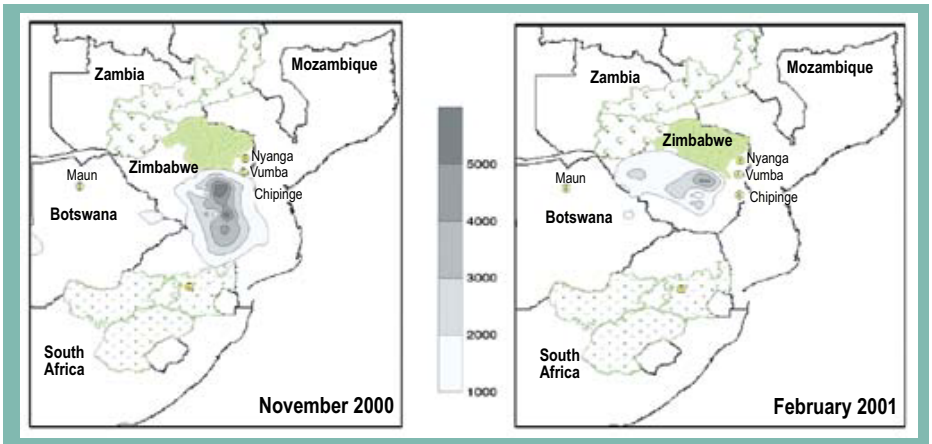


Figure 9.6: Accumulated O_3 over a threshold of 40 ppb for November 2000 and February 2001 (from van Tienhoven *et al.*, 2006)**. The northeastern parts of South Africa were affected by high levels of ozone during November, possibly causing damage to maize crops. These elevated ozone levels could be attributed partially to the presence of both anthropogenic and biogenic emissions of ozone precursors**

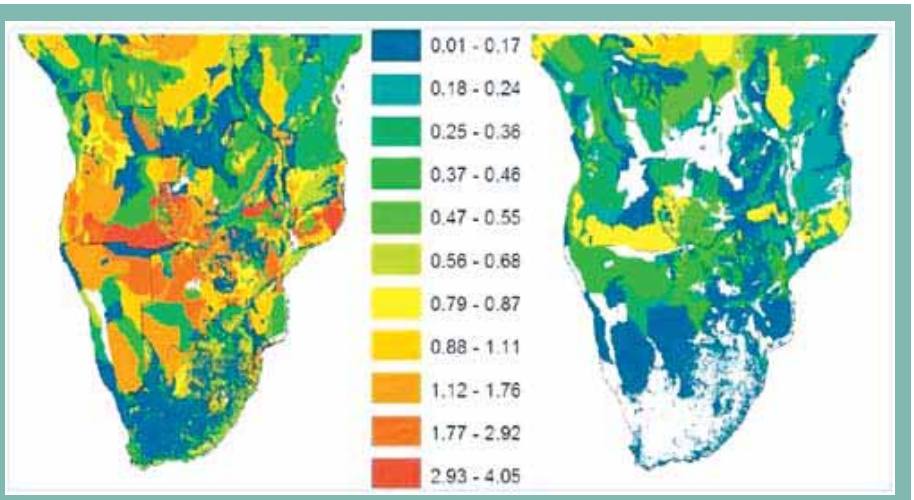


Figure 9.7: Annual average isoprene emissions in grams of carbon per square metre per month for January (left) and July (right) indicating the strong seasonal variation in biogenic emissions in the southern African region, and in South Africa in particular *(Otter et al., 2003)*



had been wet deposited in rain water – decreased over time, the drought making less and less biomass fuel available for burning during the dry season.

- In southern Africa, biomass combustion from veld fires has a controlling influence on rain acidity. A certain level of rain acidity can always be expected, because of the process of biomass burning occurring naturally in South Africa and the resultant emissions being wet deposited. In this way, a natural 'background' level is provided – that is, a level of pollution that would still be there, even without the influence of humans. If South Africa had no industrial activity, for example, it would still have a certain level of air pollution from natural emissions, such as those from veld fires or biogenic emissions from flora.

- The contribution from fossil fuel combustion by industry adds to this natural source of acidity.

- The maritime contribution to rain acidity was observed in rainfall hundreds of kilometres inland, demonstrating regional-scale recirculation of air.

An attempt to estimate dry deposition of sulphur in the three climatic zones of Mpumalanga was made by Mark Zunckel during a short campaign study. The research team found that there was a steep gradient across the highveld, with deposition rates varying from an estimated 13.1 kg of sulphur per hectare (kg S ha^{-1}) per year at Elandsfontein on the central highveld to an estimated 3.1 kg S ha^{-1} per year on the periphery at Palmer. Beyond Palmer, the estimated dry deposition rates were similar on the eastern escarpment at Blyde (3.9 kg S ha^{-1} /y^{-1}) and in the lowveld at Skukuza (3.3 kg S ha^{-1} /y^{-1}). From a modelling study, Zunckel *et al.* (2000) concluded that dry deposition of sulphur could exceed that of wet deposition in a ratio 60:40 on the central highveld.

9.7 BIOGENIC VOLATILE ORGANIC COMPOUNDS (BVOC)

Ozone is formed in the lower troposphere by the complex photochemical reactions involving NO_x and VOC precursors. It has been shown that 30–90% of the global total of VOC emissions are from biogenic sources (Guenther *et al.*, 1994) – in other words, they result from the natural VOC emissions of flora.

A typical average for an urbanized region in the USA is approximately 60%. In the southern African region, which is far less urbanized than the USA, the figure is likely to be higher over large areas. This is because, since biogenic emissions are from plants, biogenic VOC emissions are lower in areas where widespread urbanization has reduced flora. Furthermore, biogenic VOC emissions are typically more reactive than anthropogenic VOC, with lifetimes defined in hours rather than days (that is, the emissions from flora undergo changes within hours of being emitted, whereas anthropogenic VOCs may react on a timescale of days).

To estimate biogenic VOC emissions from southern Africa, and to improve on earlier estimates by Guenther *et al.* (1995), Otter *et al.* (2003) developed a comprehensive land-cover map for the continent south of the equator based on 262 types of land cover. For mapping purposes, information specific to species was used to group different plant types into 23 general land-cover categories. The average emissions for isoprene and monoterpenes (specific VOCs emitted by plants) were modelled for each land-cover category, based on leaf- and branch-level emission measurements obtained from various campaigns in southern Africa (for example, Guenther *et al.*, 1996; Otter *et al.*, 2002; Greenberg *et al.*, 2003; Harley *et al.*, 2003).

Emissions data of important African plant genera from field measurements on other continents and in greenhouses were also used to add to the information gathered locally. In this way, total biogenic VOC or isoprene emission estimates (see Figure 9.7) for approximately 400 plant species were included in the modelling exercise, together with estimated monoterpenes emissions for about 90 of them. A total annual biogenic VOC emission rate of 80 Tg C yr^{-1} (teragrams of carbon per year) was modelled for southern Africa, providing baseline information about the state of the air.

Emissions of isoprene and monoterpenes have been measured for approximately 170 plant species in three southern African savannas, as well as in mopane and Kalahari woodlands. These measurements form a small fraction of a total of approximately 24 000 plant species that grow in the region. Important exclusions from the available data are the fynbos species of the Cape Floral Kingdom,



agricultural and forestry crops, and urban trees and shrubs. The dearth of emissions information at plant-species level has been posing challenges to southern African researchers and to local and regional air-quality managers.

The most pressing need is to close this information gap. Understanding the relationships among the factors that control emissions from plants is necessary for improving emissions modelling at the landscape level, and for offering greater detail in estimations, on a spatial scale, for regional modelling. The role and relevance of biogenic VOC emissions in urban air-quality planning and management can be substantially improved. Urbanization, climate change, deforestation, and agricultural practices all cause landscapes to alter, bringing with them changes in biogenic VOC emissions rates, with concomitant effects on ozone formation and air quality.

In October 2005, a measurement and modelling project was initiated at the CSIR to develop a cadre of skilled scientists in biogenic VOC sampling techniques, using leaf and branch enclosures, relaxed eddy accumulation, and lidar techniques (that is, optical remote sensing technologies used to measure aerosols, such as VOCs, and other very small objects) to improve both the data on plant-specific emission factors and landscape emission estimates in southern Africa. The project also included the continued development of photochemical modelling expertise in the region.

9.8 REGIONAL SCALE PASSIVE MONITORING OF SO_2, NO_X AND O_3

Through a joint venture between the universities of Johannesburg and the Witwatersrand, parties from the North West Province, and the CSIR, a regional passive diffusive monitoring network was established in August 2005.

A passive diffusive sampler is a device capable of taking samples of gas or vapor pollutants from the atmosphere at a rate controlled by a physical process, such as diffusion through a static air layer or permeation through a membrane, but which does not involve the active drawing of the air through the

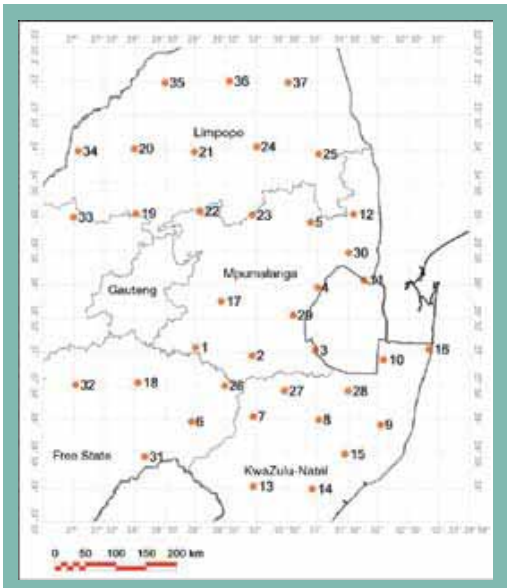


Figure 9.8: Location of 37 passive sampling monitoring sites intended to measure background sulphur dioxide, nitrogen dioxide and ozone levels in areas remote from urban centres

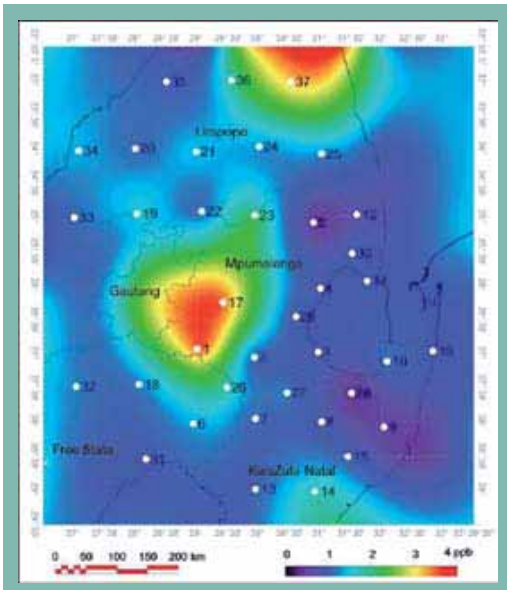


Figure 9.9: Average concentrations of nitrogen dioxide (ppb) measured between September 2005 and May 2006 (figures obtained from M. Josipovic, Department of Geography, Environmental and Energy Studies, University of Johannesburg). Clear pollution hotspots can be identified from the results of this passive sampling network, most notable of which are the industrial highveld and the northeastern parts of Limpopo

sampler (Berlin *et al.*, 1987). The South African network comprises 37 passive sampling monitoring sites situated in four provinces (Mpumalanga, Limpopo, northern KwaZulu-Natal, and eastern Free State) (see Figure 9.8).

The network was designed to characterize variations in the spread (that is, spatial variations) of air-pollutant concentrations across the highveld. Monitoring sites were located at approximately 1° latitude and longitude spacing, outside urban centres and industrial areas, and away from any specific sources of pollution (such as power stations or large industrial developments). Average concentrations of NO_2 (in parts per billion), measured from September 2005 to May 2006, are illustrated in Figure 9.9.

The first phase of the passive sampling campaign proved successful with data collection facilitating short-term analyses. The intention was to extend the project as from 2007 into the medium-term for a further two to four years, and thereafter to hand over the operational network to the National Research Foundation's South African Earth Observation Network (SAEON) for a long observation period (five to ten years). The feasibility of adding a further ten suitable sites within territories of South Africa's neighbours was also being examined in 2006.

9.9 THE SOUTH AFRICAN MERCURY ASSESSMENT (SAMA) PROGRAMME

Mercury (Hg) has been the subject of an increasing number of international studies aiming to understand more fully the sources and transport of this contaminant, where it ends up in the environment (that is, its environmental fate), and the extent and significance of the resultant risk to human health and the broader environment. The interest in the amount of Hg being mobilized and released into the biosphere is due to the fact that it has been increasing steadily since the beginning of the industrial age (Carpi, 1997; Pirrone & Mahaffey, 2005; UNEP, 2002).

Mercury derived from the atmosphere strongly influences the bioaccumulation of highly toxic methyl mercury in the aquatic food chain. Methyl mercury bioaccumulates rapidly up the chain, posing a serious health risk to humans when they eat Hg-contaminated fish or other aquatic organisms. Where Hg emissions are intense, substantial contributions can come from air as well as water, depending on ambient concentrations. (In other words, where there are intense Hg emissions to the air, there is significant deposition of that Hg to water, and it bioaccumulates in aquatic systems. In addition, there is intake of Hg

Mercury in the environment is detrimental to fauna and flora as it bioaccumulates in many ecological systems.

directly from the air where concentrations are high.)

Sources of atmospheric Hg emissions include various human and natural activities. Natural sources include wild-fires, volcanoes, and volatilization processes from mineral deposits (that is, processes by which Hg is re-emitted into the atmosphere after deposition). Anthropogenic sources of atmospheric Hg emissions include fossil-fuel combustion, mining, waste disposal, and manufacturing processes such as chlor-alkali plants and the production of most kinds of batteries (UNEP, 2002).

Reports have indicated that Hg emissions from sources in South Africa – mostly from coal combustion and gold mining – contribute more than 10% to the world's Hg emissions, and that the country ranks second, after China, on the list of global Hg polluters (Pacyna *et al.*, 2006). Despite this estimate, there are few published studies on Hg pollution or of its impacts on South Africa's natural environment and human health. Mercury potentially poses risks because coal combustion is the primary generator of the country's electricity. Small-scale coal combustion in many poorer households for cooking and heating purposes may also be a significant (and by 2006, as yet unquantified) source. The contribution of South Africa's informal artisanal mining industry, as a source of Hg to the environment, was also unquantified by 2006.

The South African Mercury Assessment (SAMA) Programme was launched in March 2006 by a group of scientists from government, academia, industry, research councils, and parastatal organizations (www.waternet.co.za/samercury). It aimed to provide a platform for coordinating research and action on Hg as a global pollutant in southern Africa, including research into

- Sources of mercury pollution
- The biogeochemistry, speciation, fate, and transport (cycling) of mercury in the environment
- The impacts of mercury on aquatic and terrestrial ecosystems
- Human health risks linked to mercury
- Mercury emission mitigation and reduction options.

Chapter 10

Developments in air quality management

At a glance

The National Environmental Management: Air Quality Act (AQA) requires a shift from source-based air pollution control to an air quality management approach that focuses on the receiving environment. In addition to this act, the minister must establish a national framework for achieving the object of the act. The act supports effective cyclical air quality governance, which comprises elements such as information management; problem identification and prioritization; strategy development; environmental impact management; authorizations; compliance monitoring; and enforcement. In addition, clear roles and responsibilities for all stakeholders (government, the private sector and civil society) are described. The AQA also introduces the concept of effective air quality management planning as a way to achieve acceptable air quality by government and industry, and, through a multi-stakeholder forum, by means of declared priority areas. In addition, the AQA allows for the identification and declaration of listed activities, controlled emitters, and controlled fuels.



10.1 LEGISLATIVE AND REGULATORY DEVELOPMENTS

10.1.1 The Constitution

Air quality and its management are addressed in the highest law of the land, The Constitution of the Republic of South Africa (Act no. 108 of 1996). In the first instance, with regard to the environment, Section 24 of the Bill Of Rights in this Constitution guarantees that "Everyone has the right: (a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that – (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development." In the second instance, "air pollution" is specifically listed in Schedule 4B as a "function area of concurrent competence" for government.

10.1.2 Integrated Pollution and Waste Management Policy

The publication in May 2000 of the government's Integrated Pollution and Waste Management (IP&WM) policy marked a turning point for pollution and waste governance in South Africa. From an air quality management perspective, the time had come for a different approach, and the new policy presented a complete paradigm shift from the outdated air pollution control measures adopted under the Atmospheric Pollution Prevention Act (APPA) (Act no. 45 of 1965).

Following the publication of the IP&WM policy, the Department of Environmental Affairs and Tourism (DEAT) set about translating it into an action plan for reforming air quality governance. Known as the National Air Quality Management Programme (NAQMP) 2000–2010, this plan embodies the vision that the programme will develop, implement, and maintain an air quality management regime that contributes to sustainable development and measurable improvement in the quality of life for all, by harnessing the energy and commitment of all South Africans for the effective prevention, minimization, and control of atmospheric pollution. The manner in which IP&WM policy goals have been translated into the NAQMP goals are outlined in Table 10.1.

10.1.3 The Air Quality Act of 2004 – a paradigm shift

The National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004) requires a shift from source-based air pollution control to an air quality management approach that focuses on the receiving environment. Key features of the legislation that is in the process of being detailed include:

- Setting ambient air quality targets as goals designed to drive emission reductions
- Decentralizing air quality management responsibilities
- Requiring all significant sources to be identified, quantified, and addressed
- Recognizing source-based (command and control) measures in addition to alternative measures, including market incentives and disincentives, voluntary programmes, and education and awareness-raising
- Promoting cost-optimized mitigation and management measures
- Stipulating air quality management planning by authorities, and emission reduction and management planning by sources[1]
- Promoting access to air quality information and public consultation during air quality management processes.

The AQA is relatively compact and concise despite the complexity of the issue that it regulates. As such, it is often referred to as 'framework' legislation (that is, legislation providing an outline designed to accommodate further detail over time). This is the result of a decision taken early in the law-reform process to expedite the development and promulgation of the AQA, and to address the inadequacies of the

1. In this context, "stipulating air quality management planning by authorities" means that where other national departments and spheres of government are required to undertake air quality management planning activities, the national department (DEAT) will detail the air quality management planning requirements and provide guidance; "stipulating emissions reduction and management planning by sources" refers to a review of current permits held by Scheduled Processes to align their licences with the requirements of the new legislation.



Table 10.1: Translation of IP&WM policy goals into NAQMP goals and progress made (as at 2005)

Integrated Pollution and Waste Management (IP&WM) policy goals	National Air quality Management Programme (NAQMP) 2000–2010 goals
Goal 1: Effective institutional framework and legislation	This goal is to create, develop, implement, maintain, and continuously improve an effective, adequately resourced, and harmonized institutional framework and integrated legislative system, and to build institutional capacity. By early 2005, the government had already delivered a key output required to meet this goal, namely, the development and promulgation of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004) (see §10.1.3 opposite). However, as the AQA is largely 'framework' legislation, work is still required to ensure an "integrated legislative system" and is likely to include, amongst other things, the development of various regulations, lists, and schedules. Although the building of an effective, adequately resourced, and harmonized institutional framework for sustainable air quality management has begun in all affected spheres of government (see §10.3), there is still a long way to go. Although AQA directs or implies the required institutional framework, its 'resourcing' remains a challenge. The remaining years of the NAQMP will have to continue to address this component of the goal.
Goal 2: Pollution prevention and impact management	This goal is to promote holistic and integrated air quality management through pollution prevention, minimization at source, and impact management. Although the AQA directly links the Atmospheric Emission Licensing process to the environmental impact assessment (EIA) process and provides regulatory tools aimed at promoting cleaner production, much remains to be done to ensure the effective use of these tools.
Goal 3: Holistic and integrated planning	This goal is to develop mechanisms to ensure that air quality management considerations are effectively integrated into the development of government policies, strategies, and programmes; all spatial and economic development planning processes; and all economic activities. AQA thus introduces an air quality management planning regime that seamlessly fits existing planning regimes (see §10.4). However, further work is required to ensure that this planning is properly implemented and fully integrated with existing plans.
Goal 4: Participation and partnerships in air quality management governance	This goal is to establish mechanisms and processes to ensure effective public participation in air quality management governance. Although AQA provides formal participatory processes, less formal but nevertheless structured participation and partnerships need to be established to ensure that the act's objectives are met, particularly with respect to the development of the National Air Quality Management Framework required by AQA.
Goal 5: Empowerment and education in air quality management	This goal is to promote the education and empowerment of South Africa's people, so as to increase their awareness of and concern for air pollution issues, and to assist in developing the knowledge, skills, values, and commitment necessary to achieve efficient and effective air quality management. This goal is likely to be a primary focus area for the remaining years of the NAQMP.
Goal 6: Information management	This goal is to develop and maintain databases and information management systems, so as to provide information that is accessible to interested and affected parties who play a supportive role in effective air quality management. Although AQA provides for a comprehensive national, provincial, and local air quality information system, work is needed to develop, implement, and maintain this system.
Goal 7: International cooperation	This goal is to develop mechanisms to deal effectively, and in the national interest, with international issues that affect air and atmospheric quality. Although AQA provides various ways for South Africa to implement its commitments and obligations in respect of various air quality related multilateral environmental agreements, work is required to use AQA effectively for this purpose.

The National Environmental Management: Air Quality Act aims to fulfill the Constitutional right of all South Africans regarding access to an environment that is not harmful to their health or well-being.

APPA, by focusing on the 'big issues' yet at the same time offering scope for future detail both through the national framework and through the drafting of regulations.

In terms of Section 7(1), the minister must establish a national framework for achieving the object of the act[2]. Amongst other things, this framework includes mechanisms, systems, and procedures for: attaining compliance with ambient air quality standards and giving effect to the Republic's obligations in terms of international agreements; national norms and standards for controlling emissions from specified sources; air quality monitoring; air quality management planning; and air quality information management.

The framework must also ensure that, amongst other things: opportunities are provided for public participation in the protection and enhancement of air quality; there is public access to air quality information; the norms and standards are in place for preventing air pollution and degradation of air quality and for reducing discharges likely to impair air quality; efficient and effective air quality management is promoted; air quality monitoring is effective and there are regular reports on air quality.

In terms of air quality monitoring, the framework had to establish national standards for the way in which municipalities were to monitor ambient air quality and source emissions, and the way in which provinces would monitor ambient air quality and the air quality management performance of municipalities.

To keep the national framework relevant to changing circumstances, it must be reviewed at least once every five years.

Issues identified in the AQA as possibly requiring future detail include: use of environmental management cooperation agreements as described in the National Environmental Management Act (NEMA) (Act no. 107 of 1998); regulation of open fires and incinerators; various codes of practice; emission trading schemes; and incentives to encourage improvements in behaviour regarding air pollution by all sectors in society. Furthermore, three 'catch-all' provisions allow immense scope for expanding the AQA, namely – (i) regulations dealing with the avoidance or reduction of harmful effects on air quality that arise from activities not otherwise regulated in terms of the AQA; (ii) regulations dealing with any matter that could or should be prescribed in terms of this act; and (iii) regulations dealing with any other matter necessary for the implementation or application of this act. Finally, offences and penalties may also be prescribed in regulations.

10.2 AIR QUALITY GOVERNANCE CYCLE

The AQA supports effective air quality governance, depicted diagrammatically in the simplified environmental governance cycle in Figure 10.1.

Information management: 'Informed decision-making' is fundamental to good governance. Decisions can be 'informed' only if decision-makers have ready access to accurate, relevant, current, and complete information. Thus the information management component of the governance cycle is crucial, and it is often described as the engine that drives the cycle towards continuous

2. While the date of the act is 2004, it was in fact promulgated by the Minister of Environmental Affairs and Tourism on 11 September 2005. The National Framework for Air Quality Management was published in the *Government Gazette* on 11 September 2007; the wording in the act refers to the establishment of the national framework to achieve the object of the act.

improvements in environmental quality. The AQA frequently refers to information and information management requirements, such as: the inclusion of national norms and standards for air quality information management within the national framework; public access to air quality information; an entire section on national monitoring and information management standards; and consideration of sound scientific information when declaring any device or operation as a Controlled Emitter.

Problem identification and prioritization: Information must be analyzed to identify the air quality problems that are being encountered and to establish whether or not air quality management interventions are effective. The AQA will not provide solutions to air quality problems in South Africa if these problems are not defined, identified, and prioritized for action. A number of sections in AQA deal with identification and prioritization of problems, including the following:

- Identification of *pollutants* which, through ambient concentrations, bioaccumulation, deposition, or in any other way, present a threat to human health and well-being or to the environment

- Declaration of *priority areas*, where ambient air quality standards are or might be exceeded, or where any other existing situation is causing, or may cause, a significantly adverse impact on air quality in the area, leading to the requirement for appropriate air quality management action in the area in order to solve the problem

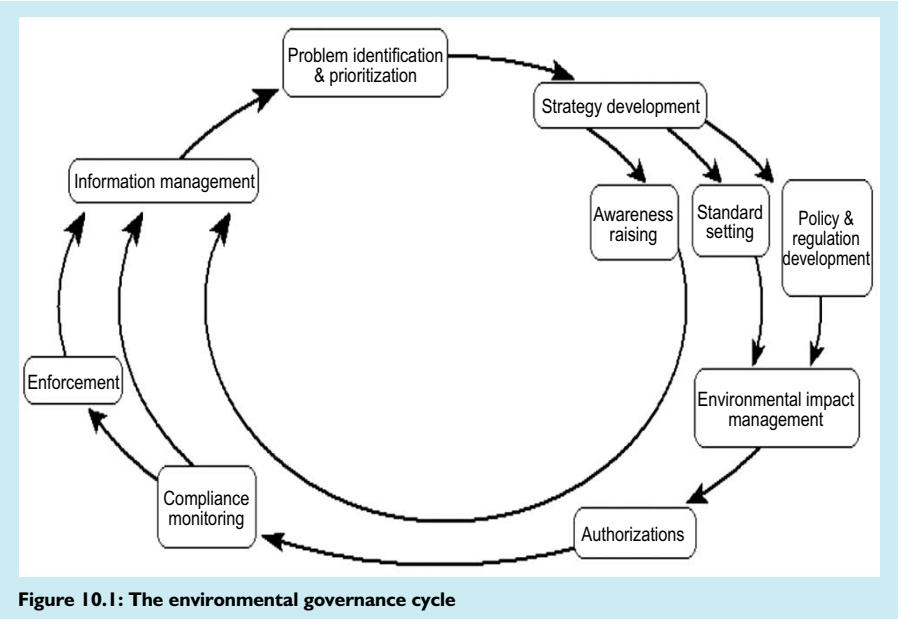


Figure 10.1: The environmental governance cycle

- Publication of a *list of activities* that generate atmospheric emissions and that may reasonably be believed by the minister to have a significant detrimental effect on the environment, such as on health, social conditions, economic conditions, ecological conditions, or cultural heritage

- Declaration of any device or activity, or any device or activity falling within a specified category, as a *controlled emitter* if it results in atmospheric emissions that, through ambient concentrations, bioaccumulation, deposition, or in any other way, presents a threat to health or the environment, or that the minister reasonably believes presents such a threat

- Declaration of a substance or mixture of substances as a *controlled fuel* if, when used in a combustion process, it generates atmospheric emissions that, through ambient concentrations, bioaccumulation, deposition, or in any other way, presents a threat to health or the environment, or that the minister reasonably believes presents such a threat



- Declaration of any substance contributing significantly to air pollution as a *priority air pollutant*, and requiring a specified category of responsible persons to submit and implement a pollution prevention plan in respect of that pollutant.

The new legislative framework thus supports the design and implementation of air quality management tools that prioritize sources contributing to high levels of ambient air pollution concentrations and the associated health risks, rather than treating all sources of emissions equally. This will help to make sure that sources posing the greatest risks are ranked as needing the most urgent attention. It will also provide a basis for cost-efficient mitigation and management measures, with the financial outlay of such measures possibly being offset by the resultant health-cost savings.

Air quality strategy development: Once problems have been identified and prioritized, strategies must be devised to address them. These strategies, in turn, need to be structured into detailed action plans that guide the implementation of solutions. The following examples illustrate the comprehensive planning regime required by the AQA:

- The national framework must detail national norms and standards for air quality management planning

- Each national department or province that is responsible for preparing an environmental implementation plan, or for an environmental management plan in terms of the NEMA, must include an air quality management plan within it, and each municipality must include an air quality management plan in its integrated development plan, as required by the Municipal Systems Act

- There must be an entire planning regime in respect of priority areas

- The minister may require persons or companies falling within a specified category to submit and implement a pollution prevention plan in respect of a priority air pollutant.

Plans such as these may detail the use of a number of strategies including, amongst others, raising awareness, setting standards, and developing policies and regulations. (For more information see §10.4.)

Environmental impact management: Cutting-edge environmental impact management has been implemented nationally and provincially since 1997 through the environmental impact assessment (EIA) process, in the course of which interested and affected parties scrutinize the safety, health, and environmental impacts of all significant developments. This participatory process provides government with the detailed information it requires to make an informed decision on whether a development should proceed or not and, in the case of an approval, what measures have to be taken to ensure that safety, health, and environmental impacts are sustained at acceptable levels. Apart from the environmental benefits of EIAs, the process also fosters industrial innovation, and has made some South African industries world leaders in sustainable development best practice. The AQA fully acknowledged the use and importance of the EIA tool, which is inextricably linked to the act's atmospheric emission licensing process.

Authorizations: An authorization (for example, permission, a permit, or a licence) is a key component of common 'command and control' regulatory practice. The principal authorization in the AQA is the Atmospheric Emission Licence (AEL).



Compliance monitoring: Laws and regulations can be ineffective if they are not properly enforced. Effective enforcement requires compliance monitoring, for which the AQA provides numerous tools and the use of Environmental Management Inspectors to carry it out.

Enforcement: Penalties provide the government's regulatory 'stick'. In all instances, they are meant to effect changes in the offenders' behaviour, and to restrict non-compliance with the relevant legislation and regulation. The penalties need to be such that potential offenders will behave differently – in other words, the penalty must serve as a deterrent. Deficiencies in the APPA included inadequate prosecution of offenders, lack of incentives for not polluting or for minimizing pollution, and an emphasis on reactive control, rather than pre-emptive measures for managing air quality. To address these shortfalls, the new policy states that, amongst other things, any pollution of the environment must be remedied by those responsible for it, and government must prosecute non-compliance by means of authorizations and legislation. Noting the inadequacies of the APPA, the AQA provisions attempt to ensure that 'the punishment fits the crime' sufficiently to act as a deterrent.

Although the AQA has considerable 'teeth', it is regarded as a "specific environmental management act" under NEMA and, as such, may be enforced by the Environmental Management Inspectorate – the so-called 'Green Scorpions'. As an example of the compliance and enforcement provisions contained in the AQA, an AEL may require its holder, on demand, to submit a certified statement to the inspector, indicating (i) the licence-holder's compliance monitoring records; (ii) particulars of instances of non-compliance; (iii) the reasons for instances of non-compliance; and (iv) any action taken, or to be taken, to prevent a recurrence of the instance of non-compliance.

10.3 COOPERATIVE GOVERNANCE

10.3.1 Roles and responsibilities

The roles and responsibilities of government, business, and civil society with respect to air quality may be summarized as good governance, duty of care, and good citizenship. Some of the main points are outlined below.

Air pollution is listed in Schedule 4B of the Constitution as a "function area of concurrent competence" for the government.
Photography: Zies van Zyl

National government: The DEAT is responsible for, amongst other things, (i) setting national norms and standards; (ii) monitoring national performance against norms and standards; and (iii) assessing plans to ensure compliance with national norms and standards.

Provincial government: Provincial environmental departments are responsible for, amongst other things, (i) setting provincial norms and standards; (ii) monitoring provincial performance against national and provincial norms and standards; and (iii) monitoring the performance of local government.

Local government: Local authorities are responsible for, amongst other things, (i) setting local emission standards; (ii) monitoring local performance against national and provincial norms and standards; and (iii) administering and enforcing air pollution regulatory instruments.

Business and industry: This sector is responsible for ensuring its compliance with the AQA. Furthermore, in terms of NEMA's provision for the "duty of care and remediation of environmental damage" (NEMA, Section 28), every person who causes, has caused, or has the potential to cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing, or recurring, or, insofar as such harm to the environment is authorized by law or cannot

reasonably be avoided or stopped, to minimize and rectify such pollution or degradation of the environment.

Civil society: The principal role of civil society is to uphold and defend the environmental rights contained in the Constitution, but the NEMA principles described above also imply an important participatory role in air quality governance.

10.3.2 Air Quality Officers and cooperative governance structures

The APPA effectively centralized air quality management, and the Chief Air Pollution Control Officer (CAPCO) was clearly identified as the government official responsible for air quality. With AQA, air quality responsibilities are associated with all three spheres of government, which presents both a service-delivery and a governance challenge in terms of identifying the responsible persons. Section 14 of AQA ensures that the minister designates a DEAT official as the National Air Quality Officer responsible for coordinating air quality management in the national government. Each provincial MEC (member of the province's executive council) responsible for the environment must also designate an officer in the provincial administration as the Provincial Air Quality Officer responsible for such coordination in the province. Finally, each municipality must designate a Municipal Air Quality Officer to be responsible for coordinating municipal air quality management.

As the 'contact person' for air quality management, the Air Quality Officer (AQO) in each sphere does not need to be a specialist in the field, but has to ensure that such specialists are available for air quality governance to be carried out efficiently and effectively. Although the roles and functions of AQOs are to be detailed further in the national framework and in regulations, some responsibilities are included in the AQA itself:

- If the minister has declared a priority area, the National Air Quality Officer is responsible for preparing a priority area air quality management plan, in consultation with the affected provincial and municipal AQOs, and for presenting this plan to the minister within a stipulated time-frame. The provincial AQO has the same responsibility in respect of provincial priority areas.
- If any AQO reasonably suspects that someone has contravened the AQA and that the contravention has had, or may have, a significant impact, the AQO is entitled to require that person to submit an atmospheric impact report. Any AQO can also require such a report when a review of a provisional atmospheric emission licence or an atmospheric emission licence is undertaken.
- An AQO may establish a programme for the public recognition of significant achievements in the area of pollution prevention.
- The licensing authority must inform the relevant Provincial Air Quality Officer, in writing, of any proposed review of an atmospheric emission licence and the reason for such a review.
- An AQO may require the holder of a provisional AEL or of an AEL to designate an emission control officer.

A National Air Quality Officer has been identified, and AQOs have been designated by each of the provinces and many local authorities. Structures designed for effective cooperative governance, as conceptualized by representatives of all three tiers of government at the first air quality governance conference held in 2005, are illustrated in Figure 10.2. The government structures have been established, including the Quarterly National-Provincial Air Quality Officers' Forum, and Quarterly Provincial-Municipal Air Quality Officers' Forums. The first air quality governance conference was held in 2005, and there it was decided to hold it annually. (This event is currently coordinated with the annual conferences of the National Association for Clean Air [NACA]).

The DEAT is in the process of delegating its powers for direct air pollution control, and is moving towards the provision of regulations, guidance, and support to facilitate decentralized air quality management. Specific steps in this process include the following:

- Development of guidance documents for the interpretation and implementation of the AQA, including atmospheric emissions licensing manuals as well as standard forms and procedures
- Publication of an information and guideline series, including books on air pollution sources and impacts, air quality management planning, and atmospheric dispersion modelling

- Planning of a guideline series on best available technologies within various industry sectors
- Conceptual design of the South African Air Quality Information System, which will include source, emissions, and ambient air quality information, and which will be hosted by the South African Weather Service
- Initiation of a project for the development of emission limits for listed activities.

10.4 AIR QUALITY MANAGEMENT PLANNING REGIME

The new approach to air quality management captured in the AQA is driven by objectives in the form of ambient air quality standards. Setting objectives is fruitless, however, without a plan as to how these objectives are to be met, improved, and/or maintained (see §10.2 above). To this end, the AQA requires a number of air quality management plans to be developed and implemented by both government and specified industries.

10.4.1 Government plans

Rather than adding to the government's planning burdens, the AQA simply stipulates a specific air quality focus in existing environmental management plans. To this end, the act requires each national department or province responsible for preparing an environmental implementation plan or environmental management plan (in terms of Chapter 3 of the NEMA) to include an air quality management plan as part of it. In the local government sphere, the AQA obliges each municipality to include an air quality management plan in its Integrated Development Plan (IDP) (as required in terms of Chapter 5 of the Municipal Systems Act).

The *national departments* that have to incorporate an air quality management plan in their environmental implementation plans include: Environmental Affairs and Tourism; Land Affairs; Agriculture; Housing; Trade and Industry; Water Affairs and Forestry; Transport; and Defence. National departments required to incorporate an air quality management plan in their environmental management plans include: Environmental Affairs and Tourism; Water Affairs and Forestry; Minerals and Energy; Land Affairs; Health; and Labour. These plans must, amongst other things, map out how the various government departments will: (a) coordinate and harmonize activities to minimize the duplication of procedures and functions, and promote consistency in the exercise of functions; (b) give effect to the principle of cooperative government in Chapter 3 of the Constitution, and enable the minister to monitor the achievement, promotion, and protection of good air quality; (c) improve air quality; (d) identify and reduce the detrimental impact of poor air quality on human health and the environment; (e) address the effects of emissions from the use of fossil-fuels in residential applications; (f) address the effects of emissions from industrial sources; (g) address the effects of emissions from any point or non-point source of air pollution; (h) implement the country's obligations in respect of international agreements (such as climate change and ozone-layer protection);

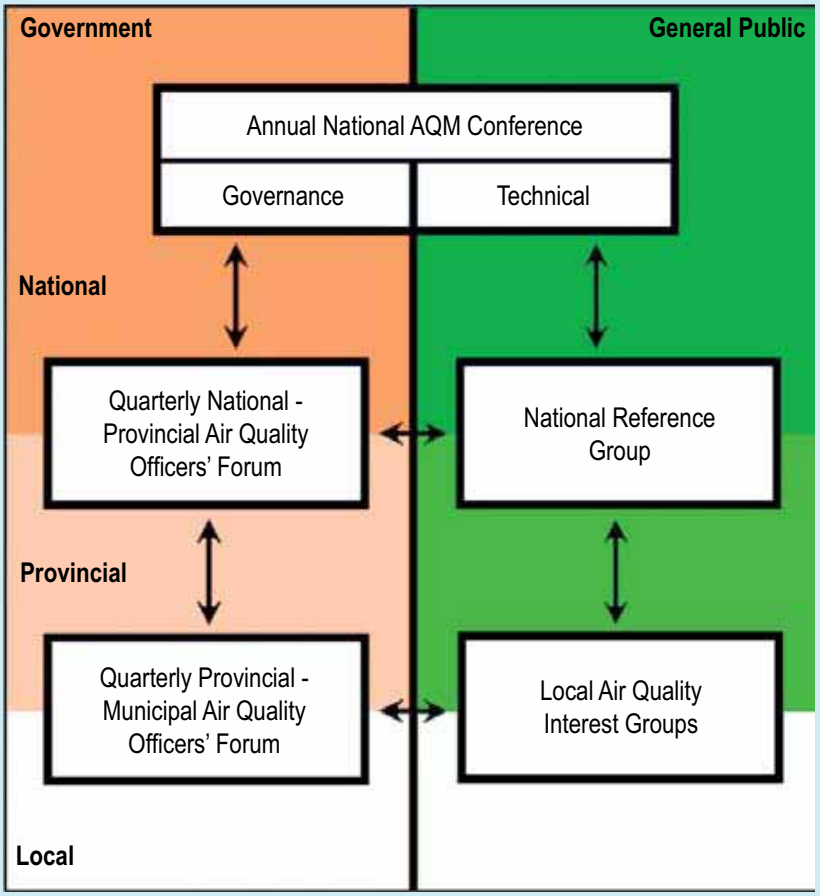


Figure 10.2: Cooperative governance structures outlined at the 2005 air quality governance conference



(i) give effect to best practice in air quality management; (j) give effect to the air quality management plan; and (k) comply with requirements that may be prescribed by the minister from time to time.

The AQA makes *local authorities* responsible for monitoring air pollution and for meeting national ambient air quality standards. To manage air quality and maintain it within these limits, local government is required to identify sources that contribute to non-compliance, and to formulate air quality management plans that detail intervention strategies to address the identified pollution sources. Air quality management systems established for baseline characterization and for tracking progress made by emission reduction programmes are to be documented in Air Quality Management Plans, which will become part of the local authority's IDPs.

In anticipation of the implementation of the new approach to air quality management, several local authorities had pre-emptively developed air quality management plans, including: the City of Johannesburg, Ekurhuleni Metropolitan Municipality, Tshwane Metropolitan Municipality, City of Cape Town, and Rustenburg Municipality.

Photography: Janet Peace

10.4.2 Industry plans

To manage prioritized atmospheric pollutants, Section 29 of AQA deals with pollution prevention plans. In essence, the minister or MEC may declare any substance contributing to air pollution as a priority air pollutant. By means of this declaration, the minister or MEC may require specific persons, industries, or industrial sectors that emit priority air pollutants to prepare and submit a pollution prevention plan that details the way in which they will take action to reduce such emissions. After the pollution prevention plan is approved by the minister or MEC, the specified persons, industries, or industrial sectors must then implement it.

10.4.3 Priority areas

In developing the AQA, the realities of air pollution 'hot-spots', air quality management capacity and best practice, and the challenges of intergovernmental coordination and cooperation had to be considered. Those drafting the act recognized that: (a) although South Africa, as a whole, does not suffer poor air quality, there are areas that are badly affected; (b) for the initial years of AQA implementation, limited human, technical, and financial resources will be available to roll-out efficient and effective air quality management nationally; (c) as air pollution respects no political boundaries, addressing it will require close coordination and cooperation among the local, provincial, and national spheres of government, especially in 'hot-spots' that cross municipal and/or provincial borders; and (d) air pollution is best managed if all the sources of air pollution that result in 'hot-spots' are taken into account – a process commonly described as the management of an 'airshed' (the concept is analogous to the management of water resources through 'catchment management').

The *priority area* approach was devised and provided for in Sections 18–21 of the AQA, and has three strategic drivers: (i) it allows for the limited air quality management capacity available (human, technical, and financial) to concentrate on dealing with acknowledged problem areas, so as to secure measurable air quality improvements in the short-, medium-, and long-term; (ii) it prescribes a cooperative governance regime by assigning air quality management authority to the sphere of government that can provide leadership and coordination. The first region to be designated as a national priority area for



the purposes of air quality management was the Vaal Triangle (*Government Gazette* No. 28732, 21 April 2006).

10.5 LISTED ACTIVITIES, CONTROLLED EMITTERS AND CONTROLLED FUELS

10.5.1 Licensing of listed activities

Arguably one of the most effective regulatory means of controlling industrial atmospheric emissions is the classic 'command and control' tool, whereby certain identified activities may operate only if they are permitted to do so by the regulatory authority. Such a permit normally contains conditions. This form of regulation, the basis for regulatory control of industrial emissions in the APPA, has, with modifications and improvements, been repeated in the AQA.

Listed activities: Not all industries emit pollution into the atmosphere, and not all industries that release atmospheric emissions have significant adverse effects on air quality. For this reason, the AQA requires the minister or MEC to identify industries needing to be controlled by publishing a set of "listed activities" that they reasonably believe are responsible for generating atmospheric emissions that have or might have significant detrimental effects on the environment (including effects on health, social conditions, economic conditions, ecological conditions, or cultural heritage). No one is allowed to conduct a listed activity without the relevant permission.

Minimum emission standards: Not only must the minister or MEC identify the industries to be controlled: they must also set minimum emission standards for specified pollutants emitted by these industries. As many listed activities are likely to be part of the processes in existing industries, the minister or MEC may also allow a transition period for these activities to achieve compliance with the new standards.

Atmospheric Emission Licence (AEL): The AEL is issued by the relevant metropolitan or district municipality, unless the provincial environmental department has been requested to do so, or unless the metro or municipality itself is the applicant.

Licensing process: In any licensing procedure, the company must make a formal application to the licensing authority. The purpose of the AEL is to provide a permit with the conditions necessary to ensure that the industry's emissions do not pose a significant detrimental effect on the environment. The licensing authority must seriously consider any decision to issue a licence. The most important tool, specifically designed for this purpose, is the EIA.

The success of air quality management initiatives relies on inter-governmental cooperation.
Photography: Zies van Zyl

Contents of licences: Unlike the earlier APPA Registration Certificates, the comprehensive licence required by the AQA deals with all the components of air quality management related to a site. It requires an atmospheric emission licence to specify (i) the activity in respect of which it is issued; (ii) the premises in respect of which it is issued; (iii) the person to whom it is issued; (iv) the period for which it is issued; (v) the name of the licensing authority; (vi) the dates when the licence is to be reviewed; (vii) the permissible maximum emission in terms of quantity, volume, emission rate, or pollutant concentration that may be discharged to the atmosphere: (a) under normal working conditions; and (b) under normal start-up, maintenance, and shut-down conditions; (viii) any other operating requirements relating to atmospheric discharges, including non-point source or fugitive emissions; (ix) point-source emission measurement and reporting requirements; (x) on-site ambient air quality measurement and reporting requirements; (xi) penalties for non-compliance;

Table 10.2: Comparison of Controlled Emitter and Listed Activity as regulatory tools

Consideration	Controlled Emitter	Listed Activity
Application	Appliances, activities, or appliances or activities falling within a specified category, which in combination release atmospheric emissions that present a threat to health or the environment	Activities which, on their own, release atmospheric emissions that have or may have significant detrimental effects on the environment (including effects on health, social conditions, economic conditions, ecological conditions, and cultural heritage)
Type of regulatory control	Emission standards	Atmospheric Emission Licence and emission standards
Typical examples	Motor vehicles; petrol stations; tank farms; small- to medium-sized fossil-fuel-fired boilers	Large power stations; oil refineries; iron and steel factories; paper and pulp plants; petro-chemical plants

(xii) greenhouse gas (GHG) emission measurement and reporting requirements; and (xiii) any other matters necessary to protect air quality or enforce standards. Furthermore, a licence may also specify conditions in respect of odour and noise, and the manner in which the holder must interact with environmental management inspectors (or 'Green Scorpions').

Shift to site authorizations: The AQA differs from the APPA in that it shifts away from the APPA's 'stack-based' authorizations to 'site' authorizations. Under APPA, a specific authorization was required for each 'scheduled' activity undertaken at a site. The consequence was that one industrial facility could hold several APPA Registration Certificates. Furthermore, as the APPA authorizations dealt only with specific activities, other atmospheric emissions were often overlooked (such as dust from stockpiles and un-surfaced roads). In contrast, AQA's atmospheric emission licences specifically cover not only the maximum allowed amount, volume, emission rate, or concentration of pollutants that may be discharged into the atmosphere, but also any other operating requirements relating to atmospheric discharges, including non-point source or fugitive emissions, as well as obligations with respect to on-site ambient air quality measurement and reporting.

The National Environmental Management: Air Quality Act has various mechanisms by which to manage emissions from all sources.

10.5.2 Controlled Emitters

Although big industries are often the most conspicuous sources of air pollution, they are not the only ones. Studies have shown that, in many 'hot-spots' in South Africa, small-scale but widespread sources of pollution – for example, motor vehicles – are major contributors to poor air quality.

Clearly, the Listed Activity regulatory tool is inappropriate for regulating vehicle emissions. Other regulatory tools are included in the AQA for managing releases from widespread but small-scale emitters, the principal one of which is the Controlled Emitter declaration.

In essence, if an emitter generates atmospheric releases that pose a threat to health or the environment, the minister or MEC may declare the emitter (which may be a device, activity, or appliance, or any of these that falls within a specified category) as a controlled emitter. In terms of Section 24 of the AQA, when the minister or MEC identifies and declares a controlled emitter, he or she must also establish emission standards for the emitter, specifying the permissible amount, volume, and emission rate or concentration of any specified substance or mixture of substances that it may emit, and the manner in which emissions must be measured. Once declared, no person may manufacture, sell, or operate a controlled emitter unless it complies with these standards.

10.5.3 Controlled Fuels

A key objective of environmental management is to encourage a move towards what is called cleaner production (CP). This idea is based on the premise that it is better to deal with potential pollution and wasteful use of resources pre-emptively, before pollution or waste occurs. The CP approach deals preventively with a problem at its source, in contrast with so-called 'end-of-pipe solutions' that attempt to deal with a problem after it has emerged.

This approach is highlighted in the preamble to the AQA with the words "[the] minimization of pollution through vigorous control, cleaner technologies and cleaner production practices is key to ensuring that air quality is improved". It is further encouraged by requiring Emission Control Officers to work towards the development and introduction of cleaner production technologies and practices.

Although both the controlled emitter and listed activity tools are directed towards CP, AQA also contains a specific source-based regulatory tool in the form of the Controlled Fuel. In terms of Section 26 of the AQA, if the minister or an MEC reasonably believes that the use of a fuel in a combustion process results in atmospheric emissions that present a threat to health or the environment, they may declare that fuel to be a Controlled Fuel.

In declaring a controlled fuel, the minister or MEC may: (a) set standards for the use of the controlled fuel in combustion processes; (b) set standards for the manufacture or sale of the controlled fuel; (c) establish specifications, including maximum or minimum levels or concentrations of the constituents of substances or mixtures of substances for the composition of controlled fuels; (d) prohibit the manufacture, sale, or use of the controlled fuel; (e) differentiate between various geographical areas; and (f) provide for the phasing-in of the various provisions. Once a controlled fuel is declared, no person may manufacture, sell, or use it without complying with the standards, specifications, and conditions set for its use.

10.6 SECTOR-SPECIFIC INTERVENTIONS AND INITIATIVES

The AQA provides the framework for diverse and flexible air pollution prevention measures. Specific measures undertaken or proposed by various government departments and other parties to reduce the impact of common source types are discussed below.

10.6.1 Household fuel combustion

Possible interventions aimed at reducing the extent, and therefore the impact, of household fuel combustion include measures to reduce the energy requirements of households, replacing traditional fuels with cleaner energy substitutes, and encouraging the proper maintenance and correct user-methods in operating their appliances.

Under the powers conferred by the Minister of Environmental Affairs and Tourism, the APPA, which will remain in force until 11 September 2009 (while some Sections of AQA have concurrently been in force since 11 September 2005), makes local authorities responsible for regulating emissions from domestic fuel combustion. Emissions from domestic fuel combustion are controlled through Smoke Control Regulations as well as through Smokeless Zones, which regulate fuel-burning appliances installed in the local authorities' areas of jurisdiction. The declaration of smokeless zones has been restricted to formerly white residential areas, and household fuel-burning has continued in many formerly black residential areas, including electrified ones. Significant fuel combustion is associated with informal settlement areas that have no access to electricity.

The Department of Minerals and Energy (DME) formulated an Integrated Clean Household Energy Strategy, which was approved by Cabinet during 2004. Since the strategy deals with a cross-cutting



issue, the Minister of Environmental Affairs and Tourism takes it into account when formulating interventions to improve air quality. The methods contained in the strategy include the following: (i) refining methods of combustion and use of appliances (for example, support for the low-smoke coal-fire ignition method known as Basa njengo Magogo, which means 'make fire like Granny' in Zulu and Xhosa), regular stove maintenance (and replacement when a stove becomes dysfunctional); (ii) replacing coal with electricity, low-smoke fuels, alternative fuels such as liquid petroleum gas (LPG), and non-polluting energy such as solar; (iii) reducing the energy requirements of dwellings through solar-passive architectural design (for new dwellings) and the insulation of existing homes. For poor households, the DME focus was on least-cost options. Emphasis was placed in the short- to medium-term on the Basa njengo Magogo intervention – a method of building fires that involves top-down fuel-loading in stoves and *mbawulas* (tin drums in which fires are lit for cooking and heating purposes, also known as braziers), which reduces smoke emissions by an estimated 50% or more and reduces coal use by some 20%, at no additional cost to the household. The Department of Housing has been undertaking research with a view to compiling a policy on integrating energy-efficiency measures into new housing developments. Research previously funded by the DME is being sourced by the Department of Housing to assist with the development of this policy.

Photography: Janet Peace

The low-cost and no-cost energy-efficient housing measures published by the International Institute for Energy Conservation (IIEC) are being implemented in some South African provinces on a project-by-project basis. Measures implemented in the country's cities include: smokeless *mbawulas* (City of Johannesburg), top-down fuel-loading method, air quality monitoring for raising awareness, and energy-efficient housing projects (on a case-study basis).

10.6.2 Electricity generation

Measures implemented to reduce emissions from coal-fired power stations include: demand-side management programmes and the renewable energy policy of the DME, and demand-side management programmes and improved pollution control technologies at Eskom's power stations (involving maintenance or upgrades). Although cleaner coal technologies are being investigated (for example, fluidized bed technology for implementation at the Komati Return-to-Service Station), and alternative fuels (notably LPG) are being considered, it is expected that coal-fired pulverized fuel (PF) power stations will continue to supply the bulk of electricity for the foreseeable future.

10.6.3 Industry

Industrial and energy generation processes releasing significant atmospheric emissions, historically regulated under the APPA, will continue to be regulated as listed activities under the AQA (see §10.5 above). In addition



to the 'command and control' approach, the government embarked on a national drive to promote its cleaner production strategy, which addresses improvements in the enforcement regime, harmonization of policies and strategies towards common cleaner production (CP) and sustainable consumption (SC) goals, the setting of incentives to promote CP and SC, and awareness-raising as well as improvement of access to information and technical support for consumers, government and industry.

10.6.4 Vehicle emissions

Some air quality management measures will require national application whereas others lend themselves to local applications. Vehicle exhaust emissions will, for example, be reduced through technology and fuel specifications stipulated by national policy. Further lowering of emissions could be realized through the implementation of traffic management measures by local authorities. While increased vehicle activity rates imply rising emissions from this sector, improvements in the fuel efficiency of vehicles, the incorporation of emission controls in new vehicles, and changes in fuel composition are expected to bring reductions.

Since unleaded petrol was introduced in 1996, catalytic-converter-equipped petrol vehicle sales have steadily risen and, as at April 2003, comprised some 47% of new passenger vehicle sales. The newer vehicles typically comply with Euro 3 technology. Changes to fuel composition have included a reduction in the sulphur content of diesel from 5 000 parts per million (ppm) to 3 000 ppm, and further reductions down to 500 ppm (introduced on 1 January 2006) form part of the *Implementation Strategy for the Control of Exhaust Emissions from Road-going Vehicles in South Africa*, proposed by the DEAT in collaboration with the DME. This strategy stipulates Euro technologies for new petrol- and diesel-driven vehicles, whilst also providing for future reductions in the sulphur, benzene, and aromatics content of fuels. It is expected that such technology and fuel specifications will be implemented by means of the AQA's Controlled Emitter regulatory measure.

10.7 AIR QUALITY MANAGEMENT AND CLIMATE CHANGE

As South Africa is a party to various international conventions and protocols such as the United Nations Framework Convention on Climate Change and the associated Kyoto Protocol, it is important for the country to legislate measures for monitoring, verifying, and reporting GHG emissions and reductions.

The AQA frequently refers (directly and indirectly) to "the Republic's obligations in terms of international agreements". The country's global responsibilities are recognized in the preamble to the AQA in the words: "...atmospheric emissions of ozone-depleting substances, greenhouse gases and other substances have deleterious effects on the environment both locally and globally". The act also includes the following in its definitions section: "greenhouse gas means gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation, and includes carbon dioxide, methane and nitrous oxide".

Furthermore, the AQA contains direct references and provisions regarding South Africa's commitments in respect of air quality as contained in multilateral environmental agreements (MEAs). For example, the national framework is required to include, amongst other things, mechanisms, systems, and procedures to give effect to "the Republic's obligations in terms of international agreements", and must establish national standards for collecting and managing relevant data. In addition, the process of developing air quality management plans and designating controlled emitters and controlled fuels must take into account South Africa's obligations in terms of any international agreements that may apply.

Current climate change debates and international negotiations tend to focus on three specific issues: (i) mitigation – the ways and means to reduce GHG emissions and atmospheric GHG concentrations; (ii) vulnerability – the extent to which nations are vulnerable to the impacts of climate change; and (iii) adaptation – how nations will adapt to climate change. As legislation specifically designed to regulate air quality, the AQA's focus is on mitigation, and it does not pay serious attention to vulnerability and adaptation. Even in so far as it deals with mitigation, the act is limited to the provision of ways and means to reduce GHG emissions, and does not provide for ways and means to consider reducing atmospheric GHG concentrations through, for example, carbon sequestration. It will be the work of other sectoral policies and legislation to deal with these and other issues outside the scope of the AQA.

Chapter 11

Conclusions and next steps

At a glance

The international challenge in air quality management is to deliver cleaner air without detriment to social and economic development. This ***State of Air Report 2005*** and the supplementary technical document provide the foundation for future state of air reports by presenting and benchmarking air quality data. Key national, regional, and global air quality issues have been identified as: human health impacts; high ambient sulphur dioxide and particulate matter concentrations; the location of heavy industries and low-income communities in close proximity to each other that presents persistent health risks; and emerging air pollution issues that are closely associated with the transport sector. South Africa is sensitive to global climate change, particularly because global warming is projected to raise the frequency and intensity of droughts and floods. The Air Quality Act provides the framework for effective and integrated air quality management in line with international best practice.



The international challenge in air quality management is to deliver cleaner air without detriment to social and economic development. The *State of Air Report 2005* builds on the information contained in previous national state of environment reports, describing the state of air in the country to assist with the implementation of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004). In so doing, areas where air quality is compromised or may become compromised are identified and pollutants of concern prioritized, thus facilitating the efficient use of air quality management resources. This report and the supplementary technical supporting document (see Appendix) also provide a foundation for future state of air reports by presenting and benchmarking air quality data. Furthermore, the information provided is of use for Air Quality Management Plans being developed by municipalities and provinces.

All cleaner production and renewable energy options, such as the generation of electricity from wind turbines, should be explored to ensure a sustainable future.

11.1 KEY AIR POLLUTION CHALLENGES

In characterizing the national state of air quality, reference is made to available information from source inventories, ambient air quality monitoring stations, and relevant literature. Monitoring data were obtained from various agencies for over 120 stations across the country. Key national, regional, and global air quality issues have been identified as follows:

- Human health impacts, related in particular to inhalation exposures to household coal and wood emissions, remain the most serious and pressing national air pollution problem. Such impacts have been estimated to result in massive direct health spending.

- High ambient sulphur dioxide (SO_2) and concentrations of fine particulate matter (PM) due primarily to fuel combustion within the household, industrial, and power-generation sectors, represent ongoing air pollution problems in many parts of South Africa.

- Elevated fine particulate (PM_{10}) concentrations occur across the country, with widespread and frequent exceedances of health thresholds. Sulphur dioxide limits are exceeded less frequently and in a more localized way (in the vicinity of significant sources).

- The location of heavy industries and communities of people in close proximity to each other presents persistent health risks and consequent conflict, exacerbated by increased pressure to situate residential areas within former industrial and mining buffer zones.

- Emerging air pollution issues are closely associated with the transportation sector, particularly road use. Growing vehicle activity and the ageing of the national vehicle fleet is projected to offset planned and proposed national emission reduction measures aimed at regulating fuel composition and new vehicle technology.

- Air quality limits for nitrogen oxides (NO_x) and ozone, aimed at protecting people against acute adverse health effects, are currently relatively infrequently exceeded within South African cities,



but a trend towards increasing concentrations of these pollutants is apparent, to which the growth in vehicle activity is expected to contribute significantly. Volatile organic compound releases from fuel filling stations and NO_X as well as hydrocarbon releases from major airports further highlight the air quality implications of the country's transportation policies.

- Questions remain regarding potential environmental impacts and the transboundary transportation of pollution generated by medium and elevated stack emissions from petrochemical, metallurgical, and mineral-processing operations, and by coal-fired power stations. Concerns have been raised over heavy metal emissions, including mercury and chromium-VI. In these fields, a consolidation of existing knowledge as well as further research are necessary.

- South Africa is sensitive to global climate change, particularly because global warming is projected to bring a rise in the frequency and intensity of droughts and floods.

- National total CO_2-equivalent emissions were reported to have increased by 9.4% during the period 1990–1994. This growth was due primarily to the significant rise in greenhouse gas (GHG) emissions from the energy sector, whose contribution increased from 75% to 78% during this time. The three source groups contributing most significantly to the energy sector's CO_2-equivalent emissions were energy industries (including electricity generation for the national grid), industry, and transport. The CO_2-equivalent emissions increased from all three groups between 1990 and 1994, with transport emissions increasing the most (by 38%). Road transportation was reported to contribute more than half of the transport sector's emissions.

- South Africa's per capita contribution to GHG emissions is estimated to be above the global average, that is, higher than most developing nations and equivalent to certain developed nations. The emissions expressed in per capita and per GDP terms are almost 20 times higher than the values for the USA (Bond, 2007).

Particularly pressing challenges facing South Africa include: (a) meeting new, more stringent air quality standards, particularly for particulate matter; (b) understanding and addressing the human health risks posed by exposure to hazardous atmospheric emissions; (c) responding to the likelihood that, for some pollutants, there may be no identifiable threshold exposure below which harmful effects cease to occur; (d) mitigating air pollution impacts that occur disproportionately in low-income communities; and (e) addressing industrial and power-station emissions without detriment to society and the economy.

11.2 STATUS OF AMBIENT AIR QUALITY MONITORING

Air quality monitoring in the country was assessed by the CSIR as part of the DEAT's Air Quality Management Programme Phase II Transition Project and documented in the national *Air Quality Information Review* (Output (c.1.)) (DEAT, 2006b). The status of monitoring was evaluated on the basis of the number of stations in operation and the integrity of the data produced. The monitoring data were further assessed in order to characterize determining trends in air pollution concentrations, and the findings were documented in the supplementary report *Technical Compilation to Inform the State of Air Report* (DEAT, 2006a) (see Appendix), where an overview of the status of ambient air quality monitoring for the year 2004 was also provided, with reference made to the guidelines for monitoring, published by Standards South Africa (SANS 1929:2005).

The status of monitoring was evaluated on the basis of the number of stations in operation and the integrity of the data produced

Conclusions were drawn as follows:

- Air quality monitoring occurred mostly in industrial areas and central urban areas. Air quality was poor (and often unmonitored) in high-density low-income residential areas, due to coal combustion for cooking and space heating as well as to unpaved roads. Data coverage is insufficient to identify all potential priority areas, nor is it supplemented by an emissions inventory or air dispersion modelling.

- At provincial and local government levels:

  - Data coverage in all provinces other than Gauteng is inadequate to facilitate effective air quality management

  - Monitoring is generally limited to central urban and industrial areas and does not extend to

rural areas. Effective air quality monitoring is conducted by a few local authorities, including eThekwini, Richards Bay, the City of Cape Town, and the City of Johannesburg

- Monitoring is generally limited to a few pollutants (typically SO_2, NO_x , and PM), while key urban pollutants such as ozone, $PM_{2.5}$, and benzene are not widely monitored

- Not all local government monitoring networks have the required quality control systems in place, nor are they audited by calibration laboratories accredited by the South African National Accreditation System (SANAS).

- To assess air quality impacts on human health, air pollution monitoring data is lacking in the following respects:

  - Air quality monitoring is focused mostly in metropolitan and industrial areas, and monitoring of low-income residential locations is often excluded, particularly those with high population densities in urban areas, and informal settlements in semi-rural and rural areas

  - Monitoring is generally limited to just a few pollutants (typically SO_2, NO_x, and PM_{10}).

  - Carcinogens that typically occur in urban environments (such as benzene and 1,3-butadiene) are not commonly monitored.

- To assess air quality impacts on the ecological environment, air pollution monitoring data is lacking in the following respects:

  - Ground-level ozone is a common pollutant that poses the highest risk to vegetation. Most ground-level ozone monitoring is conducted in urban environments and does not relate to agricultural or natural environments

  - Wet-deposition monitoring is limited to the northeastern parts of South Africa

  - Limited dry-deposition monitoring has been conducted within the limited conditions of directed research campaigns and restricted to sulphate and ozone.

The AQA provides the framework for effective and integrated air quality management in line with international best practice

The main conclusion is that existing data coverage is insufficient to identify all potential priority areas accurately or to quantify impacts of air pollution on human health and the environment.

Several recommendations are made:

- that the spatial distribution of monitoring stations and the range of pollutants measured be extended

- that some issues be addressed through campaign monitoring programmes (for example, the monitoring of volatile organic compounds from smouldering mine-dumps)

- that automated continuous monitoring be augmented by other air quality monitoring and characterization techniques

- that passive sampling be used for spatial screening of regional pollution and for baseline characterization in small municipalities and less polluted areas

- that remote sensing be considered as an important emerging tool for spatial screening and regional characterization

The specific objectives of all monitoring activities across South Africa must be clearly defined to ensure efficient and effective data collection and management.

- that an emissions inventory be developed and atmospheric dispersion modelling applied, as these represent critical components of cost-effective, ongoing air quality characterization, and can supplement monitoring by facilitating the prediction of spatial variations in air pollutant concentrations. In addition, dispersion modelling allows the projection of air quality changes that could result from new industrial, commercial, or residential developments, or from the implementation of planned emission reduction strategies.

11.3 DEVELOPMENTS IN AIR QUALITY MANAGEMENT

The AQA provides the framework for effective and integrated air quality management in line with international best practice. The main aspects of this act include:

- Setting ambient air quality targets as goals that drive emission reductions
- Decentralizing air quality management responsibilities
- Requiring all significant sources to be identified, quantified, and addressed
- Recognizing source-based ('command and control') measures, in addition to alternative measures that include market incentives and disincentives, voluntary programmes, and education and awareness-raising
- Promoting cost-optimized mitigation and management measures
- Stipulating air quality management planning by authorities and emission reduction and management planning by those responsible for pollution-generating sources
- Promoting access to air quality information, and public consultation during air quality management processes.

Although the AQA provides the framework for fair, coherent, and effective air quality management, the success of the act requires regulations to be set in the short term, and for these to be reviewed and revised in the medium to long term. Furthermore, it requires long-term resource allocation, close interdepartmental and intergovernmental cooperation, and the support of business and civil society.

Progress made in the development of air quality management in South Africa includes, but is not limited to:

- The appointment of national, provincial, and local air quality officers, and the establishment of cooperative governance structures
- Publication by national government of a series of air quality governance guidelines
- Initiation of projects to aid the transition from air pollution regulation under the Atmospheric Pollution Prevention Act (APPA) (Act no. 45 of 1965) to air quality management under the AQA, including: the Transitional Phase Project, the APPA Registration Certificate Review Project, the Emission Standard Setting and Listed Activity Project, and the Air Quality Management Planning Project
- Revision of ambient air quality standards
- Conceptual design of the South African Air Quality Information System (SAAQIS), to be hosted by the South African Weather Service
- Declaration of the Vaal Triangle as the first national priority area, and the initiation of the Vaal Triangle Airshed Priority Area Air Quality Management Plan Development Project
- Improvements in the number and quality of air quality management courses offered by higher education institutions.

Several areas require further work, including the cost-optimization of air quality monitoring systems; integration of air quality considerations into transport, energy, and spatial development planning; emission offsetting and trading; use of multi-pollutant control strategies; applicability of various market mechanisms for realizing emission reductions; and the alignment of local air quality management strategies with strategies for dealing with climate change.

Existing data coverage is insufficient to identify all potential priority areas accurately

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ACRONYMS

AEC	Atomic Energy Corporation
AEL	Atmospheric Emission Licence
Aerosols	Microscopic droplets or particles suspended in the atmosphere
Aged pollution-laden air	Air laden with pollution from distant sources
APPA	Atmospheric Pollution Prevention Act (Act no. 45 of 1965)
APU	Auxiliary power unit
AQA	National Environmental Management: Air Quality Act (Act no. 39 of 2004)
AQGs	Air quality guidelines
AQO	Air Quality Officer
ARI	Acute respiratory illnesses
ARREX	Aerosol Recirculation and Rainfall Experiment
ASTM	American Society for Testing and Materials
ATSDR	US Federal Agency for Toxic Substances and Disease Registry
BC	Black carbon
Biomass burning	Veld-fires and crop-burning (as used in this report)
BTEX	The benzene, toluene, ethylbenzene, and xylene group of VOCs
BVOC	Biogenic volatile organic compounds
CAPCO	Chief Air Pollution Control Officer
CAPIA	Cross-border Air Pollution Impact Assessment project
CBD	Central business district
CCN	Cloud condensation nuclei
CFCs	Chlorofluorocarbons
CP	'Cleaner production'
CSIR	Council for Scientific and Industrial Research
CNS	Central nervous system
DEAT	Department of Environmental Affairs and Tourism
Diffuse sources	Emissions likely to arise from less well-defined points, such as chemical spills and area sources
DME	Department of Minerals and Energy
DU	Dobson units
EC	European Commission
EIA	Environmental impact assessment
ELIDZC	East London Industrial Development Zone Corporation
EMS	Environmental Management Services
Eskom TSI	Eskom Technology Services International
ESL	Effect screening level
ETS	Environmental tobacco smoke
Fugitives	Air-pollutant emissions that are not actively emitted into the atmosphere but that 'escape' from the source, for example wind-blown dust off the top of a mine dump. They are often due to equipment leaks, evaporative processes, bulk-handling or -processing of raw materials, and windblown disturbances
Fuel-switching	A mechanism for reducing emissions by changing from 'dirty' fuel, such as coal, to a cleaner fuel such as oil or natural gas
GAW	South African Weather Service Climate Systems Global Atmosphere Watch
GHG	Greenhouse gas
GV	Guideline value
GWP	Global warming potential (a measure of the contribution of a greenhouse gas to global warming). The GWP is a relative scale, which compares the gas in question to the same mass of carbon dioxide (assigned a GWP of 1). GWP depends on the absorption of infrared radiation, the spectral location of its absorbing wavelengths, and the atmospheric lifetime of the species
HFO	Heavy fuel oil
IDP	Integrated Development Plan
IIEC	International Institute for Energy Conservation
IP&WM	Integrated Pollution and Waste Management policy
IRIS	US EPA's Integrated Risk Information System
IT	Interim target (i.e. for levels of air pollution)
IVL	Swedish Environmental Research Institute
LOAEL	Lowest observed adverse effect level
LPG	Liquid petroleum gas
MEA	Multilateral environmental agreement
MEC	Member of the executive council
Met.	Meteorological measurements
Monitoring campaigns	Scientific projects with a limited measuring time, generally focusing on a specific issue
MRL	Minimal (or maximum) risk level, depending on context
MWe	Megawatt-equivalent
NACA	National Association for Clean Air
NAQMP	National Air Quality Management Programme 2000–2010
NASA	National Aeronautics and Space Administration
NaTIS	National Transportation Information System
NEDLAC	National Economic Development and Labour Council
NEMA	National Environmental Management Act (Act no. 107 of 1998)
NMTOC	Non-methane total organic compound
NMVOCs	Non-methane (i.e. methane-excluded) volatile organic compounds
NOAEL	No observed adverse effect level
NOAEL/UF	No observed adverse effect level/uncertainty factor
ODS	Ozone-depleting substances
OEHAA	Office of Environmental Health Hazard Assessment
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PF	Pulverized fuel
PM	Particulate matter



$PM_{2.5}$	Particulate matter less than 2.5 micrometres in aerodynamic diameter
PM_{10}	Particulate matter less than 10 micrometres in aerodynamic diameter
Point sources	Single, identifiable sources of pollution
POPs	Persistent organic pollutants
ppb	Parts per billion
ppm	Parts per million
QA	Quality assurance
QC	Quality control
REL	Reference exposure level
RfCs	Inhalation reference concentrations
SAAQIS	South African Air Quality Information System
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SAFARI 2000	Southern Africa Regional Science Initiative
SAMA	South African Mercury Assessment programme
SANAS	South African National Accreditation System
SANS	South African National Standard
SAPIA	South African Petroleum Industry Association
Sensitive receptors	People or environments potentially affected by a source of pollution
SVOC	Semi-volatile organic compounds
TARA	Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division
TC	Tolerable concentration
TOCs	Total organic compounds
TRS	Total reduced sulphur
TSP	Total suspended particulates (defined as all particulates with an aerodynamic diameter of less than 100 micrometres)
TÜV	Technischen Überwachungsvereine (Technical Inspections Organizations)
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
URI	Upper respiratory infection
US EPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WHO	World Health Organization



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Appendix

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM
Environmental Quality and Protection
Chief Directorate: Air Quality Management & Climate Change

THE NATIONAL AIR QUALITY MANAGEMENT PROGRAMME (NAQMP)
OUTPUT c.4

Technical Compilation to Inform the State of Air Report 2005

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Note to the reader

This *Technical Compilation to Inform the State of Air Report* provides information on all the ambient air quality monitoring activities in South Africa during the period 1994–2004. The quality of the data is discussed and the data are used to describe the state of air, using compliance and long-term trend analysis.

This report contains the technical information used to inform the *State of Air Report 2005*.

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Executive summary

Background and purpose

The Department of Environmental Affairs and Tourism (DEAT) has embarked on a phased approach to the implementation of the National Air Quality Management Programme (NAQMP). Phase I of the implementation is the so-called "Definition Phase", which was initiated in June 2001 and was completed with the promulgation of the National Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004) in 2005. In Phase II, the "Transition Project", the DEAT invited specialist professionals, and consulting firms with project management experience and specialist expertise in the fields of air quality management, to submit tenders in respect of the implementation of the NAQMP. CSIR Environmentek (now the *Operating Unit Natural Resources and the Environment*) was appointed in May 2004 to assist the DEAT in implementing aspects of the NAQMP, through the Phase II Transition Project. The Phase II project comprises a number of activities. The activity that is specific to this report is the compilation of the database and the *Technical Compilation to Inform the State of Air Report* 2005 for the 11-year period 1994 to 2004 (Phase II Transition Project Output (C.4.)).

As such, this *Technical Compilation to Inform the State of Air Report 2005* is supplementary to the *State of Air Report 2005*. In addition, the data that have been collected form the foundation for the National Air Quality Information System (NAQIS) to be developed in 2007. This report and the *State of Air Report 2005* will also be an important source of information for many Air Quality Management Plans being initiated or developed by municipalities and provinces.

This report provides information on all of the ambient air quality monitoring activities in South Africa during the period 1994–2004. The quality of the data is discussed and the data are used to describe the state of air, using compliance and long-term trend analysis. In so doing, this report identifies areas where air quality is compromised and highlights pollutants of concern.

The purpose of the *State of Air Report 2005* is to provide an overview of the state of air quality in South Africa, providing insight into sources of emissions and associated health, welfare, and broader environmental impacts. The identification of significant sources, pollutants, and impact areas represents an important first step in air quality management. Although the report focuses mainly on criteria (common) pollutants and local and urban ambient air pollution issues, reference is made to non-criteria pollutants and regional and global challenges.

A considerable range of air quality information has been collected across the country for a number of years and is currently ongoing. The assessment in this report is based on ambient air quality data collected during the *Air Quality Information Review* (DEAT, 2006a) for the period 1994–2004.

Summary of findings

It should be borne in mind when reporting on ambient air quality that it is only possible to report where data are available. Although there is a significant amount of ambient air quality monitoring activity, and this is increasing, it is mostly concentrated in urban and industrial centres. Limited monitoring data in background, township, and smaller urban centres makes comprehensive evaluation of ambient air quality impossible.

The available data indicate that there are occurrences of a poor state of air in parts of South Africa, particularly when considering SO_2 and particulates near industrial areas and in townships. Some downward trends in pollutants such as Pb, NO_2, and SO_2 have been detected. The major findings regarding the state of air for each of the pollutants are listed here.

For ozone (O_3):
Surface O_3 is monitored at 44 stations in the country and two stations monitor total column ozone. Average background concentrations of O_3 range between 12 and 33 ppb, depending on the location of the stations. Ozone concentrations measured at all other sites are typically within the same range as the background stations, or lower, except at the Johannesburg station, Buccleuch. This station is specifically sited to measure traffic influences, amongst others, and the monthly maximum reaches 271 ppb. According to the AQA, there is no monthly or annual guideline or standard for O_3, but the 8-hour limit is 56 ppb. At 12 stations (including background), maximum monthly average exceeds 40 ppb. In these cases, the 8-hour limit could have been exceeded. At four stations the long-term trends were detected (two of them positive and two negative).

Total column O_3 is measured at Irene and Springbok. Total O_3 column thickness is greater at the higher latitude station (Springbok) and both stations exhibit clear seasonal variations with maxima in spring.

For oxides of nitrogen (NO_2 and NO):
There are 43 monitoring stations that measure NO_2. Monitoring is performed in four main cities: Cape Town, Durban, Johannesburg (including Alexandra), and Tshwane. Of these, only 24 stations measure NO. Most of these stations represent urban and industrial pollution.

No exceedances of the monthly AQA standard of 83 ppb for NO_2 occur at any monitoring stations, and no exceedances of the annual standard of 52 ppb occur. Background NO_2 concentration are typically less than 1 ppb. The highest maximum concentration occurs at Alexandra (51 ppb) in Johannesburg, while the highest average concentrations occur at Newtown and Buccleuch (29 and 35 ppb, respectively).

A downward trend is detected in NO_2 concentrations at three stations.

The only station where NO concentrations exceed standards is Buccleuch. Newtown records relatively high average concentrations. Both stations indicate the high contribution of traffic emissions. A downward trend is detected in concentrations at two stations and an upward trend at one station.

For sulphur dioxide (SO_2):
SO_2 is the most commonly measured pollutant and there are 81 continuous monitoring stations and 8 stations that measure SO_2 using passive sampling. There are stations in 4 main cities, a few industrial sites and a number of stations on the Mpumalanga Highveld to monitor power-station pollution. There are 7 background stations and 7 stations in townships. Despite the relatively large number of SO_2 monitoring stations, there are still areas where monitoring is limited or non-existent (e.g. no monitoring in the Northern Cape or Limpopo provinces).

Background concentrations of SO_2 are typically less than 2 ppb. SO_2 concentrations in Durban are reported to be the highest. Out of 20 monitoring stations with long-term monthly averages between 3 and 25 ppb, the monthly limit is exceeded at 5 stations (Southern Works, Wentworth, Drift, Ilfracombe, and Umkomaas). Other stations where exceedances occur are Boiketlong (Free State), the Club station (Secunda) and Columbus (Middleburg). These represent industrial sites, residential affected by industrial, and even residential sites. Downward trends are evident at 7 stations and upward trends at 2 stations.

For particulate matter (PM):
PM is a critical parameter with regard to the impact on health, but only 32 stations measure PM_{10} (and 3 stations measure $PM_{2.5}$).

The highest PM_{10} levels were measured at the industrial site of PE Delta, in EC and Mittal, Gauteng (87 and 132 $\mu g/m^3$). It should be noted that not all industrial sites recorded high levels of particulate pollution (e.g. average of 43 $\mu g/m^3$ was recorded at Motherwell, Eastern Cape). The township of Diepsloot has pollution levels as high as the worst industrial sites. Averages recorded at other township sites are lower, but townships in Gauteng and Free State are more polluted than in the Eastern and Western Cape because of the domestic combustion of coal. The residential sites affected by industries, and urban sites have similar levels ranging from 20 to 60 $\mu g/m^3$.

No compliance analysis can be done on the monthly data as the AQA standards for PM_{10} are daily (180 $\mu g/m^3$) and annual (60 $\mu g/m^3$). However, when the maximum monthly average is compared with the daily standards, there are 4 stations that exceed this standard for at least a whole month or more. If the results are compared to the new proposed standard of 75 $\mu g/m^3$, then at least 7 more stations will be non-compliant. *It must be noted that if the new proposed annual standard of 40 $\mu g/m^3$ is accepted, then practically all stations will be non-compliant with this standard.*

For lead (Pb):
The highest monthly averages occurred in the Johannesburg and Pretoria city centres, with Cape Town and Pietermaritzburg urban pollution somewhat lower. The other types of sites have similar pollution levels. There are no exceedances of the monthly AQA standard of 2.5 $\mu g/m^3$ at any of the stations, but at 8 out of 24 stations the annual AQA standard of 0.5 $\mu g/m^3$ was exceeded.

Strong downward trends are evident at all monitoring sites from 1993, and in Johannesburg and Pretoria from 1995. It is expected that it will decrease further after the enforcement of unleaded petrol use (1 January 2006).

For carbon monoxide (CO):
CO is monitored at 16 stations. The highest CO levels were measured at the Buccleuch station, with a maximum of 63 ppm and long-term average of 11 ppm. The other polluted stations are the township station of Alexandra and Newtown (urban station). Comparison of City Hall stations (urban) in Johannesburg and Cape Town shows that levels in Cape Town are slightly higher than in Johannesburg. Very similar CO pollution levels were measured at residential stations in Cape Town and Durban. No statistically significant trends were recorded.

For greenhouse gases (GHGs):
The greenhouse gases, CO_2, CH_4, and N_2O are monitored at Cape Point. N_2O and CH_4 levels are very stable around 300 ppb and 1.7 ppm, respectively, and a small upward trend is detected for both of them. The CO_2 levels increase steadily and reached 380 ppm in 2004. Methane was also monitored in Johannesburg and the values ranged between 2–3 ppm. This monitoring was discontinued.

For volatile organic compounds (VOCs):
Monitoring for volatile organic compounds focuses mainly on benzene, toluene, ethylbenzene, and xylene (BTEX). Very few data are available, since monitoring started only in 2004. The measured levels of benzene in 1 out of 3 stations in Gauteng (Buccleuch), 1 station in Free State (Leitrim), and 5 out of 7 stations in Durban show non-compliance with the proposed standard of 5 $\mu g/m^3$.

For metals (Cr^{6+}, Mn and Hg):
Very limited data were obtained for Cr, Mn, and Hg monitoring. The Cr^{6+} and Mn concentrations are measured around relevant industries and Hg at the background site of Cape Point. The Cr^{6+} levels range between 0.004 and 0.007 $\mu g/m^3$, the Mn levels range between 0.007 and 0.11 $\mu g/m^3$, and neither presents significant health risk. The background level of Hg is around 1.5 $\mu g/m^3$, with a single peak of 5 $\mu g/m^3$. It could be caused by biomass burning.

For hydrogen sulphide and total reduced sulphur (H_2S and TRS):
H_2S and TRS are regarded mainly as a nuisance and they do not have ambient standards. The monitoring is conducted only in cases where there are complaints. No national or regional network is required.

Recommendations

Information in this report is used to inform the *State of Air for South Africa, 2005*. Future revisions of the information presented here should, in turn, be used to inform future state of air reporting on a routine basis. It is important to consider the following recommendations in order to facilitate this process.

- The ambient air quality database that has been developed through the *Assessment of Ambient Air Quality (1994–2004)* provides the most comprehensive integrated ambient air quality database to date. This database should be used as input into the National Air Quality Information System (NAQIS). NAQIS should, in turn, be kept current and used in all future state of air reporting.

- The monitoring data collected in scientific campaigns could be centrally stored as a part of NAQIS. Alternatively, the links to the sources of the campaign reports/results could be provided. A comprehensive inventory of the research outputs (theses, research reports, journal papers, and conference papers) of all air quality-related studies is available in DEAT's air quality research database (DEAT, 2006b). It is a useful source of information, supplementing air quality data and supporting its interpretation.

- The monitoring network should be extended to enable regional characterization of air quality and identification of potential priority areas. The monitoring outside of major cities and in environmentally sensitive areas should be added. Where old smoke and SO_2 measurements indicated high level of pollution (e.g. Despatch station in the Eastern Cape), the modern equipment should be installed to verify these findings. The cost-effective approach is recommended to combine continuous and passive sampling with remote sensing and air dispersion modelling.

- The number of the air quality parameters monitored should also be extended. To quantify the potential impacts described in the *State of Air Report 2005*, additional pollutants should be monitored, and more extensive monitoring is recommended for pollutants that are at present recorded in a very limited number of locations. These should include cancer risk pollutants, such as volatile organic compounds (specifically benzene), as well as ozone (potential damage to vegetation). $PM_{2.5}$ may be considered in future reporting initiatives as this follows the worldwide trend.

- Considering the importance of climate change impacts, the need for quantification of mitigation and adaptation options, and the general lack of GHG ambient data for southern Africa, the monitoring of GHGs should also be extended.

- The data collected are not sufficient to access the impact of waste disposal on air pollution.

- There is a need to link EIA data and Waste Management Information system to NAQIS.

- The quality control process by the respective data-holding agencies is necessary before data is collated into the NAQIS. It is recommended to implement consistent QA and QC procedures and a uniform validation protocol. The further process of data ratification could also be considered.

- There are no national norms and standards for collecting ambient air quality data, nor for storing, sharing, archiving and reporting, and distributing these data. As a result, data were received in many different formats. In future, data should be drawn from the National Air Quality Information System. In order to standardize reporting, it is recommended that the requirements of the reports should be defined by the NAQIS. Concurrent development of the national framework under AQA will provide uniform and consistent solutions for this and the above-listed issue on quality control. More detailed recommendations on the improvement of the quality of data are also provided.

- This report and its consequent revisions will be an important source of information for decision-making processes related to air quality in South Africa, specifically for air quality management plans being initiated or drawn up by municipalities and provinces.

1. Introduction

The Department of Environmental Affairs and Tourism (DEAT) has embarked on a phased approach to the implementation of the National Air Quality Management Programme (NAQMP). Phase I of the implementation is the so-called "Definition Phase", which was initiated in June 2001 and was completed with the promulgation and implementation of the national Environmental Management: Air Quality Act (AQA) (Act no. 39 of 2004) in 2005. In Phase II, the "Transition Project", the DEAT invited specialist professionals and consulting firms with project management experience and specialist expertise in the fields of air quality management, to submit tenders in respect of the implementation of the DEAT's National Air Quality Management Programme (NAQMP). CSIR Environmentek was appointed in May 2004 to assist the DEAT in implementing aspects of the NAQMP, through the Phase II Transition Project. As a result of internal changes, this project became the responsibility of CSIR Natural Resources and the Environment.

The Phase II project comprised a number of activities. The activity that is specific to this report is the technical compilation of data and the report *Technical Compilation to Inform the State of Air Report 2005*. This component of the project therefore reports on data and ambient air quality for the 11-year period 1994 to 2004 and serves as one of the outputs for Phase II Transition Project Output (C.4.), the other being the *State of Air Report 2005*.

This technical compilation provides information on all of the ambient air quality monitoring activities in South Africa during the period 1994–2004. The quality of the data is discussed and the data are used to describe the state of air, using compliance and long-term trend analysis. In so doing, this report identifies areas where air quality is compromised and highlights pollutants of concern.

This report therefore supplements the *State of Air Report*. The database compiled in this task will be used as a foundation for the National Air Quality Information System (NAQIS) to be developed in 2007. This report will also be an important source of information for many air quality management plans that are being started or developed by municipalities and provinces.

2. Methodology

2.1 APPROACH

A range of air quality information is currently collected in various parts of the country to satisfy a host of different user needs. Some of the data records span many years, while others are relatively short. They include, amongst others, continuous ambient air quality monitoring data, meteorological monitoring, wet and dry deposition monitoring, emissions monitoring, and monitoring in campaign-type experiments. Despite this activity, there is currently no coordinated approach at provincial or national level to archive and evaluate air quality data for reporting of the status of air quality. Information on these monitoring initiatives has been collated in a preceding activity on the Phase II Transition Project (*The Air Quality Information Review*: Output C.1.).

The Air Quality Information Review report (DEAT, 2006) comprised the following five components:

- Development of an inventory of air quality data holders
- Acquisition of metadata
- Design and population of an air quality monitoring metadatabase
- Design and population of ArcView shape files
- Reporting of information.

The approach adopted in compiling this Assessment of Ambient Air Quality (1994–2004) makes use of the ambient air quality data collected during the Air Quality Information Review activity to describe ambient air quality in terms of national standards and to assess trends in air quality where sufficient data are available.

Respondents from this phase were again contacted by e-mail and telephonically to request the data as documented during the metadata acquisition process (DEAT, 2006). The request was specifically aimed at collecting monthly and annual average data for the 10-year period 1994–2003. In some cases agencies supplied data with a much finer time resolution. These data sets were subsequently processed to the required averaging times.

Originally, this study was also planned to include a qualitative review of emissions by sector (e.g. industrial, transport, domestic fuel use). However, since the planning stages of this project (early 2004), the *National State of The Environment: Atmosphere and Climate* report (Scorgie and Venter, 2005) has been produced, which includes a thorough review of emissions in South Africa. Additionally, an extensive review of emissions data was initiated by the DEAT in mid-2005 through the APPA Registration Review project. To minimise duplication, the focus of this report is on the evaluation of the state of air and long-term trends in ambient air quality, and includes a brief summary of the major sources of pollution and their geographical distribution (Chapter 3).

2.2 AIR QUALITY GUIDELINES AND STANDARDS

Guidelines/standards normally have a numerical value expressed either as a concentration in ambient air or as a deposition level, and is linked to an averaging time. In the case of human health, the guideline value provides a concentration below which no adverse effects and, in the case of odorous compounds, no nuisance or indirect health effects are expected, although it does not guarantee the absolute exclusion of effects at concentrations below the given value (WHO, 2000b; Koenig and Mar, 2000; Gent *et al.*, 2003). The numerical value of a standard may also include the permitted number of exceedances.

In the US, the National Ambient Air Quality Standards (NAAQS) set maximum levels for sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), lead (Pb), particulate matter less than 10 μm in diameter (PM_{10}), and particulate matter less than 2.5 μm in diameter ($PM_{2.5}$). These standards are designed to be protective of public health or welfare. Compliance with ambient air quality standards are achieved using "State Implementation Plans" that contain regulatory restrictions designed to achieve the NAAQS. The US also specifies monitoring methods and network requirements to determine whether an area has attained these standards.

In South Africa, the process of setting current air quality limits was facilitated by the South African Bureau of Standards (SABS) and published in SANS 1929:2005 – South African National Standard – Ambient Air Quality – Limits for common pollutants. These standards were gazetted as proposed national standards on 9 June 2006, but have not yet been adopted by DEAT. Until such time, the values prescribed by the Air Pollution Prevention Act (Act no. 45 of 1965; hereafter referred to as APPA) and accepted as Schedule 2 of the National Environmental Management: Air Quality Act (Act no. 39 of 2004; hereafter referred to as AQA) are recognised as interim standards (Table 2.2.1). This table also includes other guidelines that identify the maximum allowable concentrations of air pollutants in the air for nitrogen oxides, CO, particulate matter, volatile organic compounds (VOCs), O_3, and Pb. The APPA guidelines allow for 3 exceedances a year for 24-hour limits of NO_x, NO_2, PM_{10}, and TSP (total suspended particulates, sometimes referred to as TSS, total suspended solids).

The objective of this report is to evaluate historical data. The data are therefore compared with the interim standards in Schedule 2 of the AQA (Table 2.2.1). The SO_2 standard in Schedule 2 has recently been revised to reflect internationally accepted health thresholds (based on guidelines by the WHO), but the limits of other criteria pollutants have not.

Most of the data collected for this project consist of monthly averages. Only monthly and annual average concentrations could therefore be compared with standards. For the pollutants not included in Schedule 2, other standards were used (Section 2.3).

Table 2.2.1: Comparison of guidelines/standards

	APPA	AQA, 2004	SANS, 1929	WHO	US EPA
O_3					
Instant		500 $\mu g/m^3$			
1-hour		230 $\mu g/m^3$	200 $\mu g/m^3$		
8-hour			120 $\mu g/m^3$	120 $\mu g/m^3$	155 $\mu g/m^3$
NO_x					
Instant		1.4 ppm			
1-hour		0.8 ppm			
24-hour		0.4 ppm			
1-month		0.3 ppm			
Annual		0.2 ppm			
NO_2					
1-hour		400 $\mu g/m^3$	200 $\mu g/m^3$	200 $\mu g/m^3$	
24-hour		200 $\mu g/m^3$			
1-month		160 $\mu g/m^3$			
Annual		100 $\mu g/m^3$	40 $\mu g/m^3$	40 $\mu g/m^3$	100 $\mu g/m^3$
NO					
Instant peak	0.9 ppm				
1-hour	0.6 ppm				
24-hour	0.3 ppm				
1-month	0.2 ppm				
Annual	0.15 ppm				
SO_2					
Instant peak	600 ppb* 1 600 $\mu g/m^3$				
10-minute		500 $\mu g/m^3$	500 $\mu g/m^3$	500 $\mu g/m^3$	
1-hour	300 ppb * 800 $\mu g/m^3$		350 $\mu g/m^3$		
3-hour					1300 $\mu g/m^3$
24-hour	100 ppb* 260 $\mu g/m^3$	125 $\mu g/m^3$	125 $\mu g/m^3$	125 $\mu g/m^3$	365 $\mu g/m^3$
1-month	50 ppb* 130 $\mu g/m^3$				
Annual	30 ppb* 78 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$	80 $\mu g/m^3$
Pb					
1-month		2.5 $\mu g/m^3$			
Quarterly					1.5 $\mu g/m^3$
Annual			0.5 $\mu g/m^3$	0.5 $\mu g/m^3$	
PM_{10}					
24-hour		180 $\mu g/m^3$	75 $\mu g/m^3$		150 $\mu g/m^3$
Annual		60 $\mu g/m^3$	40 $\mu g/m^3$		50 $\mu g/m^3$
Total suspended solids					
24-hour		300 $\mu g/m^3$			
Annual		100 $\mu g/m^3$			
CO					
1-hour			30 mg/m^3	30 mg/m^3	40 mg/m^3
8-hour			10 mg/m^3	10 mg/m^3	10 mg/m^3
Benzene					
Annual			5 $\mu g/m^3$		

* Before Jan 2002

The AQA standards used for compliance analysis of the criteria pollutants in this report are indicated in Table 2.2.2.

Table 2.2.2: Limits used for compliance analysis of criteria pollutants

Pollutant	Period	Unit	Guideline/ Standard	Period	Unit	Standard
SO_2	Annual	$\mu g/m^3$	50[1]	Monthly	$\mu g/m^3$	130[2]
NO_2	Annual	$\mu g/m^3$	100	Monthly	$\mu g/m^3$	160
NO_X	Annual	ppm	0.2	Monthly	ppm	0.3
NO_4	Annual	ppm	0.15[4]	Monthly	ppm	0.2[4]
Particulate matter	Annual	$\mu g/m^3$	60	24-hour[3]	$\mu g/m^3$	180
O_3	NA			8-hour[3]	$\mu g/m^3$	120
Pb	Annual	$\mu g/m^3$	0.5	Monthly	$\mu g/m^3$	2.5
Smoke	Annual	$\mu g/m^3$	100	24-hour[3]	$\mu g/m^3$	250
Total suspended solids	Annual	$\mu g/m^3$	100	24-hour[3]	$\mu g/m^3$	300

[1] This standard came into effect in January 2002 but will, for consistency purposes, be used for the entire period under review.

[2] The APPA guideline was relevant up to December 2001 but is used for this exercise, as applicable guidelines are not currently available.

[3] These guidelines will be applied where comparative time-averaging periods are available as there are no monthly benchmarks.

[4] APPA guidelines.

2.3 COMPOUNDS WITHOUT STANDARDS

In the absence of an existing or proposed guideline/standard for a specific pollutant or exposure period in South Africa, health-based guidelines from other regulatory authorities such as the WHO, the European Union (EU), or the US EPA are normally used. WHO Air Quality Guidelines are designed to provide a basis for protecting public health from adverse effects of air pollutants. The guidelines are intended to provide guidance to international, national, and local authorities in making risk assessment and risk management decisions. In establishing pollutant levels below which exposure does not constitute a significant public health risk, the guidelines provide a basis for setting standards or limit values. Table 2.3.1 indicates guidelines set by the WHO for toluene and xylene.

Table 2.3.1: WHO guideline concentrations for toluene and xylene (WHO, 1999)

Pollutant	Guideline value ($\mu g/m^3$)	Basis	Period
Toluene	260	Based on the central nervous system effects in occupationally exposed workers	1 week guideline
Xylene	870	Based on neurotoxicity in rats	Annual guideline

The US EPA has an integrated risk information system (IRIS) which defines a reference concentration (RfC). This is generally used in EPA non-cancer health assessments. The RfC definition was changed in July 2005. The original definition was the following:

Reference concentration (RfC): An estimate of a daily inhalation exposure to the human population (including sensitive sub-groups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used, and is generally used in EPA's non-cancer health assessments. [Durations include acute, short-term, sub-chronic, and chronic, and are defined individually.]

The definition applied since July 2005 excluded the comment in brackets about uncertainty.

Table 2.3.2 indicates RfCs for the BTEX compounds (EPA, 2005).

Table 2.3.2: EPA reference concentrations for benzene, toluene, xylene and ethylbenzene

Pollutant	RfC ($\mu g/m^3$)	Basis	Confidence
Benzene	30	Based on human occupational inhalation study done in 1996. Outcome is reduced lymphocyte count	Medium
Toluene	5 000	Based on the neurological effects in occupationally exposed workers. Latest study was conducted in 2000	High
Xylene	100	Based on impaired motor coordination effects in male rats. Study done in 1994	Medium
Ethylbenzene	1 000	Based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis	Low

In the event of there being no guidelines/standards from these authorities, the last option is to make use of occupational threshold limit values (TLVs) (NACA, 1999). It should be noted that these exposure limit values are for healthy adult workers and cannot be applied directly to the general population.

Since the early seventies, this obstacle has been overcome in South Africa by the practice of dividing the TLV by 50 in the case of non-carcinogenic pollutants and by 100 in the case of carcinogenic pollutants. This practice was, however, never officially accepted (Odendaal, 2005). The TLVs used were those from the American Conference of Governmental Industrial Hygienists (ACGIH) (Odendaal, 2005), a private organisation that publishes occupational threshold limit values and biological exposure indices (BEI).

The guidelines which were used for compliance analysis of non-criteria pollutants are given in Table 2.3.3.

Table 2.3.3: Limits used for compliance analysis of non-criteria pollutants

Pollutant	Type of guideline	Period	Unit	Guideline
Benzene	AQA proposed standards	Annual	ppb/$\mu g\ m^{-3}$	1.56/5
Toluene	RfC	Annual & monthly	ppb/$\mu g\ m^{-3}$	1 330/ 5 000
Xylene	RfC	Annual & monthly	ppb/$\mu g\ m^{-3}$	23/100
Ethylbenzene	RfC (UF: 300)	Annual & monthly	$\mu g\ m^{-3}$	1 000
Hydrogen sulphide (H_2S)	ACGIH	No averaging period specified	$\mu g\ m^{-3}$	11
Chromium (Cr^{6+})	RfC	Annual/monthly	$\mu g\ m^{-3}$	0.1 (IRIS)
Total reduced sulphur (TRS)	Limit by South Durban Steering Committee	30 min	ppb	7.8
Manganese (Mn)	WHO (UF: 200)	Annual	$\mu g\ m^{-3}$	0.15 (IRIS)

Comment: RfC refers to a value that should never be exceeded (see definition above) and as such can be used to compare with monthly and annual averages – no acceptable number of exceedances is specified.

2.4 GEOGRAPHICAL DISTRIBUTION AND STATION TYPES

The ambient air quality data are described and categorized in terms of different pollutants and the geographical distribution of the monitoring sites. The objective is to obtain representation from urban, industrial, traffic, residential and background sites for each province. Gaps in monitoring are identified in Chapter 4 with regard to spatial and temporal distribution and the selection of pollutants.

2.5 DATA PROCESSING

A statistical analysis of all available data was performed to determine averages and temporal variations for all available monitoring sites (Chapter 5). Where possible, the data were compared with existing air quality standards. To ensure consistency of the inter-comparison between stations, the statistical analysis evaluated data for the period 1994 to 2004. The original terms of reference for this activity specified the cut-off point as the end of 2003. However, when the data were sent to the CSIR, most of the respondents provided data up to the present. The data revealed that there has been an increase in monitoring since 2004. It was therefore agreed to extend the analysis period to the end of 2004. Where more recent data were available, they were also included in the database.

At monitoring sites with more than 5 years of data, the data were further analyzed to learn whether any of the pollutants exhibited trends over time. The results for stations with correlation coefficients above 0.1 were summarised in tables.

The pollutants of concern that are described in this report are grouped into 4 categories.

Criteria pollutants according to Schedule 2 of AQA, 2004:

1. Ozone (O_3)
2. Oxides of nitrogen (NO_x) and nitrogen dioxide (NO_2)
3. Sulphur oxides (SO_x)
4. Lead (Pb)
5. Particulate matter including PM_{10} and TSP

Criteria pollutants added by SANS1969:

6. Carbon monoxide (CO)
7. Benzene (C_6H_6); other volatile organic compounds (VOCs) such as toluene, xylene, and ethylbenzene were also discussed

Greenhouses gases (GHGs):

8. Methane (CH_4)
9. Carbon dioxide (CO_2)

Miscellaneous other pollutants:

10. Smoke and SO_2
11. Hydrogen sulphide (H_2S) and TRS (total reduced sulphur)
12. Trace elements, such as chromium (Cr and Cr^{6+})
13. Hazing index/visibility
14. Acid deposition.

The smoke and SO_2 (bubbler) data are presented separately in Section 4.9 to avoid confusion with SO_2 data measured by modern continuous samplers. Acid deposition monitoring is discussed separately in Chapter 6.

2.6 AIR POLLUTION AND CLIMATE CHANGE

The links between greenhouse gas emissions and climate change have been intensively researched during the last few decades (Winkler, 2004). GHG emissions are summarised in the SoE report (DEAT, 2005). High levels of emissions from the energy sector are due primarily to the energy intensity of the South African economy, which is dependent on large-scale primary extraction and processing in the mining and minerals beneficiation sector. The three source groups that contribute the most to the energy sector CO_2 equivalent emissions are: energy generating industries (includes electricity generation for the national grid), industry, and transport. These sectors contributed 57%, 18%, and 15% of the 1994 aggregated energy sector CO_2 equivalent emissions, respectively. Carbon dioxide equivalent emissions from all three groups increased from 1990 to 1994, with transport emissions increasing the most (38%), followed by industry (13%), and then energy (5%). Carbon dioxide is the most significant greenhouse gas, contributing 81% and 83% of the total CO_2 equivalent emissions in 1990 and 1994, respectively. Methane contributed 12.4% and 11.4% and nitrous oxide 6.7% and 5.4% of such emissions for these years, respectively. A third GHGs emission inventory is planned by the DEAT to start in 2007.

On 17–20 October 2005, a conference on climate change was held in Midrand, South Africa. Over 600 representatives from government, business, the scientific and academic communities, and civil society considered the science relating to climate change and key responses to the potential social and economic impacts associated with the compelling scientific evidence of climate change. In opening the conference, Deputy President, Phumzile Mlambo-Ngcuka affirmed that South Africa will accept its responsibility to address climate change and will mobilise different economic sectors to meet this challenge. The likely consequences of climate change on South Africa include increases in the distribution and intensity of drought; reduced agricultural crop yields impacting on food security; potential species extinction; increased growth rates of invasive species; and an increase in the areas affected by vector-borne diseases, including malaria. In all of these circumstances, it is the poor who will be most affected.

The conference agreed that climate change is one of the most significant threats to sustainable development across the globe (National Climate Change Conference statement, 2005). An action plan of 24 points was accepted. One of these points refers to AQM:

- Use the Air Quality Act to regulate greenhouse gas emissions and encourage a move to cleaner production, including the setting of emission standards that encourage energy efficiency.

South Africa, as a non-Annex 1 (developing) country, has no obligations to reduce greenhouse gas emissions *under the first commitment period* (2008–2012) of the Kyoto Protocol. Subsequent periods, or a post-Kyoto regime, will most likely have to include obligations for leading developing countries if it is to be politically viable.

Decisions in the next few years regarding long-term fixed energy investments are therefore critical, and must take into account the potentially adverse environmental consequences of carbon-intensive energy sources.

3. Description of available data

3.1 MONITORING SITES: DATA AVAILABILITY

Data were obtained from 136 out of the 160 stations described in the Ambient Air Quality Information Review (DEAT, 2006), at the time of preparing the *Assessment of Ambient Air Quality (1994–2004)*. In addition to these, there are 10 stations of the International Global Atmospheric Chemistry (IGAC) Deposition of Biogeochemically Important Trace Species (DEBITS) project that measure NO_2, O_3, and SO_2 using passive samplers; 5 of these stations measure O_3. Data were also obtained for 20 stations that measured smoke and SO_2. The detailed description of the available data appears in Appendix A. The table in Appendix A indicates instances where there are discrepancies between data availability in the *Ambient Air Quality Information Review* and the actual data received for the *Assessment of Ambient Air Quality (1994–2004)*. Table 3.1.1 provides a summary of monitoring stations and parameters measured at each.

To represent different types of pollution, the monitoring stations have been classified according to the following categories:

U – urban
R – residential
RI – residential affected by industrial pollution
T – township
TU – township affected by road traffic
I – industrial area
W – waste site
B – background station
P – affected by power generation

Table 3.1.1: Summary of air quality monitoring stations and parameters measured at each station

Province	Area	Station Description	Type	Parameter
EC	Buffalo City Local Municipality	B: On-site adjacent to highway	W	BTEX, dust, PM_{10}
EC	Buffalo City Local Municipality	C: Nqonqweni residential area	W	BTEX, dust
EC	Buffalo City Local Municipality	D: Border Technikon entrance	W	BTEX, dust
EC	Buffalo City Local Municipality	E: Thorn Hill farm	W	BTEX, dust
EC	Buffalo City Local Municipality	F: Lily Stone farm	W	BTEX, dust
EC	Nelson Mandela Municipality	Amsterdam Plein	I	SO_2, TSP
EC	Nelson Mandela Municipality	Coega Salt Works	U	SO_2, TSP
EC	Nelson Mandela Municipality	Motherwell	T	PM_{10}, SO_2
EC	Nelson Mandela Municipality	PE Delta	I	NO_2, O_3, PM_{10}, SO_2
EC	Nelson Mandela Municipality	Port Elizabeth CBD	U	Pb
EC	Senqu Local Municipality	Ben McDhui	B	NO_2, O_3, SO_2
FS	Metsimaholo Local Municipality	AJ Jacobs	RI	H_2S, NO_2, NO_X, SO_2
FS	Metsimaholo Local Municipality	Boiketlong	RI	H_2S, SO_2
FS	Metsimaholo Local Municipality	Hospital	RI	H_2S, SO_2
FS	Metsimaholo Local Municipality	Leitrim	T	Benzene, NO_2, O_3, PM_{10}, SO_2, toluene, xylene
FS	Metsimaholo Local Municipality	Makalu	P	Hazing, NO, NO_2, NO_X, O_3, SO_2
FS	Phumelela Local Municipality	Warden	P	NO_2, O_3, SO_2
FS	Metsimaholo Local Municipality	Steam Station	RI	NO_X, O_3
GAU	City of Johannesburg	Alexandra	T	CO, NO_2, O_3, PM_{10}, SO_2
GAU	City of Johannesburg	Buccleuch	U	Benzene, CO, NO, NO_2, NO_X, O_3, PM_{10}, $PM_{2.5}$, SO_2, toluene, xylene
GAU	City of Johannesburg	City Deep	U	CO, O_3
GAU	City of Johannesburg	Delta Park	R	NO, NO_2, NO_X, O_3, PM_{10}
GAU	City of Johannesburg	Diepsloot	T	PM, PM_{10}, TSP
GAU	City of Johannesburg	Fordsburg	U	Pb
GAU	City of Johannesburg	Jabavu	T	PM_{10}
GAU	City of Johannesburg	Jhb City Hall	U	CO, methane, NO, NO_2, O_3, Pb
GAU	City of Johannesburg	Newtown	U	CO, methane, NO, NO_2, NO_X, O_3, Pb, PM_{10}
GAU	City of Johannesburg	Northern Works	W	Methane, NO, NO_2, O_3
GAU	City of Johannesburg	Orange Farm	T	PM_{10}, SO_2
GAU	City of Johannesburg	Rosebank	U	H_2S
GAU	City of Johannesburg	South Hills	U	Pb
GAU	City of Tshwane	Irene	R	O_3
GAU	City of Tshwane	Pretoria: Beatrix St	U	Pb
GAU	City of Tshwane	Rosslyn	U	CO, NO, NO_2, NO_X, O_3, SO_2
GAU	Ekurhuleni Municipality	Germiston	U	Pb
GAU	Ekurhuleni Municipality	Springs Girls' High School	RI	H_2S
GAU	Emfuleni Local Municipality	350 site	I	Benzene, CO, H_2S, NO_2, O_3, PM_{10}, SO_2, toluene, xylene
GAU	Emfuleni Local Municipality	620 site	I	Benzene, CO, H_2S, NO_2, O_3, PM_{10}, SO_2, toluene, xylene
GAU	Emfuleni Local Municipality	Bedworth Park	I	NO, NO_2, O_3, SO_2

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Province	Area	Station Description	Type	Parameter
GAU	Emfuleni Local Municipality	Mittal mobile caravan	I	CO, H_2S, NO_2, O_3, PM_{10}, SO_2
GAU	Emfuleni Local Municipality	Vereeniging CBD	U	Pb
KZN	eThekwini Municipality	Ilfracombe	I	SO_2
KZN	eThekwini Municipality	Umkomaas	I	SO_2
KZN	eThekwini Municipality	TLC	I	SO_2
KZN	eThekwini Municipality	Dlambula School	I	SO_2
KZN	eThekwini Municipality	Naidooville School	I	SO_2
KZN	eThekwini Municipality	Brighton reservoir	RI	Pb
KZN	eThekwini Municipality	Cato Manor	U	Pb
KZN	eThekwini Municipality	Chatsworth	U	Pb
KZN	eThekwini Municipality	Congella Fire Station	I	Pb
KZN	eThekwini Municipality	Cowies Hill	B	Pb
KZN	eThekwini Municipality	Drift	I	SO_2
KZN	eThekwini Municipality	Durban City Hall	U	Pb
KZN	eThekwini Municipality	Gillits Road	R	Pb
KZN	eThekwini Municipality	Hosley Road	R	Pb
KZN	eThekwini Municipality	Isipingo	RI	Pb
KZN	eThekwini Municipality	Merewent	RI	Pb
KZN	eThekwini Municipality	Palmfield Road	U	Pb
KZN	eThekwini Municipality	Pinetown Civic Centre	U	Pb
KZN	eThekwini Municipality	Settlers	RI	CO, NO, NO_2, PM_{10}, SO_2, TRS
KZN	eThekwini Municipality	South Bluff	RI	Pb
KZN	eThekwini Municipality	Southern Roof	I	Pb
KZN	eThekwini Municipality	Southern Works	I	NO, NO_2, SO_2, TRS
KZN	eThekwini Municipality	Wentworth	RI	NO, NO_2, O_3, Pb, PM_{10}, SO_2
KZN	eThekwini Municipality	Warwick	U	CO, NO, NO_2, NO_x, TRS
KZN	Newcastle Local Municipality	Arbor Park School	R	Cr, Cr^{6+}, TSP
KZN	Newcastle Local Municipality	Karbochem effluent plant	I	Cr, Cr^{6+}, TSP
KZN	Newcastle Local Municipality	Keyway Motors	U	Cr, Cr^{6+}, TSP

Continued next column

Province	Area	Station Description	Type	Parameter
KZN	Newcastle Local Municipality	Newcastle Airport	U	Cr, Cr^{6+}, TSP
KZN	Newcastle Local Municipality	Siza Centre	RI	Dust, NO, NO_2, NO_x, SO_2
KZN	The Msunduzi Local Municipality	Pietermaritzburg City Hall	U	Pb
KZN	The Msunduzi Local Municipality	Publicity House	U	PM_{10}
KZN	uMhlathuze Local Municipality	Arboretum	R	SO_2
KZN	uMhlathuze Local Municipality	Arboretum Extension	R	SO_2
KZN	uMhlathuze Local Municipality	Brackenham	R	O_3, SO_2
KZN	uMhlathuze Local Municipality	Esikhawini	T	O_3, SO_2
KZN	uMhlathuze Local Municipality	Hillside	I	PM_{10}, SO_2
KZN	uMhlathuze Local Municipality	Richards Bay caravan	U	SO_2
KZN	uMhlathuze Local Municipality	Scorpio	I	SO_2
KZN	uMhlathuze Local Municipality	Umhlatuze	T	SO_2
KZN	uMhlathuze Local Municipality	Veldenvlei	R	SO_2
KZN	uMhlathuze Local Municipality	Wildenweide	R	SO_2
KZN	uMngeni Local Municipality	Cedara	B	NO_2, O_3, SO_2
LPM	Makhado Local Municipality	Louis Trichardt	B	NO_2, O_3, SO_2
MPU	Delmas Local Municipality	Kendal 3	P	SO_2
MPU	Dipaleseng Local Municipality	Grootvlei	RI	H_2S, SO_2
MPU	Emalahleni Local Municipality	Kendal 1	P	SO_2
MPU	Emalahleni Local Municipality	Kendal 2	P	Hazing, NO, NO_2, NO_x, O_3, SO_2
MPU	Govan Mbeki Local Municipality	Bosjesspruit	I	H_2S, NO, NO_2, NO_x, O_3, SO_2
MPU	Govan Mbeki Local Municipality	Club	RI	H_2S, NO, NO_2, NO_x, O_3, $PM_{2.5}$, SO_2
MPU	Govan Mbeki Local Municipality	Elandsfontein	P	Hazing, NO, NO_2, O_3, SO_2
MPU	Govan Mbeki Local Municipality	Langverwacht	RI	CO, H_2S, O_3, $PM_{2.5}$, SO_2
MPU	Govan Mbeki Local Municipality	Leandra	P	Hazing, SO_2
MPU	Highlands Local Municipality	Palmer	P	Hazing, NO, NO_2, NO_x, O_3, PM_{10}, SO_2
MPU	Pixley Ka Seme Local Municipality	Amersfoort (2 stations)	I	H_2S, O_3, SO_2
MPU	Pixley Ka Seme Local Municipality	Majuba 1	P	Hazing, SO_2

Continued next page

Province	Area	Station Description	Type	Parameter
MPU	Pixley Ka Seme Local Municipality	Majuba 2	P	SO_2
MPU	Pixley Ka Seme Local Municipality	Majuba 3	P	SO_2
MPU	Pixley Ka Seme Local Municipality	Verkykkop	P	NO, NO_2, O_3, SO_2
MPU	Steve Tshwete Local Municipality	Columbus	I	NO_2, NO_X, PM_{10}, SO_2
MP	West Rand Cross Boundary District Municipal	Skukuza	B	NO_2, O_3, SO_2
MP		Houtbosrand	B	NO_2, O_3, SO_2
NC	Ga-Segonyana Cross Boundary Local Municipality	Site E-Kuruman	R	Mn
NC	Magareng Local Municipality	Site D-Van Zyls Rus	R	Mn
NC	Nama Khoi Local Municipality	Springbok Weather Office	B	O_3
NWP	Local Municipality of Madibeng	Between stack & tailings dam (C5)	I	SO_2
NWP	Local Municipality of Madibeng	End of town (C3)	RI	SO_2
NWP	Local Municipality of Madibeng	Karee K4 (C9)	RI	SO_2
NWP	Local Municipality of Madibeng	L2 BMR	I	SO_2
NWP	Local Municipality of Madibeng	L5 Sewerage Plant	I	SO_2
NWP	Local Municipality of Madibeng	L6-K4 Shaft	I	SO_2
NWP	Ditsobotla Local Municipality	Lichtenburg	B	NO_2, O_3, SO_2
NWP	Local Municipality of Madibeng	Middle of town (C2)	RI	SO_2
NWP	Local Municipality of Madibeng	Opposite Tlhapi Supermarket (C1)	RI	SO_2
NWP	Local Municipality of Madibeng	Rowland Shaft (C10)	I	SO_2
NWP	Local Municipality of Madibeng	Selokwaneng House (301 C6)	T	SO_2
NWP	Local Municipality of Madibeng	Selokwaneng House (355 C7)	T	SO_2
NWP	Local Municipality of Madibeng	Substation: Marikana Rd (C8)	I	SO_2
NWP	Local Municipality of Madibeng	C4: WPL offices	I	SO_2
NWP	Rustenburg Local Municipality	Bergsig School	R	PM_{10}, SO_2
NWP	Rustenburg Local Municipality	Hexrivier	I	SO_2
NWP	Rustenburg Local Municipality	Kroondal Station	R	SO_2
NWP	Rustenburg Local Municipality	Paardekraal	I	PM_{10}, SO_2
NWP	Rustenburg Local Municipality	Waterval	RI	PM_{10}, SO_2
WC	City of Cape Town	Athlone	P	O_3, SO_2
WC	City of Cape Town	Bothasig	RI	NO_2, SO_2
WC	City of Cape Town	Cape Point (2 stations)	B	CO, CO_2, methane, N_2O, O_3, Hg
WC	City of Cape Town	Central Cape Town (City Hall)	U	CO, NO_2, SO_2, Pb
WC	City of Cape Town	Central Cape Town (Drill Hall)	U	PM_{10}
WC	City of Cape Town	Goodwood	R	CO, NO_2, O_3, PM_{10}, SO_2
WC	City of Cape Town	Khayelitsha	TU	PM_{10}
WC	City of Cape Town	Oranjezicht	R	O_3
WC	City of Cape Town	Table View	RI	NO_2, PM_{10}, SO_2
WC	Saldanha Bay Local Municipality	Mittal Steel Saldanha	I	PM_{10}, SO_2

The location of fallout dust monitoring sites is indicated where they are included as part of other monitoring activities, but stations measuring fallout dust from mines are excluded. Where data on dust monitoring activities were received, they were included in Appendix C. A few typical sites for mining fallout dust are described in the main *State of Air Report 2005*. This report excluded the compliance analysis of the fallout dust as it has been excluded from the proposed AQ standards.

At some stations, more than one agency is monitoring different pollutants, for example, in Elandsfontein both Eskom and DEBITS have indicated monitoring activities.

From the tables above it is clear that KwaZulu-Natal has the most comprehensive monitoring network, both from the point of geographical coverage and also from the selection of pollutants. Some sites are well located to monitor emissions from landfill and sewage treatment plants. The only omission is that there is no truly representative background station. With this said, the new monitoring station at Alverstone is regarded as a background station for the South Industrial Basin, and the newly commissioned station, run by the provincial Department of Agricultural and Environmental Affairs (DAEA), will help to fill this requirement. During 2005, DAEA established air quality monitoring sites at Mandini, Newcastle, Empangeni, Estcourt, Port Shepstone, and Pietermaritzburg.

Gauteng province has a reasonable number of monitoring stations to cover the Johannesburg area, but not sufficient for the rest of the province. This includes a station at Northern Works to monitor emissions from the treatment plant. Additional stations were added after 2004 in the Vaal Triangle area, where the monitoring dearth is particularly acute. The data for Tshwane are also very limited, but according to the Tshwane AQMP, will be significantly extended from 2006.

A similar situation exists in the Western Cape, with only Cape Town having reasonable monitoring coverage.

The Eastern Cape has a few stations to monitor mainly industrial

pollution in Port Elizabeth. Six new monitoring stations were established to evaluate the impact at the new landfill site outside East London (five of them represent ambient pollution and are included in this study).

In the Free State, most of the stations focus on the impact of industry on residential areas around Sasolberg. Eskom operates one of the stations in the Free State (Makalu).

The monitoring in Mpumalanga is run mainly by Eskom and Sasol and focuses on monitoring the effects of their emissions. The only station that monitors pollution around Middelburg is inside the perimeter of an industrial complex and is affected by a few low-lying sources nearby.

The Northern Cape has one background station for measuring total column O_3.

The North West province has one station representing background/ regional pollution, a large number of stations around Lonmin platinum mine, and a few stations in Rustenburg.

The rest of the provinces do not have any regular monitoring initiatives.

The number of datasets, representing results of monitoring a specific pollutant at a particular station, is summarised for each province in Table 3.1.2.

Table 3.1.2: Number of air quality monitoring datasets per parameter per province (sorted in descending order)

Parameter/ province	EC	FS	GAU	KZN	LMP	MP	NC	NWP	WC	Total
SO_2	8	6	8	35	1	20		21	7	107
Dust	6			1				48		55
O_3	2	4	13	4	1	12	1	1	5	43
NO_2	2	4	11	7	1	11		1	7	43
PM_{10}	4	1	10	6		2		3	6	32
Pb	1		7	17					1	26
Smoke	4			16						20
NO		1	7	6		6			5	24
CO			9	2		1			4	16
H_2S		3	5			5			1	14
NO_X		3	4	3		5				15
TSP	2		1	4						7
BTEX	6									6
Hazing		1				5				6
Benzene		1	3							4
Cr				4						4
Cr^{6+}				4						4
Methane			3						1	4
Toluene			2			2				4
Xylene		1	3							4
$PM_{2.5}$		1	3							4
Mn							2			2
TRS				3						3
CO_2									1	1
N_2O									1	1
Total	**35**	**26**	**89**	**112**	**3**	**69**	**3**	**74**	**39**	**449**

The highest number of datasets exists for SO_2, but it includes old smoke and SO_2 data and new passive sampling. The criteria pollutants (including dust) have the largest number of datasets, ranging from 55 for dust to 16 for CO. Non-criteria pollutants have a very limited number of datasets and a very poor geographical distribution. GHG pollutants, carbon dioxide, and N_2O are measured only at the Global Atmosphere Watch station at Cape Point.

3.2 DATA QUALITY

3.2.1 Data quality objectives of monitoring

Two of the objectives of ambient air quality sampling are:

- to provide data on the areas within zones and agglomerations where the highest concentrations of pollutants occur, to which the population is likely to be directly or indirectly exposed, and

- to provide data on pollutant concentrations to which the general population is exposed.

In order to achieve this, the monitoring stations need be correctly located and must meet a number of location criteria in the immediate vicinity of the monitoring station. The macro- and microscale location criteria are detailed in SANS 1929: *Ambient Air Quality – Limits for common pollutants*. In addition, a minimum number of sampling points are required in zones and agglomerations in order to assess compliance with ambient air pollutant limit values (Tables 3.2.1.1 and 3.2.1.2).

Table 3.2.1.1: Minimum number of sampling points for fixed measurements to assess compliance with SO_2, NO_2, PM_{10}, CO, benzene and lead limit values (from SANS 1929)

Population of agglomeration or zone (thousands)	If concentrations exceed the upper assessment threshold	If maximum concentrations are between the upper and lower assessment thresholds	For SO_2 and NO_2 in agglomerations where maximum concentrations are below the lower assessment threshold
0 – 250	1	1	Not applicable
250 – 499	2	1	1
500 – 749	2	1	1
750 – 999	3	1	1
1 000 – 1 499	4	2	1
1 500 – 1 999	5	2	1
2 000 – 2 749	6	3	2
2 750 – 3 749	7	3	2
3 750 – 4 749	8	4	2
4 750 – 5 999	9	4	2
> 6 000	10	5	3

[a] Areas in which the 99th percentile pollutant levels represent a value exceeding 70% of a limit value (taking into account limit values for all periods used to derive averages).
[b] Areas in which the 99th percentile pollutant levels represent a value between 50% and 70% of a limit value (taking into account limit values for all periods used to derive averages).
[c] Agglomerations where the 99th percentile pollution levels are below 50% of all limit values (taking into account limit values for all specified averaged periods).

Table 3.2.1.2: Minimum number of sampling points for fixed measurements to assess compliance with O_3 lead limit values (from SANS, 1929)

Population of agglomeration or zone (thousands)	Agglomerations (urban and suburban)[a]	Other zones (urban or suburban)[b]	Rural background
0 – 250	-	1	1 station per 50 000 km² as an average density over all zones within a country[b]
250 – 499	1	2	
500 – 999	2	3	
1 000 – 1 499	3	4	
1 500 – 1 999	4	5	
2 000 – 2 749	5	6	
2 750 – 3 749	1 additional station per 2 million inhabitants	1 additional station per 2 million inhabitants	
> 3 750			

[a] At least one station is in a suburban area, where the highest exposure of the population is likely to occur. In agglomerations at least 50% of the stations should be located in suburban areas.
[b] One station per 25 000 km² for complex terrain is recommended.

3.2.2 Data quality control, data assurance and accreditation

Any large-scale monitoring programme that is implemented and managed by different groups using different methods and equipment, requires quality assurance (QA) in order to ensure data quality, reliability, and comparability. The New Zealand Ministry for the Environment (2000) states that: "data gathered by different techniques or to varying levels of quality assurance, may not be able to be compared with guideline values and data from other locations, or used to develop a picture of air quality".

All aspects of air quality monitoring are subjected to recognised procedures to ensure standardisation, conformity in approach so that the resultant data are representative, and comparable. These procedures relate to: the siting of stations, site and equipment operating procedure, routine equipment performance tests and calibration procedures, site and equipment auditing, inter-laboratory testing, data processing and storage. Standard site operating procedures have been detailed by organisations such as the US EPA (1994) and Standards South Africa (SANS 1929, 2005).

It is important to differentiate between quality control and quality assurance. *Quality control (QC)* refers to activities done at the site by the respective agencies to ensure that the site operates according to specifications. *Quality assurance (QA)* refers to activities performed by others to ensure that quality control is practised, e.g. site auditing.

QC measures include the following:

- Clearly defined and documented *site operating procedures:* These define the necessary activities and conditions to ensure that all aspects of operating an air quality monitoring site are done in accordance with accepted norms and standards.
- Clearly defined and documented *instrument operating procedures:* These define the necessary activities and conditions to ensure that all equipment at the site is maintained and operates in accordance with accepted norms and standards.
- *Precision testing,* i.e. checks to ensure the ability of a measurement to be consistently reproduced. Precision tests often include routine zero and span tests.
- *Calibration of air quality monitoring systems* on a regular basis by means of recognised procedures and using traceable standards ensures that monitored data are representative and comparable within the immediate agency network.

In addition, the QC should include data validation, which sometimes can be performed off-site. The US EPA, 1998 states that "the purpose of data validation is to detect and then verify any data values that may not represent actual air quality conditions at the sampling station. Effective data validation procedures usually are handled completely independently from the procedures of initial data collection." It also states that "data validation procedures should be recommended as standard operating procedures".

The New Zealand Ministry for the Environment, 2000 states that data validation can range "from very simple procedures such as checking that data are present, to sophisticated error correction and outlier removal". For example, as a part of a pilot for the Gauteng Air Quality Information System the following steps are considered for data validation:

- Check dates and times to ensure that there are no gaps in the time series
- Format date/time columns (e.g. as dd/mm/yy hh:mm)
- Label columns with the units used
- Identify instrument downtime from the site file, and remove invalid data
- Graph raw data to identify any anomalies, including spikes, and annotate it accordingly
- Adjust data for calibrations, zero drift and span as outlined in the site file. All adjustments made should be noted on the worksheet
- Convert data from ppm or ppb to mg/m³ or µg/m³ (assuming 25°C and 101.3 kPa/760 torr).

Quality assurance means auditing air quality monitoring systems by a recognised external auditing authority. This should ensure that all aspects of monitoring are conducted according to recognised norms and standards and that resultant data are representative and comparable with other audited systems. South Africa has the South African National Accreditation System (SANAS), which provides accreditations for testing and calibration laboratories. SANAS was formed as a result of a Cabinet decision in 1994 as a single national accreditation body. Accreditation is an independent assessment on

the competence of an organisation to perform tests / calibrations / inspections against a schedule of accreditation.

When SANAS gives accreditation to an air monitoring laboratory, the following is assessed:

- technical competency of staff
- validity and appropriateness of methods
- traceability of measurements to national standards
- suitability, calibration and maintenance of test equipment
- suitable environmental conditions
- handling of test items
- quality assurance of test and/or calibration data.

The standards applied by SANAS include SANS 1929 and SANAS R07.

At present there are only four industrial laboratories that have been accredited (Table 3.2.2.1).

Table 3.2.2.1: Accredited laboratories

Laboratory number	Laboratory name	Location	Disciplines
T0237	Sasol SCI	Infrachem Laboratory	Ambient air quality monitoring
T0121	SASOL Synfuels (Pty) Ltd	Secunda Laboratory	Ambient air quality monitoring
T0199	Technology Services International on behalf of Eskom Resources and Strategy	Cleveland	Air quality monitoring
T0183	Technology Services International – Anglo Platinum	Jhb, Rosherville	Air quality

This list may not be complete as some laboratories receive accreditation for certain types of analysis, which could be used not only in air quality but in other fields, and could be listed under other disciplines. For example, CSIR Knowledge Centre for Specialised Environmental Analysis has accreditation for a number of chemical analysis methods, including determination of BTEX components by thermal desorption GC-MS.

Only one laboratory has been accredited as a calibration laboratory: Eskom Enterprises – Technology Services International (TSI) in Cleveland.

3.2.3 Evaluation of quality of monitoring data in South Africa

During the Air Quality Information Review (DEAT, 2006), the agencies that collect monitoring data in South Africa were asked to report on their QA and QC (see Table 3.2.3.1).

Table 3.2.3.1: QA/QC reported in metadata (DEAT, 2006)

Agency	QC	QA	Calibration laboratory
African Explosives Ltd	No	No	
Air Pollution Liaison Committee (APOLCOM)	No	No	
Air Quality Monitoring Laboratory, City of Cape Town	Yes	Yes	Air Quality Monitoring, City of Cape Town
Anglo Coal	No info.	No info.	
Annegarn Environmental Research (AER)	Yes	Yes	AER
City of Johannesburg	No info.	Yes	Eskom TSI
City of Tshwane Metropolitan Municipality	No info.	No	
C & M Consulting Engineers	No info.	No info.	
Columbus Stainless Ambient Air Quality Station	No info.	No	
Coega Development Corporation	Yes	Yes	Scientific Services, Grant Ravenscroft
Chrome International South Africa (Pty) Ltd	Yes	No info.	
East London Industrial Development Zone Corporation (ELIDZC)	No info.	No	
East London Regional Waste Disposal Site	No	Yes	Ecoserv (Pty)
Ekurhuleni Metro: Eastern Region	No info.	No info.	
Eskom	Yes	Yes	Eskom Calibration Laboratory (SANAS No. 1503)
Eskom (for AngloPlat)	Yes	Yes	Eskom TSI
eThekwini Municipality	No info.	Yes	Eskom TSI
Lonmin	No info.	No info.	
Mittal Steel	Yes	Yes	TUV & NOSA for SO_2, no info. for NO_X, CO and O_3)
Mondi Packaging	No info.	No info.	
Msunduzi Air Quality Forum	Yes	No info.	
Nelson Mandela Metropolitan Municipality	Yes	No info.	
North-West University (DEBITS programme)	Yes	No	
Palabora Mining Company	Yes	Yes	C&M Consulting Engineers
PetroSA Environmental Department	Yes	Yes	Gaschrom Analytical Services cc
Richards Bay Clean Air Association	Yes	Yes	Eskom TSI
Sappi Saiccor	Yes	Yes	Internal/SANAS Audit Laboratory
Sasol Synfuels	Yes	Yes	CSIR
South African Weather Service Climate Systems, Global Atmosphere Watch (GAW)	Yes	Yes	UBA, Germany (NO_X); EMPA, Zurich, Switzerland (CO and O_3)

Not all agencies provided information on their QA and QC procedures and even fewer use accredited laboratories for calibration. A high level of confidence exists in the data collected by audited networks.

Monitoring stations that form part of international networks, such as the DEBITS and GAW station, are conducted under strict international QC procedures. QA is achieved through site and laboratory audits and inter-laboratory calibration testing. A high level of confidence exists in the data from these stations. A low level of confidence exists where no or limited QC or QA are applied at air quality monitoring stations.

QA and QC are key components of an air quality monitoring programme. Data ratification is a further step that can be undertaken to ensure long-term sustainability of the monitoring data.

The WHO, 1999 recommends data ratification and defines it as "a high-skill exercise involving considerable knowledge of pollutant behaviour and dispersion, instrument characteristics, field experience and judgment", which is "typically based on databases covering 3–6 months, allowing long-term performance drift, site and instrument anomalies to be reliably identified." No standards or guidelines are available in South Africa for air quality data ratification.

There are currently no norms and standards for storing, sharing, and distributing ambient air quality data. A number of bodies and organisations have well-developed data management and archiving systems (e.g. City of Cape Town, eThekweni Municipality, Eskom). The implication is that data are fragmented and are the property of the collecting agencies. Access to data for provincial and national scale assessment and reporting is therefore limited and is exacerbated by different data-sharing policies.

The underlying assumption about data quality for this report is that all data received have undergone a quality control process by the respective data holding agencies. In other words, in the scope of the project it was planned that no additional quality control measures would be applied to the data that are reported here.

However, on inspection of the data, it became apparent that this assumption was not valid as the data from a few organisations contain spurious points, including negative concentrations. In such cases these data points are excluded from this assessment.

An example of this occurs for Alexandra Township, where monthly results are published on a website (www.alexandra.co.za/updates/progress_air_quality.htm). In this case, a large negative peak in PM_{10} concentrations measured in June 2005 is clearly incorrect. This and all other negative values were excluded from the database. Some unrealistically high values were also excluded from the database after checking the spikes with the relevant agency.

3.2.4 Improvement of quality of monitoring data in South Africa

The quality control observed by the various data holding agencies is necessary before data are collated into the NAQIS. It is recommended that consistent QA and QC procedures and uniform validation protocol be implemented. The addition of data ratification could also be considered.

There is also a need for norms and standards for storing, sharing, and distributing ambient air quality data. Development of the national framework under AQA will provide uniform and consistent solution to the issues listed above.

For data collection in future, it is recommended that the following information be provided by station operators:

- Physical location, geographical co-ordinates, and relevant contact details of the station operator or owner (it is useful to have a photograph and street address where possible)
- The operational status and condition of the monitoring station and associated equipment (the percentage of the time when each instrument is operational should be reported)
- Consistency of monitoring methods with local or international standards
- The frequency of calibration of the equipment by accredited independent companies using local or international reference methods e.g. the US Environmental Protection Agency Reference Methods. If the station is accredited by SANAS, provide details of accreditation
- Details of data capture, processing, and telemetry at each station. These details must include a description of specific programmes or databases used
- A description of the current use, distribution, and confidentiality of the data
- A description of the validation protocol applied to the data collected at each station.

3.3 NATIONAL OZONE (O_3) MONITORING

Ozone is measured at 44 stations (Table 3.3.1). Of these, there are two types of O_3 measurements: the monitoring of surface O_3 concentrations and measurement of total column O_3. The latter measures the amount of O_3 in the atmospheric column extending from the earth's surface to the top of the atmosphere. Surface O_3 is measured in ppb or $\mu g/m^3$, whereas total column O_3 is measured in Dobson units (DU).

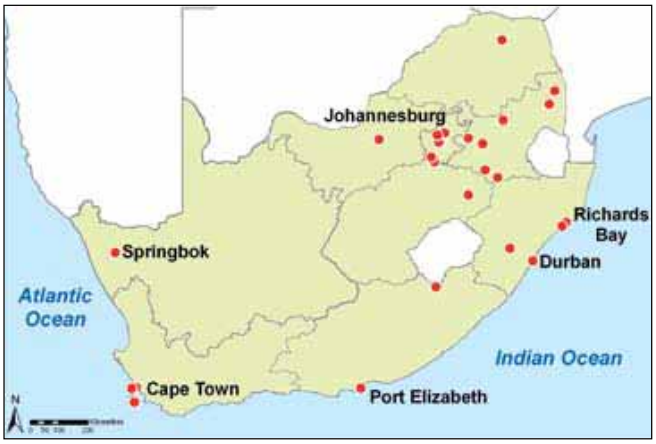


Figure 3.3.1: National distribution of ozone monitoring stations

Total column O_3 is relatively homogeneous on a regional scale, generally decreasing slowly with decreasing latitude. Total column O_3 also varies relatively slowly with time. Measurements of total column O_3 are conducted at Springbok and Irene. These measurements, separated by some six degrees of latitude, are considered to be adequate to represent total column O_3 over South Africa.

Ozone in the lower troposphere forms through the reaction of NO_x and hydrocarbons in the presence of sunlight. This reaction takes time; it is dependent on the ratios between the precursors and on available sunlight. Considering the dependence of its formation process on sunlight and the time taken for the reaction, O_3 is not usually found near the source of the precursors, but most often some distance downwind, depending on the prevailing meteorology. Ozone is therefore regarded as a regional-scale pollutant. In most cases, surface O_3 measurements are conducted in urban environments. This type of monitoring is useful for urban-scale monitoring. There are only 7 stations outside of urban areas and these are not sufficient for evaluation of regional-scale impact. According to Table B.2 in SANS 1929, ozone should be measured in urban, suburban and rural areas and there should be a station every 50 000 km^2. For a cost-effective monitoring network, however, the continuous measurements could be supplemented by passive sampling and measurements of total column for regional characterization.

Table 3.3.1: Summary of O_3 monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2004
EC	Ben McDhui	B	1999-11-01 to 2001-03-01	16
EC	PE Delta	I	1998-10-01 to 2005-06-01	49
FS	Makalu	P	1994-01-01 to 2004-12-31	8734
FS	Warden	P	1999-11-01 to 2000-07-01	7
FS	Leitrim	T	2003-04-25 to 2006-02-01	2293
FS	Steam Station	RI	2004-01-01 to 2006-02-01	11
GAU	350 site	I	2005-01-01 to 2005-09-01	0
GAU	620 site	I	2005-01-01 to 2005-09-01	0
GAU	Bedworth Park	I	1994-01-01 to 1995-01-01	11
GAU	Mittal mobile caravan	I	2004-12-01 to 2005-09-01	1
GAU	Delta Park	R	2004-05-14 to 2004-12-31	5 009
GAU	Alexandra	T	2002-04-13 to 2005-07-01	22 355
GAU	Buccleuch	U	2004-03-30 to 2004-12-31	13 633
GAU	City Deep	U	1996-11-12 to 1999-11-01	23 619
GAU	Jhb City Hall	U	1982-06-01 to 1994-04-07	1 953
GAU	Newtown	U	1994-12-13 to 2004-12-31	54 315
GAU	Rosslyn	U	2003-11-01 to 2004-07-31	1 388
GAU	Northern Works	W	1985-07-01 to 1999-11-01	16 413
GAU	Irene	R	1990-01-01 to 2002-12-01	108
KZN	Cedara	B	1999-11-01 to 2000-09-01	10
KZN	Wentworth	RI	2004-02-11 to 2005-01-01	25 747
KZN	Brackenham	R	2001-01-01 to 2002-01-01	2
KZN	Esikhawini	T	1998-01-01 to 1998-01-01	1
LMP	Louis Trichardt	B	1999-11-01 to 2000-11-01	12
MPU	Skukuza	B	2000-06-01 to 2000-07-01	2
MPU	Amersfoort	I	1999-11-01 to 2000-11-01	11
MPU	Amersfoort	I	2001-08-22 to 2004-12-31	16 020
MPU	Bosjesspruit	I	2000-01-01 to 2003-12-31	25 317
MPU	Elandsfontein	P	1994-01-01 to 2003-12-01	116
MPU	Elandsfontein	P	1999-11-01 to 2001-02-01	14
MPU	Kendal 2	P	1994-01-01 to 2004-12-31	7 086
MPU	Palmer	P	1994-01-01 to 2004-01-10	341
MPU	Verkykkop	P	1994-01-01 to 2003-12-01	119
MPU	Club	RI	1998-01-01 to 2004-12-31	44 897
MPU	Langverwacht	RI	2004-01-05 to 2004-12-31	7 662
NC	Springbok Weather Office	B	1995-03-01 to 2003-09-01	100
MPU	Houtbosrand	B	2000-06-01 to 2000-07-01	2
NWP	Lichtenburg	B	1999-11-01 to 2000-04-01	6
WC	Cape Point (DEBITS)	B	1999-11-01 to 2001-03-01	15
WC	Cape Point (GAW)	B	1991-01-16 to 2004-12-16	132
WC	Goodwood	R	1994-01-01 to 2005-06-01	96
WC	Athlone	P*	1996-05-01 to 2005-07-01	79
WC	Oranjezicht	R	1994-01-01 to 2005-08-01	131
WC	Khayelitsha	TU	2004-05-01 to 2004-12-31	5 572

The national distribution of O_3 monitoring stations is indicated in Figure 3.3.1.

3.4 NATIONAL OXIDES OF NITROGEN (NO_x) MONITORING

NO_x commonly refers to NO + NO_2, with NO rapidly oxidising to NO_2 in the ambient environment. Monitoring stations are indicated in Tables 3.4.1 (NO_2), 3.4.2 (NO) and 3.4.3 (NO_x). Ambient air quality monitoring is typically not conducted for NO_x, but rather for one of the contributing species. The relative location of NO_2 monitors on a national scale is presented in Figure 3.4.1, while the relative location of NO monitors is shown in Figure 3.4.2. Nitrous oxide (N_2O), which is a greenhouse gas, is measured at Cape Point only.

Table 3.4.1: Summary of NO_2 monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2004
EC	Ben McDhui	B	1999-11-01 to 2001-02-01	14
EC	PE Delta	I	1998-10-01 to 2005-06-01	49
FS	Makalu	P	1994-01-01 to 2004-12-31	8 652
FS	Leitrim	T	2003-04-25 to 2006-02-01	2 239
FS	AJ Jacobs	RI	2005-01-01 to 2006-02-01	0
FS	Warden	P	1999-11-01 to 2000-07-01	8
GAU	350 site	I	2005-01-01 to 2005-09-01	0
GAU	620 site	I	2005-01-01 to 2005-09-01	0
GAU	Bedworth Park	I	1994-01-01 to 1995-01-01	11
GAU	Mittal mobile caravan	I	2004-05-01 to 2005-09-01	8
GAU	Delta Park	R	2004-04-30 to 2004-12-31	1 495
GAU	Alexandra	T	2002-04-13 to 2005-07-01	22 061
GAU	Buccleuch	U	2004-03-30 to 2004-12-31	13 718
GAU	Jhb City Hall	U	1982-06-01 to 1994-04-07	2 204
GAU	Newtown	U	1995-02-23 to 2004-12-31	53 677
GAU	Rosslyn	U	2003-11-01 to 2004-07-31	1 918
GAU	Northern Works	W	1985-09-25 to 1989-05-02	0*
KZN	Southern Works	I	2003-12-09 to 2005-01-01	50 277
KZN	Settlers	RI	2001-01-21 to 2003-09-01	25 3072
KZN	Siza Centre	RI	2000-01-01 to 2003-12-31	20 9753
KZN	Wentworth	RI	2004-02-11 to 2005-01-01	33 898
KZN	Cedara	B	1999-11-01 to 2000-09-01	10
KZN	Warwick	U	2004-01-01 to 2004-12-15	6 827
KZN	Durban City Hall	U	2004-01-03 to 2005-01-01	7 404
LMP	Louis Trichardt	B	1999-11-01 to 2000-11-01	12
MPU	Bosjesspruit	I	2000-01-01 to 2003-12-31	23 100
MPU	Elandsfontein	P	1994-01-01 to 2003-12-01	113
MPU	Kendal 2	P	1994-01-01 to 2004-12-31	7 800
MPU	Palmer	P	1994-01-01 to 2004-01-10	346
MPU	Verkykkop	P	1994-01-01 to 2003-12-01	117
MPU	Club	RI	1998-01-01 to 2004-12-31	39 723
MPU	Skukuza	B	2000-06-01 to 2000-07-01	2
MPU	Amersfoort	I	1999-11-01 to 2000-11-01	11
MPU	Columbus	I	2000-07-01 to 2005-07-01	44
MPU	Elandsfontein	P	1999-11-01 to 2001-02-01	15
MPU	Houtbosrand	B	2000-06-01 to 2000-07-01	2
NWP	Lichtenburg	B	1999-11-01 to 2000-04-01	6
WC	Goodwood	R	1995-03-01 to 2005-07-01	114
WC	Cape Town (City Hall)	U	1994-01-01 to 2005-08-01	129
WC	Cape Point	B	1999-11-01 to 2001-03-01	15
WC	Bothasig	RI	1995-01-01 to 2005-08-01	100
WC	Table View	RI	1994-11-01 to 2005-08-01	118
WC	Khayelitsha	TU	2004-08-03 to 2004-12-31	3 493
WC	Athlone	P	2004-01-01 to 2004-12-31	7 835

* Excluded in station count as monitoring stopped before 1994.

Continued next column

Nationally, there are 44 monitoring stations that measure NO_2. Monitoring is performed in four main cities: Cape Town, Durban, Johannesburg, and Tshwane (only one station in Rosslyn). The townships have very little in the way of monitoring activities, with only one station in Alexandra (Johannesburg). Eskom has a reasonable geographical distribution of monitoring stations covering Mpumalanga and the northern Free State.

Table 3.4.2: Summary of NO monitoring history and locations in South Africa

Province	Name	Type	Period	No. of points 1994–2004
FS	Makalu	P	1994-01-01 to 2004-12-31	8 651
GAU	Buccleuch	U	2004-03-30 to 2004-12-31	13 822
GAU	JHB City Hall	U	1982-06-01 to 1994-04-07	1 941
GAU	Newtown	U	1995-02-23 to 2004-12-31	52 508
GAU	Rosslyn	U	2003-11-01 to 2004-07-31	1 773
GAU	Bedworth Park	I	1994-01-01 to 1995-01-01	11
GAU	Northern Works	W	1985-09-25 to 1989-05-02	0*
GAU	Delta Park	R	2004-04-30 to 2004-12-31	4 188
KZN	Settlers	RI	2001-01-21 to 2003-09-01	240 119
KZN	Siza Centre	RI	2000-01-01 to 2003-12-31	153 371
KZN	Southern Works	I	2003-12-09 to 2005-01-01	36 567
KZN	Wentworth	RI	2004-02-11 to 2005-01-01	30 196
KZN	Warwick	U	2004-01-01 to 2004-12-15	6 798
KZN	Durban City Hall	U	2004-01-03 to 2005-01-01	7 071
MPU	Bosjesspruit	I	2000-01-01 to 2001-12-31	8 164
MPU	Elandsfontein	P	1994-01-01 to 2003-12-01	112
MPU	Kendal 2	P	1994-01-01 to 2004-12-31	7 794
MPU	Palmer	P	1994-01-01 to 2004-01-10	346
MPU	Club	RI	1998-01-01 to 2001-12-31	16 549
MPU	Verkykkop	P	1994-01-01 to 2003-12-01	117
WC	Cape Town (City Hall)	U	2004-01-01 to 2004-12-31	8 628
WC	Table View	RI	2004-01-01 to 2004-12-31	8 523
WC	Goodwood	R	2004-01-01 to 2004-12-31	8 469
WC	Khayelitsha	TU	2004-08-03 to 2004-12-31	3 489
WC	Athlone	P	2004-01-01 to 2004-12-31	7 775

* Excluded in station count as monitoring stopped before 1994.

Only 24 stations measure NO (out of 43 that measure NO_2). Most of these stations represent urban and power station pollution. It makes sense that most of the residential or background stations do not have to measure NO as it rapidly oxidises to NO_2 and should only be measured close to the source.

Table 3.4.3: Summary of NO_x monitoring in South Africa

Province	Name	Type	Period	No. of points 1994–2004
FS	Makalu	P	2004-01-01 to 2004-12-31	8 547
FS	AJ Jacobs	RI	2005-01-01 to 2006-02-01	14
FS	Steam Station	RI	2004-01-01 to 2006-02-01	15
GAU	Buccleuch	U	2004-03-30 to 2004-12-31	13 616
GAU	Delta Park	R	2004-04-30 to 2004-12-31	4 190
GAU	Newtown	U	2004-03-11 to 2004-12-31	13 773
GAU	Rosslyn	U	2003-11-01 to 2004-07-31	2 008
KZN	Siza Centre	RI	2000-01-01 to 2003-12-31	191 369
KZN	Warwick	U	2004-01-01 to 2004-12-15	6 829
KZN	Durban City Hall	U	2004-01-03 to 2005-01-01	7 405
MPU	Columbus	I	2000-08-01 to 2005-07-01	50
MPU	Kendal 2	P	2004-01-01 to 2004-12-31	7 696
MPU	Palmer	P	2004-01-01 to 2004-01-10	226
MPU	Bosjesspruit	I	2000-01-01 to 2001-12-31	8 428
MPU	Club	RI	1998-01-01 to 2001-12-31	16 755

NO_x data are available for 15 monitoring stations; most of these stations also monitor NO and NO_2.

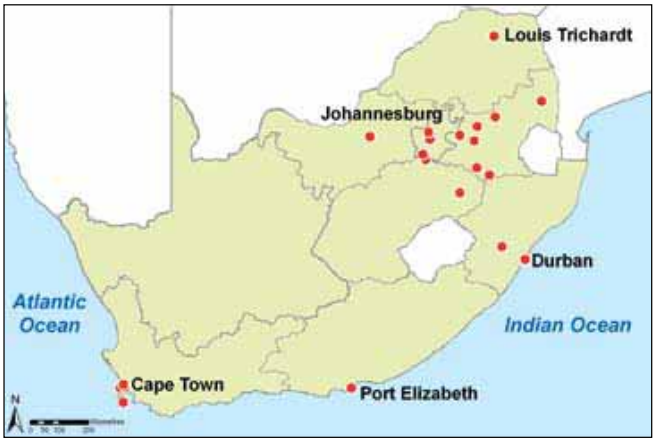


Figure 3.4.1: National distribution of nitrogen dioxide monitoring stations

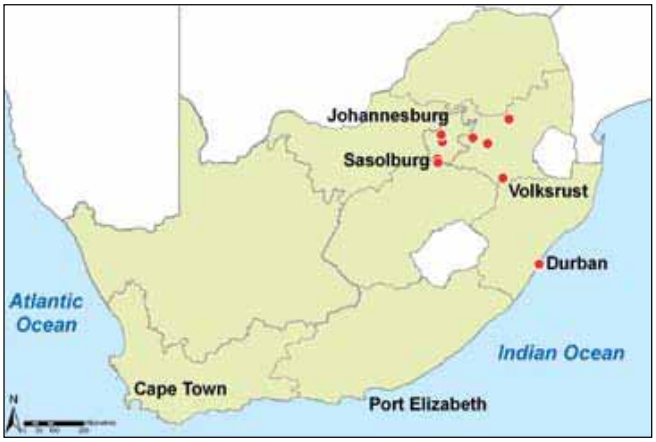


Figure 3.4.2: National distribution of nitric oxide monitoring stations

3.5 NATIONAL SULPHUR DIOXIDE (SO_2) MONITORING

Historically, smoke and SO_2 were measured at most of the stations using so-called bubblers. However, current SO_2 monitoring equipment is very different. The newer technology for SO_2 monitoring may be either a continuous monitoring point or passive samplers. In order to make a fair comparison, SO_2 data are split into three groups and each group is presented separately. The data for SO_2 from the bubblers are presented together with the smoke data. SO_2 data from continuous (81 stations) and passive samplers (8 stations) are presented here (Tables 3.5.1 and 3.5.2) with the national distribution of SO_2 monitoring sites shown in Figure 3.5.1 (on next page).

Table 3.5.1: Summary of continuous SO_2 monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2004
KZN	Cedara	B	1999-11-01 to 2000-09-01	9
WC	Cape point	B	1999-11-01 to 2001-03-01	15
EC	PE Delta	I	1998-10-01 to 2005-06-01	60
EC	Amsterdam Plein	I	2000-05-01 to 2003-12-01	44
GAU	350 site	I	2005-01-01 to 2005-09-01	0
GAU	620 site	I	2005-01-01 to 2005-09-01	0
GAU	Bedworth Park	I	1994-01-01 to 1995-01-01	11
GAU	Mittal mobile caravan	I	2004-05-01 to 2005-09-01	8
KZN	Hillside	I	1997-01-01 to 2002-05-01	18
KZN	Southern Works	I	1997-01-01 to 2005-01-01	345 931
KZN	Ilfracombe	I	1996-03-03 to 2005-12-04	95
KZN	Umkomaas	I	1995-04-01 to 2005-12-04	112
KZN	TLC	I	2000-03-01 to 2005-11-03	53
KZN	Dlambula School	I	2001-01-01 to 2005-12-04	43
KZN	Naidooville School	I	2001-01-01 to 2005-09-04	46
KZN	Drift	I	1994-05-01 to 2005-06-05	123
KZN	Scorpio	I	2003-01-01 to 2004-01-01	11
MPU	Amersfoort	I	2001-08-29 to 2002-12-31	9 454
MPU	Bosjesspruit	I	2000-01-01 to 2004-12-31	30 389
MPU	Columbus	I	2000-08-01 to 2005-07-01	34
NWP	Paardekraal	I	2003-02-04 to 2004-08-31	11 411
NWP	Between stack & tailings dam (C5)	I	2004-02-01 to 2005-11-01	10
NWP	Hexrivier	I	2003-01-01 to 2004-08-31	13 800
NWP	L2 BMR	I	2004-02-01 to 2005-02-01	10
NWP	L4 smelter caravan	I	2004-02-01 to 2005-11-01	11
NWP	L5 sewerage plant	I	2005-03-01 to 2005-11-01	0
NWP	L6- K4 Shaft	I	2005-05-01 to 2005-11-01	0
NWP	Regen Tank smelter	I	2004-02-01 to 2005-11-01	9
NWP	Rowland shaft (C10)	I	2004-07-01 to 2005-11-01	5
NWP	Substation: Marikana Road (C8)	I	2004-04-01 to 2005-11-01	8
NWP	WPL offices (C4)	I	2004-02-01 to 2005-10-01	11
WC	Mittal Steel Saldanha	I	1997-01-01 to 2000-12-01	47
FS	Makalu	P	1994-01-01 to 2004-12-31	8 762
MPU	Elandsfontein	P	1994-01-01 to 2003-12-01	118
MPU	Kendal 2	P	1994-01-01 to 2004-12-31	8 665
MPU	Leandra	P	1995-09-01 to 2003-12-01	100

Continued next page

Province	Station name	Type	Period	No. of points 1994–2004
MPU	Majuba 1	P	1994-12-01 to 2004-12-31	7 345
MPU	Palmer	P	1994-01-01 to 2004-01-10	342
MPU	Verkykkop	P	1994-01-01 to 2003-12-01	118
MPU	Kendal 1	P	1994-01-01 to 1994-08-01	8
MPU	Kendal 3	P	1994-01-01 to 1994-08-01	7
MPU	Majuba 2	P	1995-04-01 to 2000-12-01	66
MPU	Majuba 3	P	2001-01-01 to 2004-12-31	6 709
WC	Athlone	P*	1997-08-01 to 2005-06-01	62
FS	Leitrim	T	2003-04-25 to 2006-02-01	2 307
KZN	Brackenham	R	2002-11-01 to 2004-01-01	11
KZN	Arboretum	R	1997-01-01 to 2004-01-01	72
KZN	Arboretum Extension	R	2002-01-01 to 2004-01-01	19
KZN	Veldenvlei	R	2000-01-01 to 2002-01-01	11
KZN	Wildenweide	R	1997-01-01 to 2002-03-01	52
NWP	Bergsig School	R	2003-01-01 to 2004-08-31	13 014
NWP	Kroondal Station	R	2003-01-01 to 2004-08-31	5 379
WC	Goodwood	R	1993-09-01 to 2005-08-01	115
FS	A J Jacobs	RI	2002-07-01 to 2006-02-01	8 916
FS	Boiketlong	RI	2002-07-01 to 2006-02-01	9 069
FS	Hospital	RI	2002-07-01 to 2006-02-01	9 204
KZN	Settlers	RI	2001-01-21 to 2005-11-10	328 245
KZN	Siza Centre	RI	2000-01-01 to 2029-10-17	298 691
KZN	Wentworth	RI	1985-01-01 to 2005-01-01	318 305
MPU	Club	RI	1998-01-01 to 2004-12-31	41 576
MPU	Grootvlei	RI	2001-12-07 to 2001-12-31	507
MPU	Langverwacht	RI	1998-01-01 to 2004-12-31	44 229
NWP	Waterval	RI	2003-01-01 to 2004-08-31	13 109
NWP	End of town (C3)	RI	2004-02-01 to 2005-11-01	10
NWP	Karee K4 (C9)	RI	2004-07-01 to 2005-11-01	5
NWP	Middle of town (C2)	RI	2004-02-01 to 2005-11-01	11
NWP	Opposite Tlhapi Supermarket(C1)	RI	2004-02-01 to 2005-11-01	11
WC	Bothasig	RI	1995-01-01 to 2005-08-01	116
WC	Table View	RI	1994-11-01 to 2005-08-01	121
EC	Motherwell	T	1999-04-01 to 2003-12-01	37
GAU	Alexandra	T	2002-04-13 to 2005-07-01	22 196
GAU	Orange Farm	T	2004-03-17 to 2005-08-15	8 186
KZN	Esikhawini	T	1997-12-01 to 2000-12-01	35
KZN	Umhlatuze	T	1997-01-01 to 2000-12-01	37
NWP	Selokwaneng House (301 C6)	T	2004-03-01 to 2005-11-01	8
NWP	Selokwaneng House (355 C7)	T	2004-03-01 to 2005-11-01	10
EC	Coega Salt Works	U	2000-11-01 to 2003-11-01	37
GAU	Buccleuch	U	2004-03-30 to 2004-12-31	12 478
GAU	Rosslyn Air Quality Monitoring Station	U	2003-11-01 to 2004-07-30	1 695
KZN	Richards Bay caravan	U	1997-10-01 to 2004-01-01	72
WC	Cape Town City Hall	U	1994-01-01 to 2005-06-01	8 777

Table 3.5.2: Summary of passive SO_2 monitoring in South Africa

Province	Name	Type	Period	No. of points 1994–2004
MPU	Amersfoort	I	1999-11-01 to 2000-11-01	11
EC	Ben McDhui	B	1999-11-01 to 2001-03-01	15
MPU	Elandsfontein	P	1999-11-01 to 2001-02-01	15
MPU	Houtbosrand	B	2000-06-01 to 2000-07-01	2
NWP	Lichtenburg	B	1999-11-01 to 2000-03-01	5
LMP	Louis Trichardt	B	1999-11-01 to 2000-11-01	12
MPU	Skukuza	B	2000-06-01 to 2000-07-01	2
FS	Warden	P	1999-11-01 to 2000-07-01	6

Sulphur dioxide is the most commonly measured pollutant and there are 89 stations that measure the gas on a continuous basis and 8 stations that measure by passive sampling. There are stations in four main cities, a few industrial sites, and a number of stations on the Mpumalanga Highveld to monitor power station pollution. There are 12 background stations and 7 stations in townships. Despite the relatively large number of SO_2 monitoring stations, there are still areas where monitoring is limited or non-existent. For example, all monitoring in the Western Cape is located only in the City of Cape Town, there is no monitoring in East London, and limited monitoring in the greater Vaal Triangle area. There is no monitoring in the Northern Cape or Limpopo provinces.

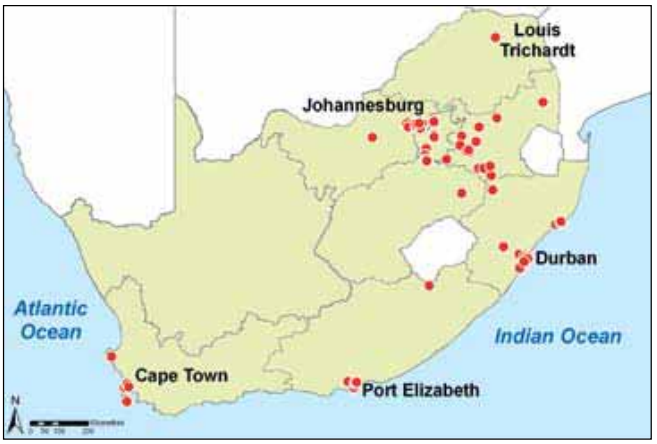


Figure 3.5.1: National distribution of sulphur dioxide monitoring stations

3.6 NATIONAL PARTICULATE MATTER (PM) MONITORING

With the development of air pollution monitoring equipment, smoke measurements were replaced by measurements of particulate matter, more specifically, PM_{10}. Some stations measure both PM_{10} and $PM_{2.5}$. The national distribution of PM_{10} monitoring is indicated in Figure 3.6.1. The relative locations of the stations monitoring these parameters are indicated in Tables 3.6.1–3.6.2.

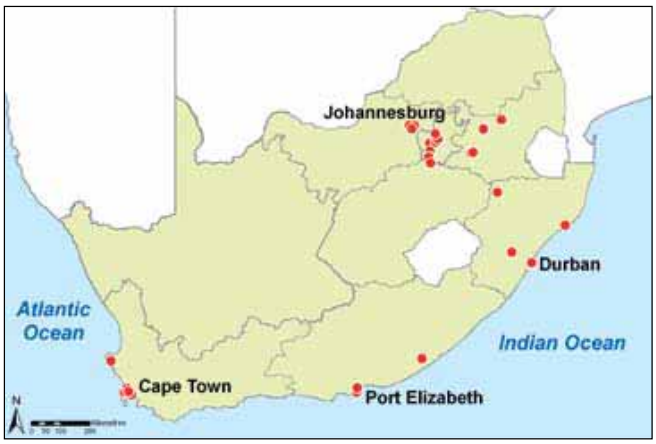


Figure 3.6.1: National distribution of PM_{10} and $PM_{2.5}$ monitoring stations

Table 3.6.1: Summary of PM monitoring in South Africa

Province	Station name	Type	Parameter	Period	No. of points 1994–2004
EC	PE Delta	I	PM_{10}	1999-05-01 to 2004-07-01	37
EC	B: adjacent to the highway	W	PM_{10}	2004-06-25 to 2005-06-30	10
EC	Motherwell	T	PM_{10}	2000-11-01 to 2003-12-01	22
FS	Leitrim	T	PM_{10}	2003-04-25 to 2006-02-01	2 920
GAU	620 site	I	PM_{10}	2005-01-01 to 2005-09-01	0
GAU	350 site	I	PM_{10}	2005-01-01 to 2005-09-01	0
GAU	Mittal mobile caravan	I	PM_{10}	2004-05-01 to 2005-09-01	8
GAU	Delta Park	R	PM_{10}	2004-04-29 to 2004-12-31	4 840
GAU	Alexandra	T	PM_{10}	2002-04-13 to 2005-07-01	874
GAU	Diepsloot	T	PM_{10}	2004-06-28 to 2004-11-24	13 438
GAU	Buccleuch	U	PM_{10}	2004-03-30 to 2004-12-31	13 575
GAU	Newtown	U	PM_{10}	1997-06-24 to 2004-12-31	13 344
GAU	Buccleuch	U	$PM_{2.5}$	2004-03-30 to 2004-12-31	13 492
GAU	Jabavu	T	PM_{10}	2004-07-09 to 2005-08-14	4 072
GAU	Orange Farm	T	PM_{10}	2004-05-14 to 2005-07-14	5 069
GAU	Diepsloot	T	PM_{10}	2004-06-28 to 2004-11-24	13 443
KZN	Settlers	RI	PM_{10}	2001-01-21 to 2003-09-01	264 311
KZN	Wentworth	RI	PM_{10}	2004-02-11 to 2005-01-01	31 094
KZN	Hillside	I	PM_{10}	1998-01-01 to 1999-01-01	2
KZN	Publicity House	U	PM_{10}	2003-06-04 to 2003-08-31	89
KZN	Siza Centre	RI	PM_{10}	2000-01-04 to 2003-12-02	72 756
KZN	Durban City Hall	U	PM_{10}	2004-01-14 to 2005-01-01	8 113
MPU	Columbus	I	PM_{10}	2000-08-01 to 2005-07-01	45
MPU	Palmer	P	PM_{10}	2004-01-01 to 2004-01-10	225
MPU	Langverwacht	RI	$PM_{2.5}$	2001-02-15 to 2003-12-30	18 269
MPU	Club	RI	$PM_{2.5}$	2001-02-27 to 2003-12-30	14 918
NWP	Paardekraal	I	PM_{10}	2003-01-29 to 2003-02-28	478
NWP	Bergsig School	R	PM_{10}	2003-01-01 to 2004-08-23	4 245
NWP	Waterval	RI	PM_{10}	2003-01-07 to 2004-07-20	7 264
WC	Goodwood	R	PM_{10}	1995-03-01 to 2005-08-01	118
WC	Table View	RI	PM_{10}	1994-11-01 to 2005-08-01	122
WC	Mittal Steel Saldanha	I	PM_{10}	1997-04-01 to 2000-08-01	40
WC	Khayelitsha	TU	PM_{10}	1999-03-01 to 2005-08-01	55
WC	Cape Town (Drill Hall)	U	PM_{10}	1995-03-01 to 2005-08-01	118
WC	Bellville South	U	PM_{10}	2004-01-01 to 2004-12-31	6 357

Particulate matter is a critical parameter with regard to the impact on health. The size and composition of the particulate matter, and therefore its impact, vary greatly depending on the source and the distance from it. Eskom had a detailed monitoring network from 1982 to 1992. North-West University investigated particulate matter composition in Rustenberg (Ngobeni and Kgabi, 2005). Considering the importance of PM (and particularly the finer fraction) to human

health, the 32 stations that measure PM_{10} (and three stations that measure $PM_{2.5}$) are considered to be inadequate.

The composition of trace metals is important for determining health and ecological impacts. However, very little is known about trace metal composition of the atmosphere in South Africa. Only three metals have been studied:

1. Lead (Pb) is the metal that has been monitored the most because it is a criteria pollutant (see Section 3.7).

2. Chromium (Cr) monitoring has been ongoing in Newcastle (see Section 4.4.6).

3. Manganese (Mn) in air has been measured in the Northern Cape since 1999.

4. Monitoring of total gaseous mercury was established at the Cape Point Global Atmosphere Watch station in September 1996 (Baker *et al.*, 2002) (see Section 4.4.8).

Table 3.6.2: Summary of TSP monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2004
EC	Amsterdam Plein	I	2000-11-01 to 2003-12-01	34
EC	Coega Salt Works	U	2000-05-01 to 2003-11-01	43
GAU	Diepsloot	T	2004-06-28 to 2004-11-24	13 438
KZN	Karbochem effluent plant	I	1998-04-21 to 2005-07-30	106
KZN	Arbor Park School	R	1998-04-21 to 2005-07-30	105
KZN	Keyway Motors	U	1998-04-21 to 2005-07-30	106
KZN	Newcastle Airport	U	1998-04-21 to 2005-07-30	104

Total suspended particulates may create a nuisance in many parts of South Africa given the generally arid nature of the country and the intensity of agricultural and mining activities. Unpaved roads are also a source of TSP.

Fallout dust is monitored by means of the ASTM 1739 method (bucket method). Since this method of monitoring is relatively cheap, it is widely used by the mining industry. There is a need for more thorough data collection to obtain dust monitoring data available from consultants and industries. Many dust monitoring sites are located within mining areas and therefore do not represent ambient pollution. The next data collection exercise should consider only stations that may affect either ecosystems or residential areas in the vicinity of mines.

3.7 NATIONAL LEAD (Pb) MONITORING

Lead monitoring was conducted mainly through focused campaigns in urban settings at 25 stations (Table 3.7.1). No monitoring station continues to monitor lead.

Table 3.7.1: Summary of Pb monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2004
EC	Port Elizabeth – CBD	U	1992-04-01 to 1997-03-01	26
GAU	Newtown	U	1994-04-01 to 1996-03-01	24
GAU	Fordsburg	U	1994-02-01 to 1995-12-01	22
GAU	Germiston	U	1992-04-01 to 1998-03-01	15
GAU	Johannesburg City Hall	U	1992-04-01 to 1998-02-01	36
GAU	Pretoria: Beatrix St	U	1992-04-01 to 1997-06-01	29
GAU	South Hills	U	1994-03-01 to 1995-12-01	22
GAU	Vereeniging – CBD	U	1992-04-01 to 1998-03-01	37
KZN	Wentworth	RI	2003-01-31 to 2003-09-29	9
KZN	Cowies Hill	B	2003-01-31 to 2003-08-29	6
KZN	Congella fire station	I	2003-01-31 to 2003-09-29	9
KZN	Southern Roof	I	2003-01-31 to 2003-09-29	9
KZN	Gillits Road	R	2003-01-31 to 2003-09-29	9
KZN	Hosley Road	R	2003-01-31 to 2003-09-29	9
KZN	Brighton Beach reservoir	RI	2003-01-31 to 2003-09-29	9
KZN	Isipingo	RI	2003-01-31 to 2003-09-29	9
KZN	Merewent	RI	2003-01-31 to 2003-09-29	9
KZN	South Bluff	RI	2003-01-31 to 2003-09-29	9
KZN	Cato Manor	U	2003-01-31 to 2003-09-29	9
KZN	Chatsworth	U	2003-01-31 to 2003-09-29	8
KZN	Durban City Hall	U	1992-04-01 to 1998-03-01	38
KZN	Durban City Hall	U	2003-02-28 to 2003-09-29	8
KZN	Palmfield Road	U	2003-01-31 to 2003-09-29	9
KZN	Pietermaritzburg City Hall	U	1994-02-01 to 1998-01-01	33
KZN	Pinetown Civic Centre	U	2003-01-31 to 2003-09-29	9
WC	Cape Town City Hall	U	1992-04-01 to 1997-01-01	23

Lead pollution has never been a major problem in South Africa and it is expected that it will decrease after the enforcement of unleaded petrol use (1 January 2006), so only minimal monitoring is required at key stations to determine a long-term trend.

Figure 3.7.1: National distribution of lead monitoring stations

3.8 NATIONAL CARBON MONOXIDE (CO) MONITORING

The monitoring of CO is conducted at 16 stations (Table 3.8.1), which represent all categories of CO monitoring stations – urban, industrial, residential and township. CO is monitored in four provinces (Gauteng, Western Cape, KwaZulu-Natal and Mpumalanga), with only Gauteng having a relatively wide monitoring network. The national distribution of monitoring sites is indicated in Figure 3.8.1.

Table 3.8.1: Summary of carbon monoxide (CO) monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2004
GAU	350 site	I	2005-01-01 to 2005-09-01	0
GAU	620 site	I	2005-01-01 to 2005-09-01	0
GAU	Buccleuch	U	2004-03-30 to 2004-12-31	13 647
GAU	Mittal mobile caravan	I	2004-12-01 to 2005-09-01	1
GAU	Alexandra	T	2002-04-13 to 2005-07-01	14 697
GAU	City Deep	U	1996-07-22 to 1998-05-05	13 945
GAU	Jhb City Hall	U	1982-06-01 to 1994-04-07	2 205
GAU	Newtown	U	1994-12-13 to 2004-12-31	52 421
GAU	Rosslyn	U	2003-11-01 to 2004-07-31	1 852
KZN	Settlers	RI	2001-01-21 to 2003-09-01	272 488
KZN	Warwick	U	2004-06-01 to 2005-01-01	3 967
MPU	Langverwacht	RI	2004-05-27 to 2004-12-31	2 354
WC	Cape Point	B	1991-01-16 to 2004-12-16	128
WC	Goodwood	R	1999-06-01 to 2005-08-01	66
WC	Cape Town City Hall	U	1999-06-01 to 2005-08-01	63
WC	Khayelitsha	TU	2004-08-01 to 2004-12-31	3 559

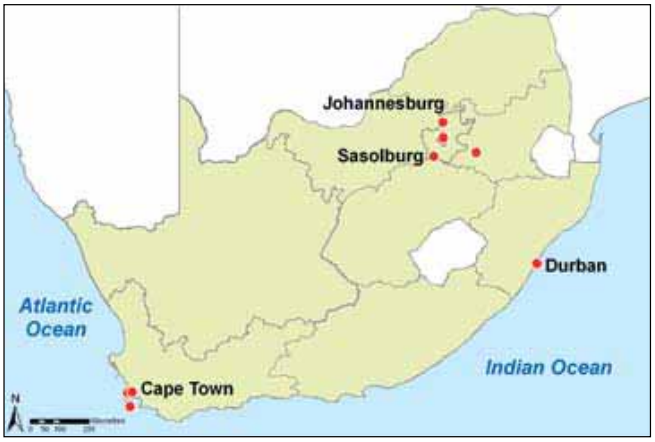


Figure 3.8.1: National distribution of carbon monoxide monitoring stations

Extension of CO monitoring should be considered only in the areas with potential for high pollution.

3.9 NATIONAL BTEX MONITORING

Monitoring for volatile organic compounds focuses mainly on benzene, toluene, ethylbenzene and xylene (BTEX). The monitoring is done using either continuous measurements or passive samplers. Very few data are available as monitoring started only in 2004. Monitoring for BTEX is summarized in Table 3.9.1.

Table 3.9.1: Summary of BTEX monitoring in South Africa

Province	Station name	Type	Parameter	Period	No. of points 1994–2004
GAU	Buccleuch	U	Benzene	2004-06-11 to 2004-12-31	3 523
GAU	620 site	I	Benzene	2005-01-01 to 2005-09-01	0
GAU	350 site	I	Benzene	2005-01-01 to 2005-09-01	0
FS	Leitrim	T	Benzene	2003-04-25 to 2006-01-01	229
GAU	Buccleuch	U	Toluene	2004-06-11 to 2004-12-31	3 424
GAU	620 site	I	Toluene	2005-01-01 to 2005-09-01	0
GAU	350 site	I	Toluene	2005-01-01 to 2005-09-01	0
FS	Leitrim	T	Toluene	2003-04-25 to 2003-08-31	468
GAU	Buccleuch	U	Xylene	2004-03-30 to 2004-12-31	3 504
GAU	620 site	I	Xylene	2005-01-01 to 2005-09-01	0
GAU	350 site	I	Xylene	2005-01-01 to 2005-09-01	0
FS	Leitrim	T	Xylene	2003-04-25 to 2003-08-31	825
EC	B: Site adjacent to highway	W	BTEX	2004-06-26 to 2005-07-07	4
EC	C: Background site in Nqonqweni residential area	W	BTEX	2004-06-26 to 2005-07-07	4
EC	D: Background site at Border Technikon entrance	W	BTEX	2004-06-26 to 2005-07-07	4
EC	E: Background site at Thorn Hill farm	W	BTEX	2004-06-26 to 2005-07-07	2
EC	F: Background site at Lily Stone farm	W	BTEX	2004-06-26 to 2005-07-07	4

At present none of the BTEX compounds is included as a criteria pollutant, but benzene has become an important pollutant and is already included in proposed air quality standards (DEAT, 2006). The spatial distribution of benzene monitoring will therefore be expanded.

3.10 GREENHOUSE GASES

3.10.1 National CO_2 monitoring

Carbon monoxide is an important GHG with the only monitoring data available from the GAW station at Cape Point.

3.10.2 National methane (CH_4) monitoring

Methane is also an important GHG, recorded by only a few monitoring stations in South Africa, in Johannesburg and Cape Point only (Table 3.10.2.1).

Table 3.10.2.1: Summary of methane monitoring in South Africa

Province	Name	Type	Period	No. of points 1994–2004
GAU	Newtown	U	1996-03-28 to 1999-11-01	26 741
GAU	Northern Works	W	1985-10-15 to 1989-05-02	12 746
GAU	Jhb City Hall	U	1983-08-25 to 1994-04-07	31 505
WC	Cape Point	B	1991-01-16 to 2004-12-16	167

Considering the consequences of climate change, the need to quantify mitigation and adaptation options and the general lack of data on greenhouse gases in southern Africa, this type of monitoring should be extended.

3.11 OTHER NATIONAL INITIATIVES

3.11.1 Smoke and SO_2 monitoring

The methods used for smoke and SO_2 (bubbler) sampling were based on development work carried out by the Air Pollution Research Group of the CSIR during the early 1960s. Monitoring was conducted nationally. Table 3.11.1.1 indicates the stations for which data are available.

Table 3.11.1.1: Summary of smoke and SO_2 monitoring in South Africa

Province	Station name	Type	Parameter	Period	No. of points 1994–2004
EC	Motherwell	T	Smoke	1999-03-01 to 2000-08-01	14
EC	Uitenhage Stores	I	Smoke	2002-10-01 to 2005-09-01	26
EC	Despatch	R	Smoke	2002-02-01 to 2005-09-01	31
EC	Uitenhage Parks	R	Smoke	2002-10-01 to 2005-09-01	26
KZN	Cowies Hill	B	Smoke	2001-01-01 to 2003-09-29	53
KZN	Congella Fire Station	I	Smoke	1985-01-01 to 2003-09-29	73
KZN	Southern Roof	I	Smoke	1999-01-01 to 2003-09-29	71
KZN	Gillits Road	R	Smoke	2001-01-01 to 2003-09-29	70
KZN	Hosley Road	R	Smoke	1994-01-01 to 2003-09-29	75
KZN	Brighton Beach reservoir	RI	Smoke	1985-01-01 to 2003-09-29	70
KZN	Isipingo	RI	Smoke	1988-01-01 to 2003-09-29	73
KZN	Merewent	RI	Smoke	1985-01-01 to 2003-09-29	77
KZN	South Bluff	RI	Smoke	1985-01-01 to 2003-09-29	75
KZN	Wentworth	RI	Smoke	1985-01-01 to 2003-09-29	76
KZN	Cato Manor	U	Smoke	2000-01-01 to 2003-09-29	71
KZN	Chatsworth	U	Smoke	1991-01-01 to 2003-09-29	68
KZN	Durban City Hall	U	Smoke	1985-01-01 to 2003-09-29	78
KZN	Palmfield Road	U	Smoke	1996-01-01 to 2003-09-29	76
KZN	Pinetown Civic Centre	U	Smoke	2001-01-01 to 2003-09-29	70
None	Bluff Army Base	RI	Smoke	1994-01-01 to 1998-01-01	5
EC	Uitenhage Stores	I	SO_2	2002-10-01 to 2005-09-01	27
EC	Despatch	R	SO_2	2002-02-01 to 2005-08-01	32
EC	Uitenhage Parks	R	SO_2	2002-10-01 to 2005-09-01	27
KZN	Cowies Hill	B	SO_2	2001-01-01 to 2004-01-01	56
KZN	Congella Fire Station	I	SO_2	1985-01-01 to 2004-01-01	77
KZN	Southern Roof	I	SO_2	1999-01-01 to 2004-01-01	76
KZN	Gillits Road	R	SO_2	2001-01-01 to 2004-01-01	70
KZN	Hosley Road	R	SO_2	1994-01-01 to 2004-01-01	81
KZN	Brighton Beach reservoir	RI	SO_2	1985-01-01 to 2004-01-01	74
KZN	Isipingo	RI	SO_2	1988-01-01 to 2004-01-01	76
KZN	Merewent	RI	SO_2	1985-01-01 to 2003-09-29	78
KZN	South Bluff	RI	SO_2	1985-01-01 to 2004-01-01	80
KZN	Cato Manor	U	SO_2	2000-01-01 to 2004-01-01	74
KZN	Chatsworth	U	SO_2	1991-01-01 to 2004-01-01	71
KZN	Durban City Hall	U	SO_2	1985-01-01 to 2004-01-01	81
KZN	Palmfield Road	U	SO_2	1996-01-01 to 2004-01-01	78
KZN	Pinetown Civic Centre	U	SO_2	2001-01-01 to 2004-01-01	71
WC	Cape Town City Hall	U	SO_2	1994-01-01 to 2005-06-01	86

DEAT ceased funding the project in 1998, but several local authorities, including Centurion, Pretoria, Port Elizabeth, Witbank, Polokwane, Durban, and Welkom, elected to continue with the monitoring work for their own benefit and at their own cost. Both Centurion and Pretoria were recently incorporated into the City of Tshwane Metropolitan Municipality, within which the air pollution monitoring activities have been centralized.

3.11.2 Hydrogen sulphide (H_2S) and total reduced sulphur

Hydrogen sulphide (H_2S) and total reduced sulphur (TRS) are associated mostly with odour from sewage treatment plants, paper production, tanneries, chemical industries, and some other industrial processes. No data are available for evaluation of pollution from sewage plants. Monitoring of H_2S is conducted in the Free State, Gauteng, and Mpumalanga and TRS is monitored in KwaZulu-Natal – see Table 3.11.2.1. The national distribution of H_2S monitoring is indicated in Figure 3.11.2.1.

Table 3.11.2.1: Summary of H_2S and TRS monitoring in South Africa

Province	Station name	Type	Parameter	Period	No. of points 1994–2004
FS	AJ Jacobs	RI	H_2S	2002-07-01 to 2006-02-01	8 098
FS	Boiketlong	RI	H_2S	2002-07-01 to 2006-02-01	7 754
FS	Hospital	RI	H_2S	2002-07-01 to 2006-02-01	8 925
GAU	350 site	I	H_2S	2005-01-01 to 2005-09-01	0
GAU	620 site	I	H_2S	2005-01-01 to 2005-09-01	0
GAU	Mittal mobile caravan	I	H_2S	2004-05-01 to 2005-09-01	8
GAU	Springs Girls' High School	RI	H_2S	2002-01-01 to 2004-12-31	14 924
GAU	Rosebank	U	H_2S	2004-01-01 to 2004-12-31	8 262
MPU	Langverwacht	RI	H_2S	1998-01-01 to 2004-12-31	42 851
MPU	Amersfoort	I	H_2S	2001-08-23 to 2002-12-31	8 863
MPU	Bosjesspruit	I	H_2S	2000-01-01 to 2004-12-31	32 359
MPU	Club	RI	H_2S	1998-01-01 to 2004-12-31	39 392
MPU	Grootvlei	RI	H_2S	2001-12-07 to 2004-12-31	15 182
WC	Table View	RI	H_2S	2004-01-01 to 2004-12-17	8 060
KZN	Warwick	U	TRS	2004-10-05 to 2004-10-30	510
KZN	Southern Works	I	TRS	2004-07-15 to 2005-01-01	3 660
KZN	Settlers	RI	TRS	2001-01-21 to 2005-11-10	279 287

As these pollutants are regarded mainly as a nuisance and do not have ambient standards, the monitoring is conducted only in cases when there are complaints. No national or regional network is required.

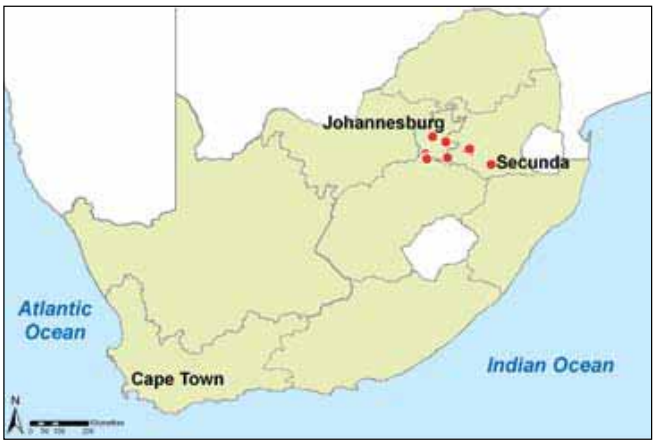


Figure 3.11.2.1: National distribution of hydrogen sulphide monitoring sites

3.11.3 Hazing index

The hazing index is a parameter that relates to the concentration of fine particles ($PM_{2.5}$) and to visibility. The index is recorded over the Mpumalanga Highveld by Eskom and has been the subject of a few campaigns (Table 3.11.3.1). The national distribution of haze monitoring is indicated in Figure 3.11.3.1.

Table 3.11.3.1: Summary of haze monitoring in South Africa

Province	Station name	Type	Period	No. of points 1994–2002
MPU	Elandsfontein	P	1994-01-01 to 1998-06-01	53
MPU	Kendal 2	P	1994-01-01 to 1998-03-01	51
MPU	Leandra	P	1995-09-01 to 1997-11-01	27
MPU	Majuba 1	P	1994-12-01 to 1995-02-01	3
FS	Makalu	P	1994-01-01 to 1997-06-01	39
MPU	Palmer	P	1994-01-01 to 1997-08-01	43

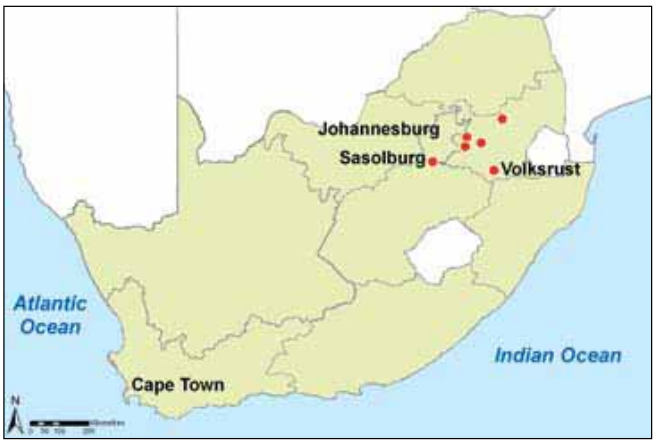


Figure 3.11.3.1: National distribution of stations that monitor hazing (haze index)

4. Ambient air quality: 1994–2004

4.1 DATA ANALYSIS

4.1.1 Long-term analysis

The monthly and annual averages were plotted for all the stations that have at least 5 years of data and are illustrated with the maps showing the location of the stations (section 4.2). These plots show the temporal variations and compliance with long-term standards.

The data were analyzed to see if they revealed a temporal trend. The results for stations with a correlation coefficient above 0.1 were summarized in tables that contain the following columns:

1. Period — Start and end dates for the period for which data are available
2. Num. — Number of monthly averages used for trend analysis
3. Avg — Average concentration during that period
4. Slope — Slope of the trend line
5. Intercept — Theoretical value where line would intercept the y-axis (concentration)
6. RSq — Pearson product moment correlation coefficient which represents the proportion of variance in concentrations attributable to variance over time. The closer this value is to 1.0, the stronger the trend
7. % growth — The slope divided by average concentration and expressed as a percentage.

A negative value for % growth means that there was a decreasing trend, and vice versa.

4.1.2 Compliance analysis

The results of the statistical analysis are presented for each pollutant and for each province in section 4.3.

For each station and each parameter, the following outcomes of statistical analysis of monthly concentrations are presented in tabular format:

1. Num. — Number of monthly averages available in the database for the period 1994–2004
2. Num. (all) — Number of monthly averages available in the database for the full period provided (include data from 1993–2005)
3. Avg — Average concentration for the period 1994–2004
4. Avg (all) — Average concentration for the entire period available
5. Median — Median concentration (50th percentile) for the period 1994–2004
6. Std dev. — Standard deviation of the monthly concentrations for the period 1994–2004
7. Top 5% — 95th percentile concentration (top 5 percentile) for the period 1994–2004
8. Max — Maximum monthly average for the period 1994–2004

Interpretation of these parameters is described below.

The comparison of Num. (1) and Num. (all) (2) shows the size of the data set that was analyzed and the temporal extent of the data. For example, if the station has been operating at least 90% of the time the value for the whole period (1994–2004) in the 1st column should be 119. There are very few stations with such a good record.

From this comparison one can also see if the station has recently come into operation. In such cases the value in the 1st column is low, while the value in the 2nd column is higher. For these stations one should look at the average for the entire period, Avg (all) (4), because the value for the study period may not be representative.

The value in Num. (1) can also be compared with the corresponding values in the tables in section 4. Should the latter be much larger, it means that the frequency of the received data was higher than monthly.

Comparison of the Avg (3) with the Median (5) helps to show whether the distribution is symmetrical or not. If the median is higher than the average, it means that more than half of the values measured are higher than the average value and vice versa.

The value of the Std dev. (6) shows the variability in the measurements. The higher the standard deviation compared to the average, the larger the range.

The comparison of the Top 5% (7) with the Max. (8) helps to evaluate the validity of the maximum value. If the maximum is significantly higher than the top 5 percentile, the maximum value could be an outlier and should be checked and treated with caution.

For example, the data recorded at one of the stations showed concentrations of NO_2 measured during the first month of the station operation: 89 $\mu g/m^3$ compared to the range of 1–17 $\mu g/m^3$ for the rest of the months. It was therefore assumed that this value is an outlier. The outliers so identified were checked by responsible organisations and some were subsequently removed from the database.

The results of Avg, i.e. the calculated monthly average, and the top 5% for the same period were also depicted graphically and compared with all available guidelines and standards where practical. The main purpose of this was to provide a visual picture of the spread

of these limit values, but it also showed the geographical distribution and variations for different station types.

The results of statistical analysis of annual concentrations are also presented in tabular format and include the following parameters:

1. Num. Number of annual averages available in the database for the period 1994–2004

2. Avg Average annual concentration for the period 1994–2004

3. Max Maximum annual average for the period 1994–2004

4. % limit Average value divided by annual limit and expressed as a percentage

% limit provides a comparison between the long-term average and the annual limit value. For example, if this value is greater than 50%, it means that the long-term average is more than half the annual limit. If the value is greater than 100%, then the pollution level is consistently above standard.

4.2 LONG-TERM ANALYSIS FOR CRITERIA POLLUTANTS

The monthly data for the stations that have at least 5 years' data were analyzed to determine possible trends. Monthly and annual averages were depicted to indicate the trends in monthly and annual averages and compared with the relevant standards. These graphs also display the continuity in monthly and annual data capture.

4.2.1 Ozone

The results of the long-term trend analysis of O_3 are shown in Table 4.2.1.1, indicating stations with correlation coefficients above 0.1. The trends in long-term averages of O_3 are indicated in Figures 4.2.1.1-4.2.1.5.

Table 4.2.1.1: Long-term analysis of monthly data for O_3

Province	Station Type	Name	Period	Num.	Avg	Slope	Intercept	RSq	growth%
E Cape	I	PE Delta	1998-10-01 to 2005-06-01	52	25.7	–0.341	62.23	0.52	–1.32
MPU	P	Elandsfontein	1994-01-01 to 2003-12-01	116	22.5	–0.081	28.33	0.19	–0.36
W Cape	P	Athlone	1996-05-01 to 2005-07-01	86	13.4	0.038	9.51	0.14	0.28
W Cape	R	Goodwood	1994-01-01 to 2005-06-01	102	13.6	0.035	10.41	0.14	0.26

* See explanations of the meaning of columns in section 4.1.1

The trends vary between being positive and negative but correlation coefficients (expressed as RSq) are low with the exception of PE Delta in the Eastern Cape. There the biggest negative trend of about 1.3% was measured with a correlation coefficient of 0.52. The positive trend of about 0.3% applies to the Cape Town sites of Athlone and Goodwood.

The monthly and annual averages in O_3 in and around Cape Town are indicated in Figure 4.2.1.1.

Location of ozone monitoring stations in and around Cape Town

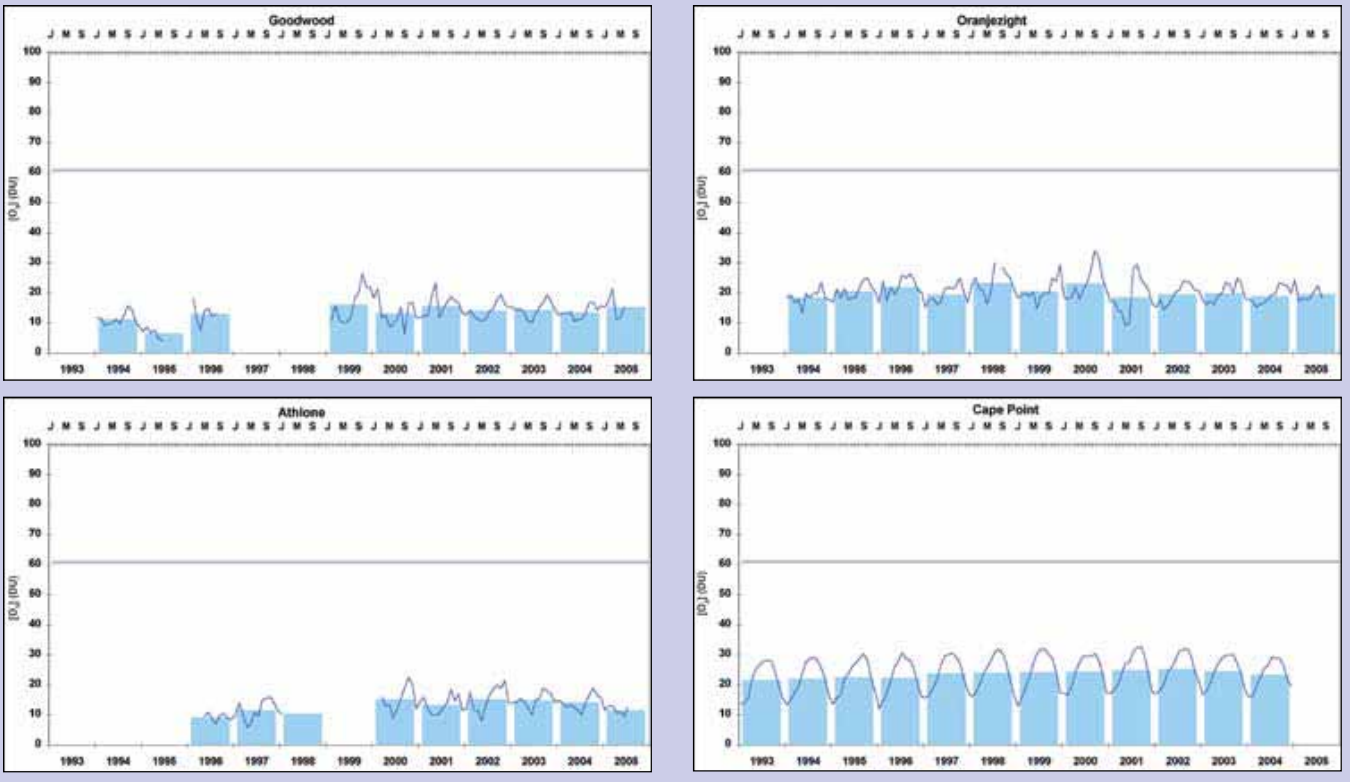
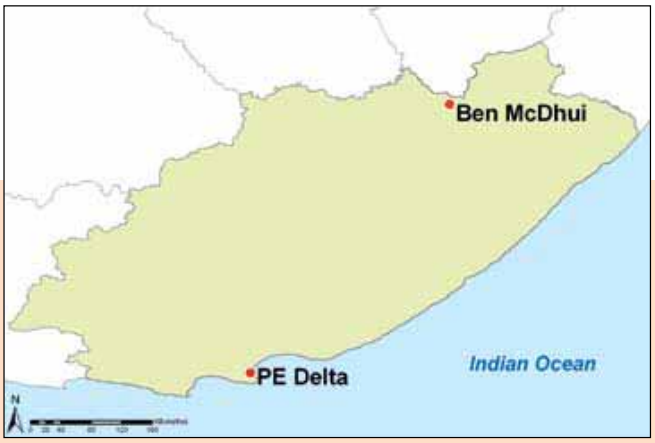
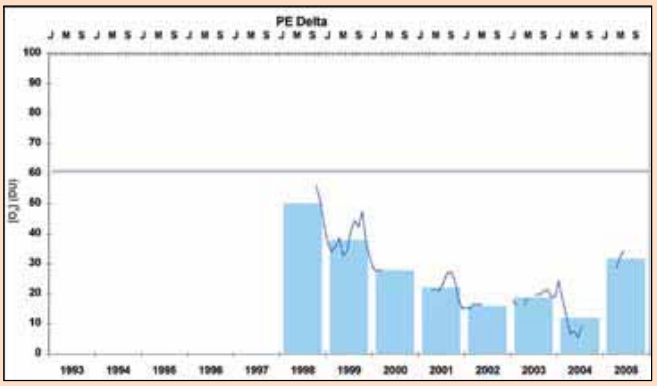


Figure 4.2.1.1: Long-term trend of ozone levels in and around Cape Town

The long-term trend of O_3 concentration in the Eastern Cape is indicated in Figure 4.2.1.2.



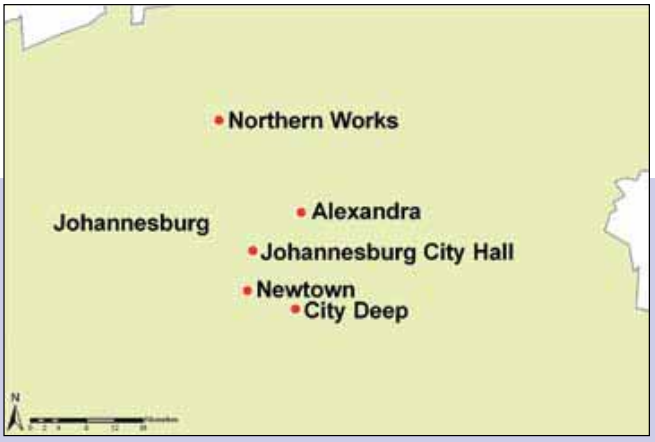
Location of ozone monitoring stations in the Eastern Cape



Monthly average (ppb)
Annual average (ppb)
8-h SANS-1929 limit (60 ppb)

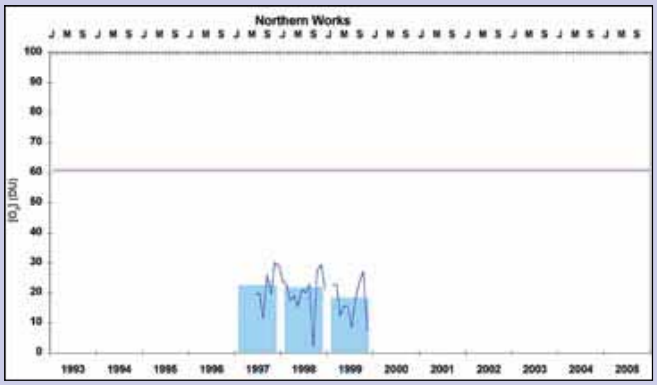
Figure 4.2.1.2: Long-term trend of ozone levels in the Eastern Cape

The long-term trend of O_3 concentration around Johannesburg is indicated in Figure 4.2.1.3.



Location of ozone monitoring stations around Johannesburg

Monthly average (ppb)
Annual average (ppb)
8-h SANS-1929 limit (60 ppb)



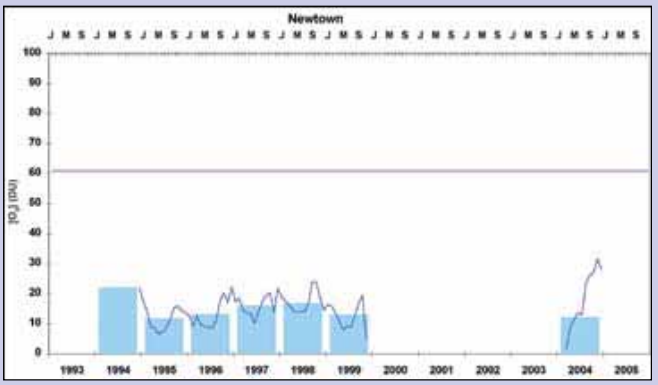
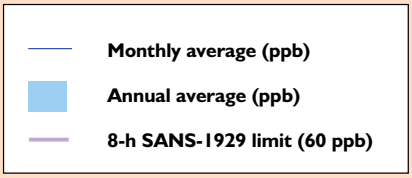
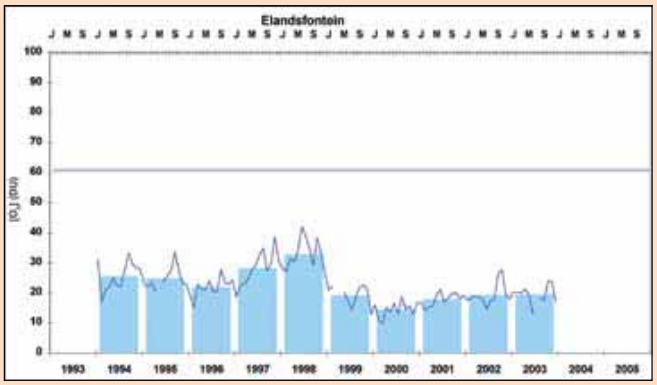


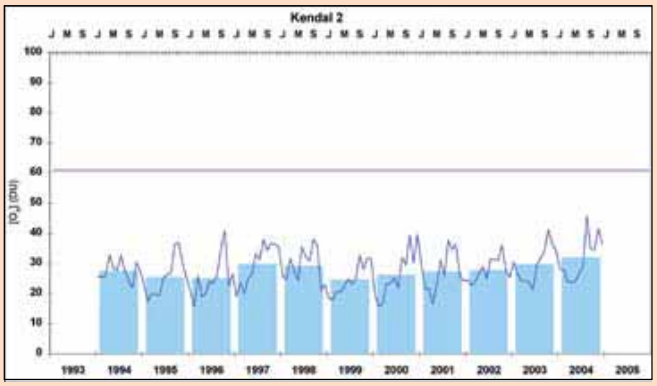
Figure 4.2.1.3: Long-term trend of ozone levels around Johannesburg

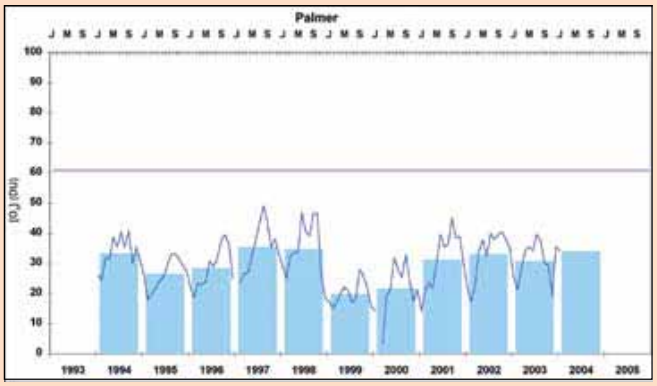
The long-term trend of O_3 in Mpumalanga is indicated in Figure 4.2.1.4.

Location of ozone monitoring stations in Mpumalanga









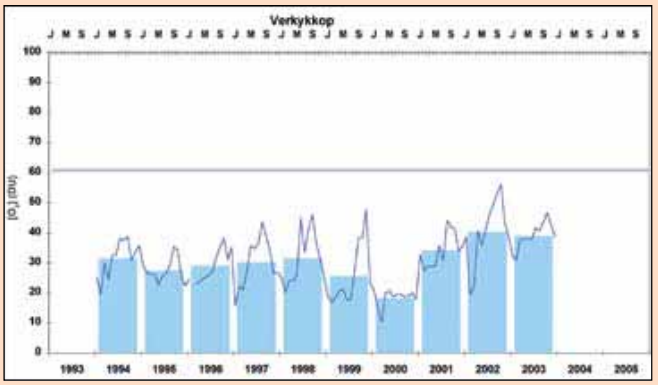
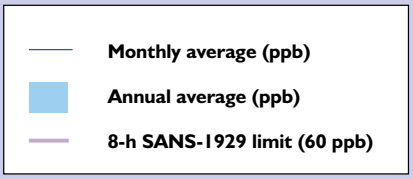


Figure 4.2.1.4: Long-term trend of ozone levels in Mpumalanga

The long-term trend in O_3 levels near Vanderbijlpark are indicated in Figure 4.2.1.5.

Location of ozone monitoring stations near Vanderbijlpark



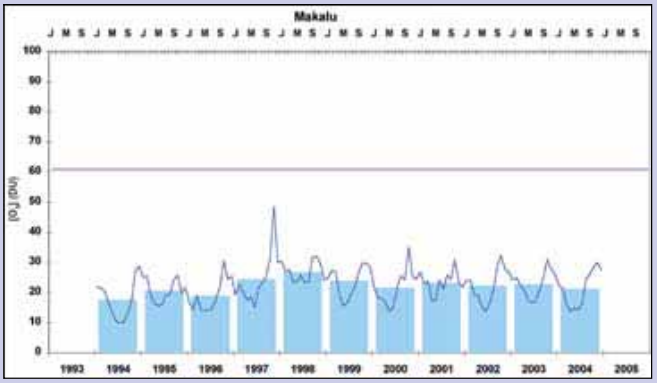


Figure 4.2.1.5: Long-term trend of ozone levels near Vanderbijlpark

The following can be derived from Figures 4.2.1.1–4.2.1.5 (also see Table 4.2.1.1):

No monthly averages exceeded the 8-hour standard. Furthermore, no real trend can be seen other than the monthly fluctuations in O_3 at Cape Point, reaching a peak in early winter (Figure 4.2.1.1). The station at Cape Point detects the natural seasonal variation while the variation at other stations in an urban setting is influenced by changes in the contributing precursor sources.

A downward trend was noticed up to 2004 in the Eastern Cape, where a sudden increase was seen. It should be noted that monthly data capture seems to be sporadic.

4.2.2 Oxides of nitrogen

The results of the long-term trend analysis of NO_2 concentrations are shown in Table 4.2.2.1, and the corresponding averages are indicated in Figures 4.2.2.1–4.2.2.4.

Table 4.2.2.1: Results of the trend analysis for oxides of nitrogen

Province	Type	Name	Parameter	Period	Num.	Average	Slope	Intercept	RSq	growth%
GAU	U	Newtown	NO	1995-02-23 to 2004-12-31	68	55.36	–0.254	72.39	0.19	–0.46
MPU	RI	Club	NO_2	1998-01-01 to 2006-03-31	66	35.79	–1.308	173.81	0.16	–3.66
MPU	P	Elandsfontein	NO	1994-01-01 to 2003-12-01	112	2.99	–0.014	4.00	0.11	–0.48
MPU	P	Verkykkop	NO	1994-01-01 to 2003-12-01	118	1.74	0.012	0.83	0.19	0.71
WC	B	Cape Point	N_2O **	1994-04-16 to 2004-12-16	93	314.48	0.064	308.91	0.98	0.02
WC	U	Central Cape Town (City Hall)	NO_2	1994-01-01 to 2005-08-01	137	25.30	–0.113	34.66	0.32	–0.45
WC	R	Goodwood	NO_2	1995-03-01 to 2005-07-01	121	14.99	–0.092	23.22	0.27	–0.62

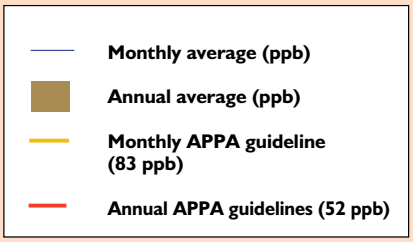
See explanations on the meaning of columns provided in section 4.1.1.

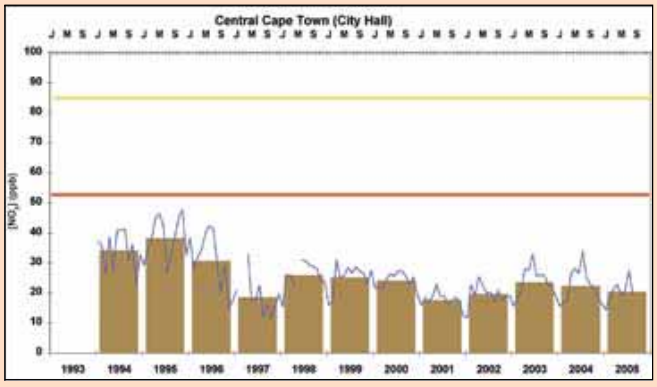
** In units of ppb.

The percentage change indicates a downward trend in NO_2 concentrations at most sites, though the correlation coefficients for the trends are low. NO follows the same trend with the exception of increasing pollution at the Verkykkop station in Mpumalanga. The upward trend of N_2O at Cape Point, though very small (0.02%), indicates a strong trend (RSq = 0.977), which demonstrates clear growth in GHG pollution.

The long-term trends in NO_2 levels in Cape Town are shown in Figure 4.2.2.1.

Location of NO_2 monitoring stations at Cape Town





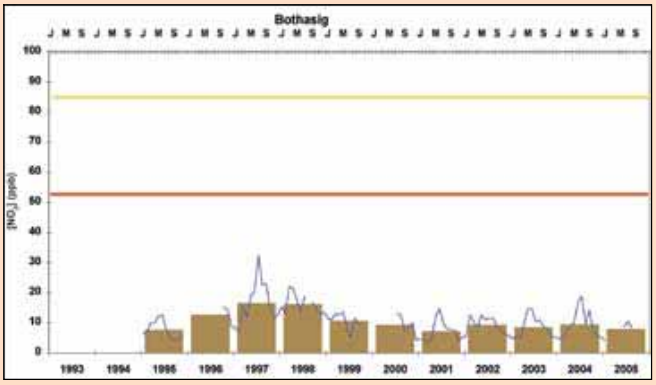


Figure 4.2.2.1: Long-term NO_2 trends at Cape Town

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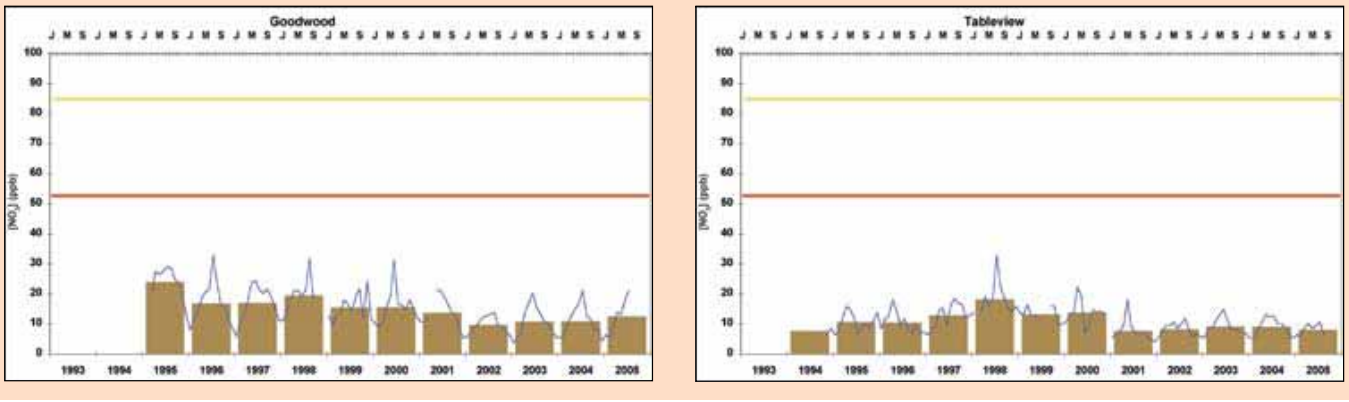
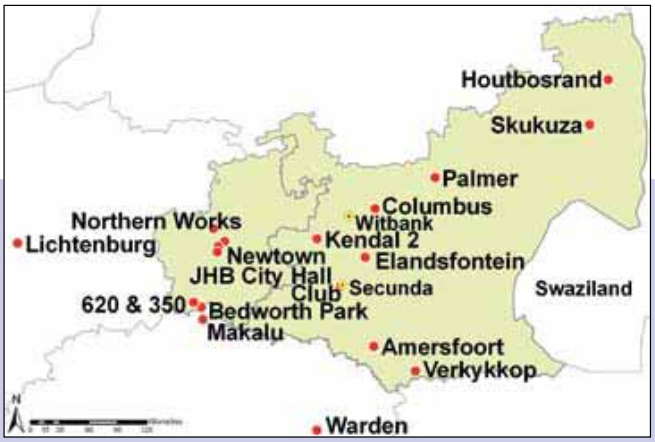
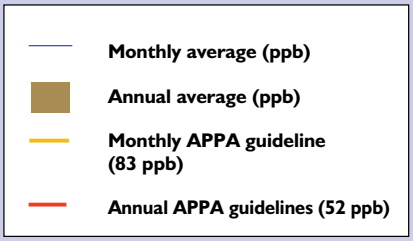


Figure 4.2.2.1: Long-term NO_2 trends at Cape Town

The long-term trend in NO_2 levels in Gauteng and Mpumalanga are illustrated in Figure 4.2.2.2.



Location of NO_2 monitoring stations in Gauteng and Mpumalanga



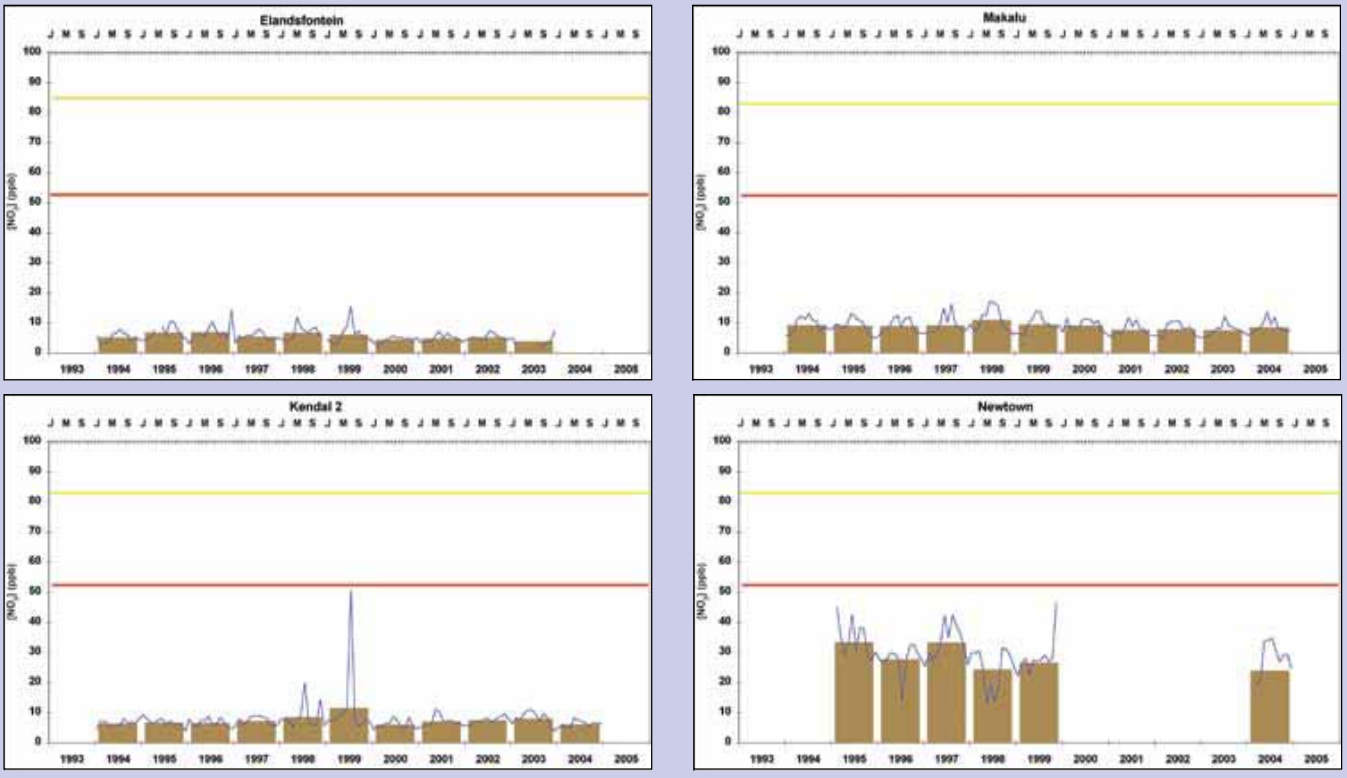


Figure 4.2.2.2: Long-term trend in NO_2 levels in Gauteng and Mpumalanga

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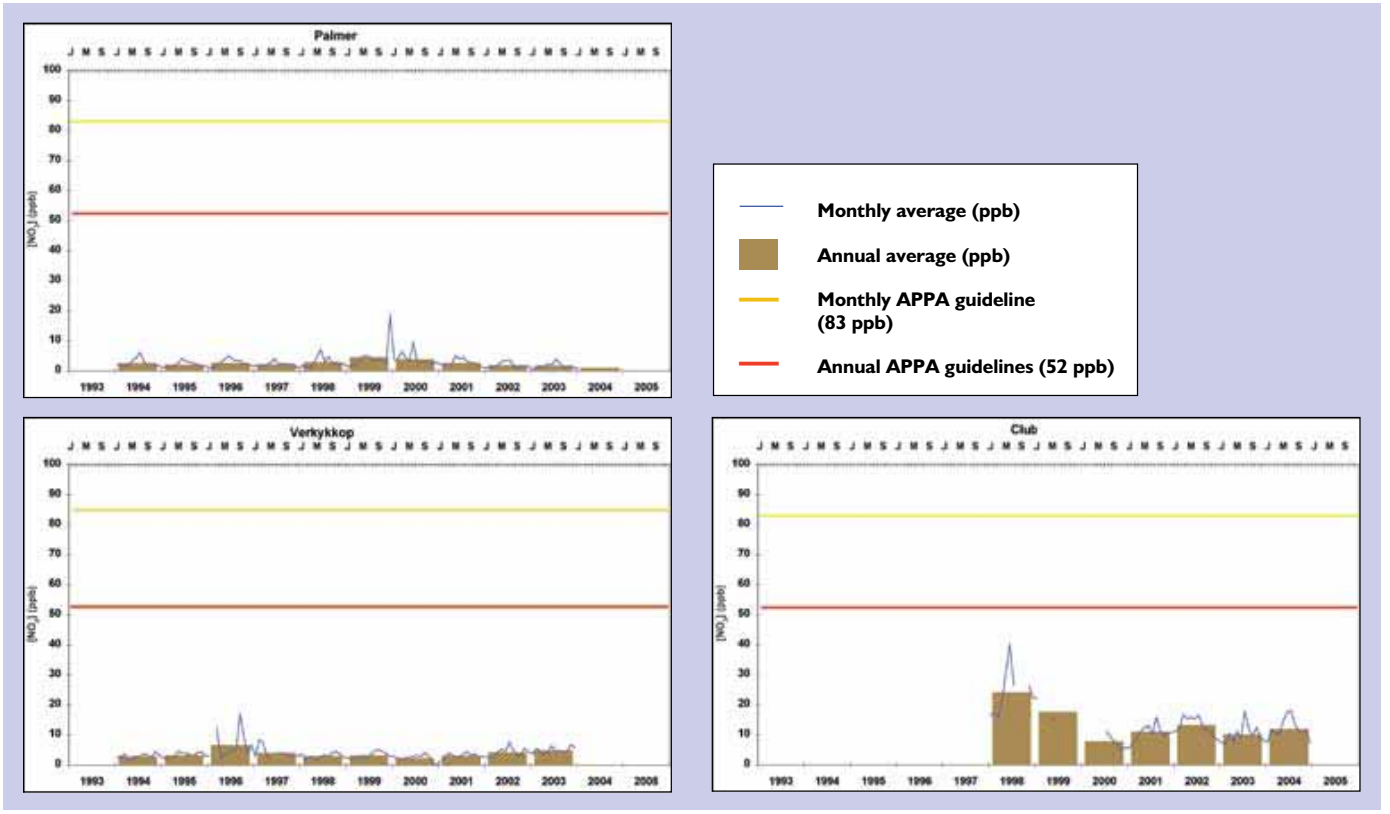
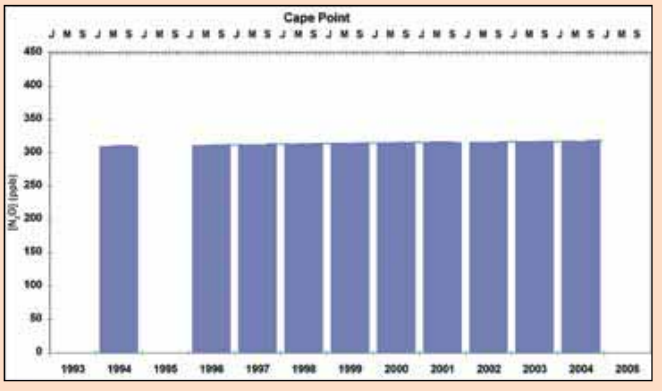


Figure 4.2.2.2: Long-term trend in NO_2 levels in Gauteng and Mpumalanga

The long-term trend in N_2O levels, measured at Cape Point, is indicated in Figure 4.2.2.3.

Location of N_2O monitoring station at Cape Point



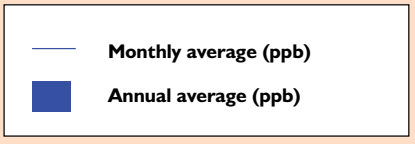
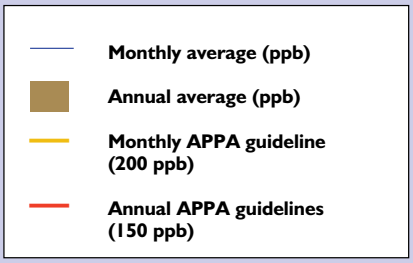


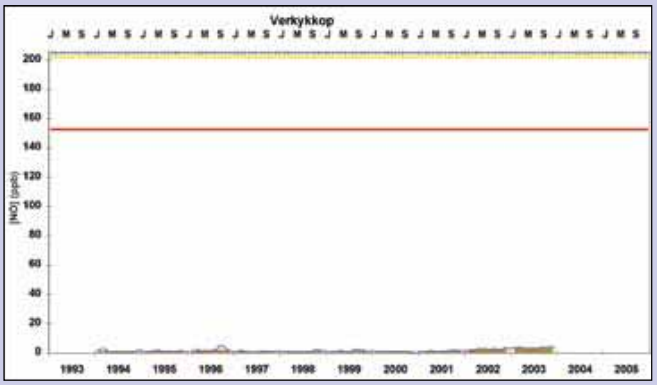
Figure 4.2.2.3: Long-term N_2O levels at Cape Point

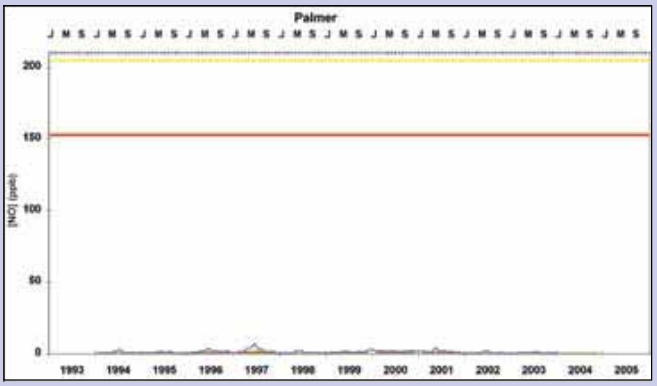
Figure 4.2.2.3 indicates that the long-term annual average N_2O levels appear to be stable at 300 ppb.

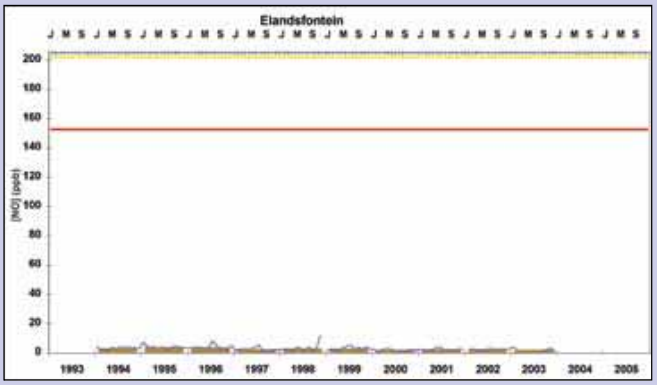
The long-term NO averages in Mpumalanga and Gauteng are shown in Figure 4.2.2.4.

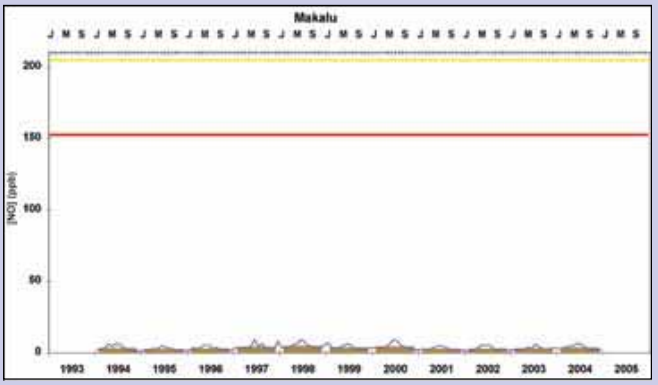
Location of NO monitoring stations in Gauteng and Mpumalanga

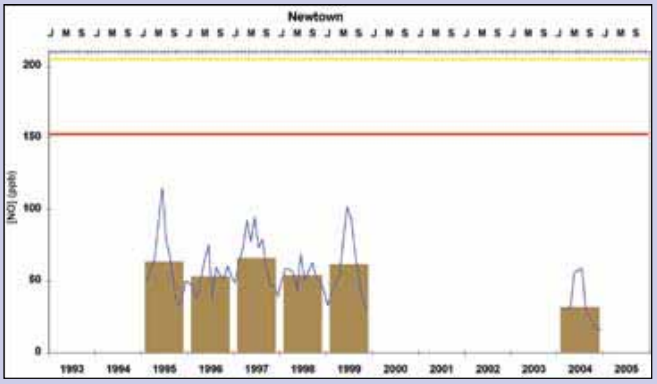












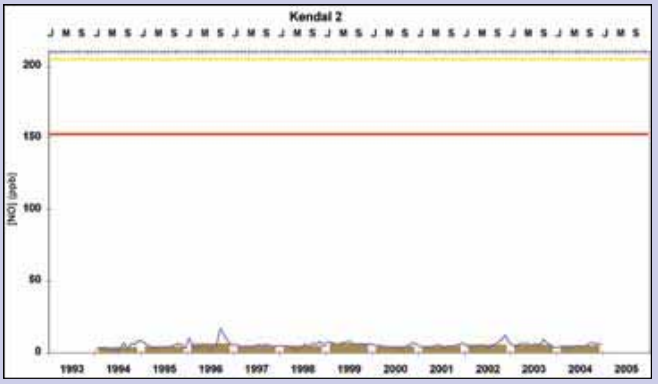


Figure 4.2.2.4: Long-term trends in NO concentration levels in Gauteng and Mpumalanga

The following can be derived from Figures 4.2.2.1–4.2.2.4 (also compare results in Table 4.2.2.1):

- NO_2 in Cape Town - the general trend at all sites is downward, with no exceedances of the monthly or annual standards
- NO_2 in Mpumalanga and Gauteng - the general trend is again down, with no exceedance of either of the monthly or annual standards.
- N_2O levels in Cape Town - from Table 4.2.2 a small increase can be seen
- NO levels in Mpumalanga and Gauteng - levels were generally very low, with no exceedances of either the monthly or annual standards. Levels at Newtown seem to be significantly higher than at any of the other stations.

4.2.3 Sulphur dioxide

The results of the long-term trend analysis of SO_2 concentrations are shown in Table 4.2.3.1. See also Figures 4.2.3.1–4.2.3.5.

Table 4.2.3.1: Results of the trend analysis for SO_2

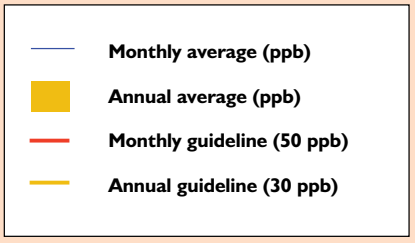
Province	Type	Name	Period	Num	Avg	Slope	Intercept	RSq	growth%
KZN	I	Drift	1994-05-01 to 2005-06-05	130	14.82	-0.214	32.79	0.55	-1.44
KZN	I	Southern Works	1997-01-01 to 2005-01-01	95	25.04	-0.119	36.52	0.16	-0.47
KZN	RI	Wentworth	1985-01-01 to 2005-01-01	95	18.51	-0.200	37.81	0.38	-1.08
MPU	I	Columbus	2000-08-01 to 2005-07-01	39	15.23	-0.479	73.29	0.48	-3.14
MPU	P	Leandra	1995-09-01 to 2003-12-01	100	11.42	-0.062	16.50	0.11	-0.54
MPU	P	Verkykkop	1994-01-01 to 2003-12-01	118	3.74	0.017	2.48	0.11	0.46
MPU	RI	Club	1998-01-01 to 2004-12-31	69	14.20	-0.278	43.47	0.35	-1.95
MPU	RI	Langverwacht	1998-01-01 to 2004-12-31	72	10.59	0.094	0.63	0.17	0.89
WC	R	Goodwood	1993-09-01 to 2005-08-01	127	5.64	-0.025	7.73	0.14	-0.44

* See explanations on the meaning of columns in section 4.1.1.

The percentage growth indicates an upward trend at some stations and a downward trend at others, with the correlation coefficients for the trends being very low. The biggest reduction of about 3.1% was measured at the Columbus Station in Mpumalanga, whereas the biggest upward trend of 0.89% was recorded at Langverwacht in Mpumalanga.

The long-term SO_2 trends for the area surrounding Cape Town are indicated in Figure 4.2.3.1.

Location of SO_2 monitoring stations at Cape Town



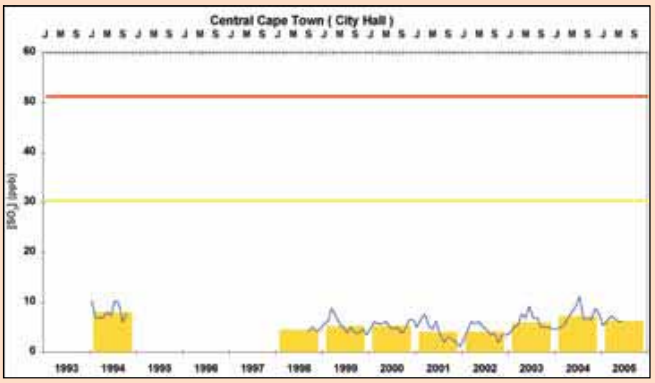


Figure 4.2.3.1: Long-term trends in SO_2 levels at Cape Town

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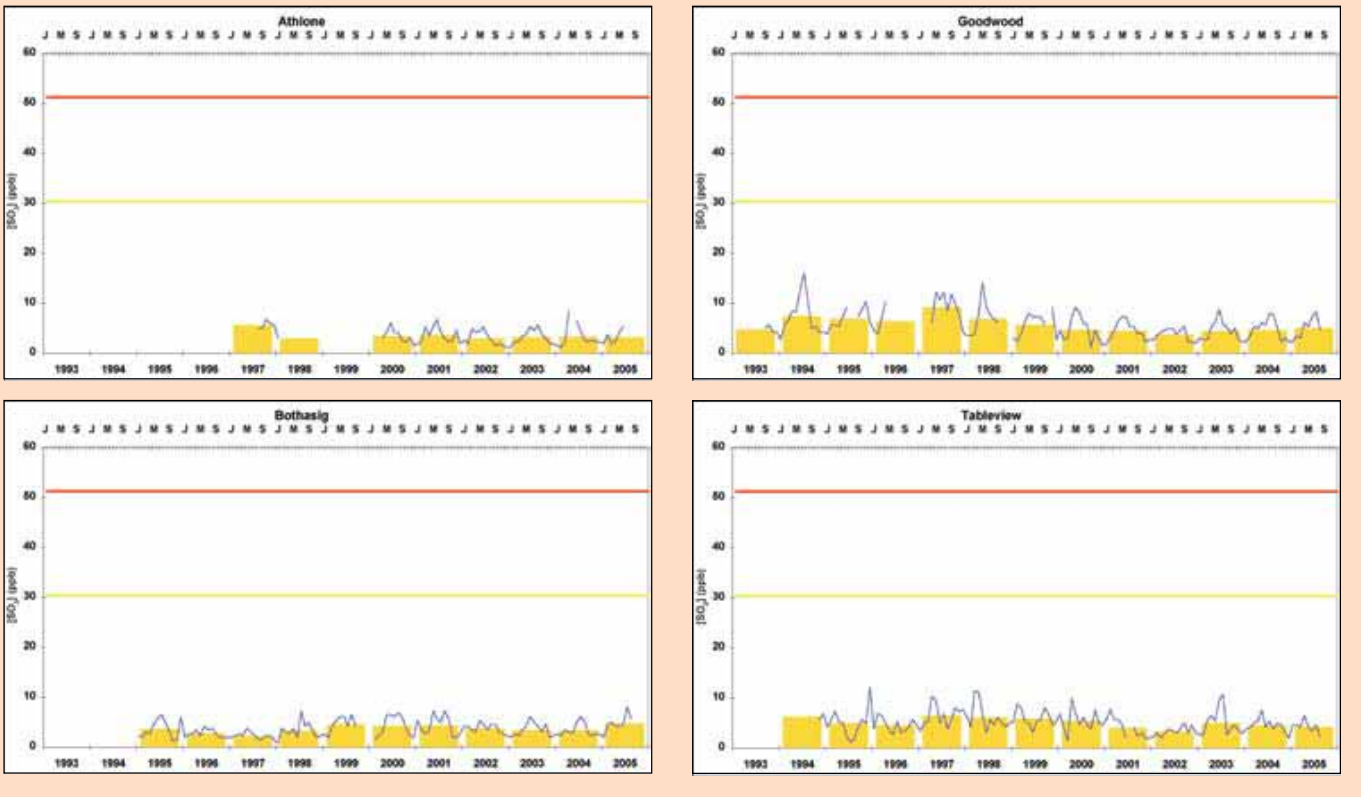
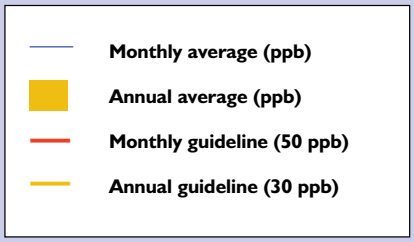


Figure 4.2.3.1: Long-term trends in SO_2 levels at Cape Town

Long-term trends of SO_2 levels at Port Elizabeth are indicated in Figure 4.2.3.2.

Location of SO_2 monitoring stations at Port Elizabeth



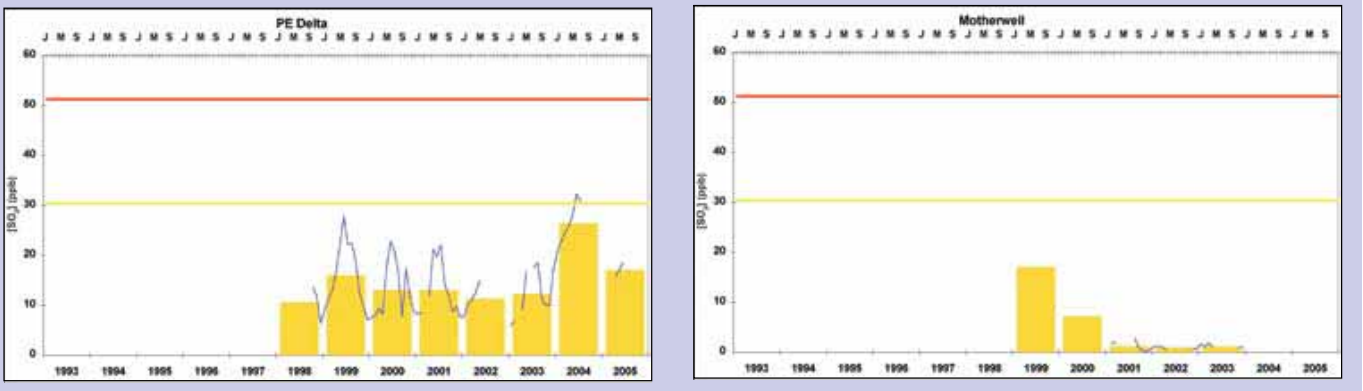
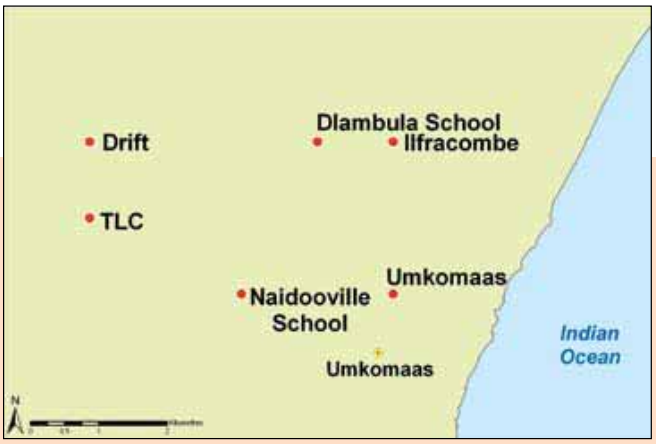
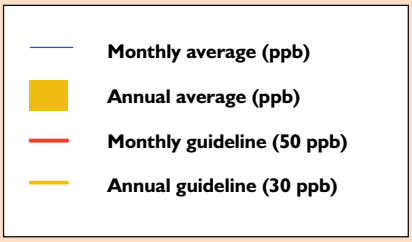


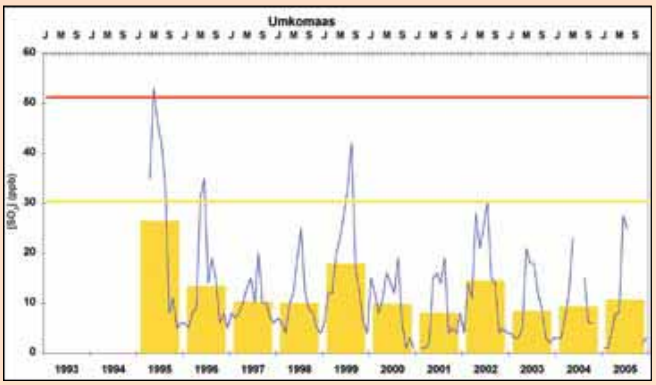
Figure 4.2.3.2: Long-term trends in SO_2 levels at Port Elizabeth

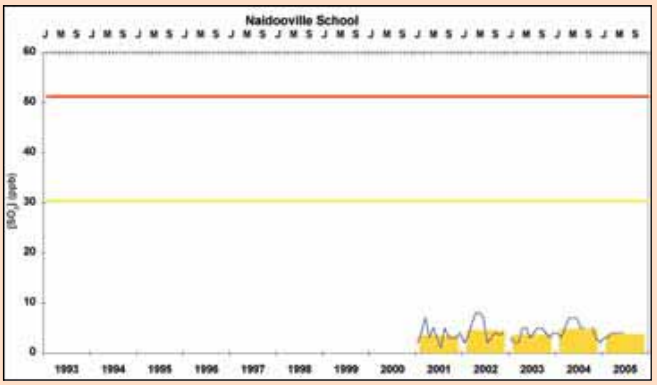
Long-term SO_2 levels at Umkomaas are indicated in Figure 4.2.3.3.

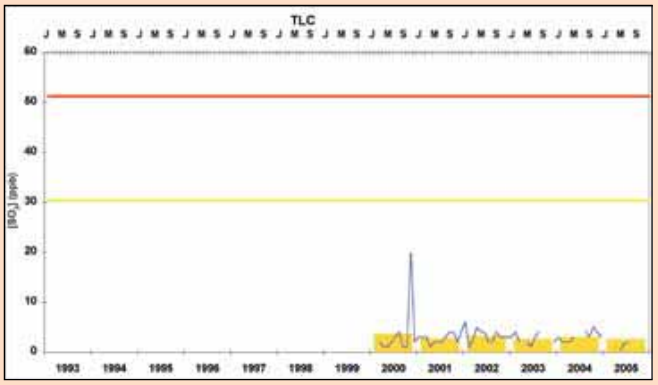


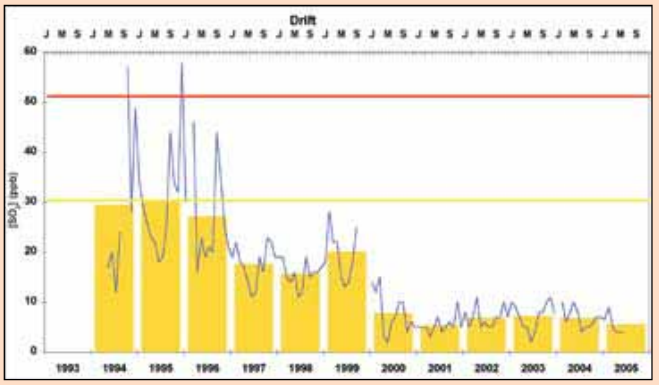
Location of SO_2 monitoring stations around Umkomaas

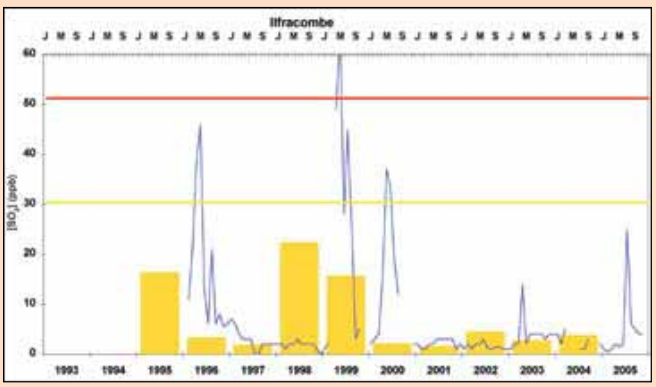












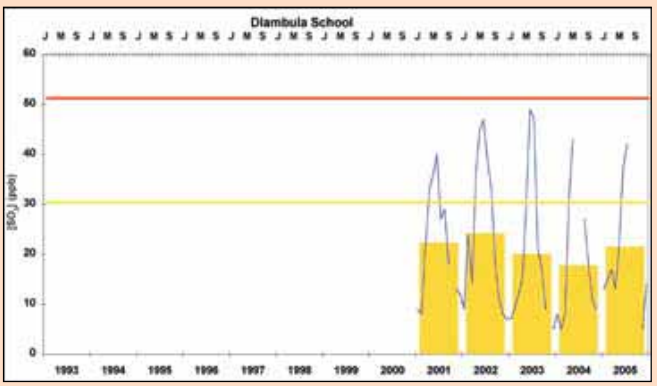
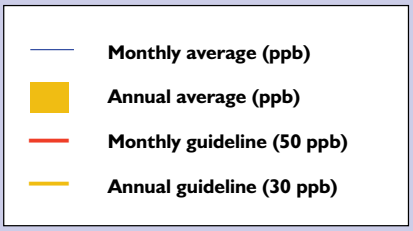
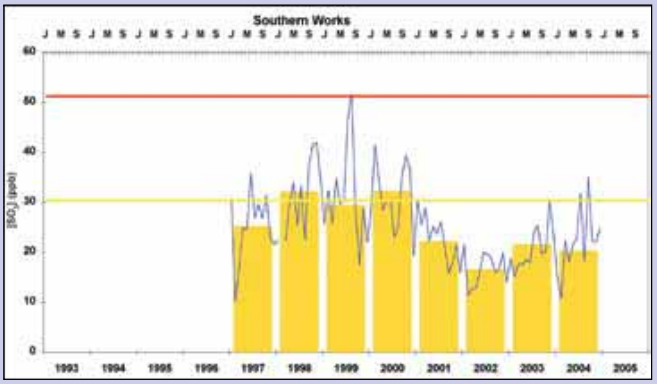


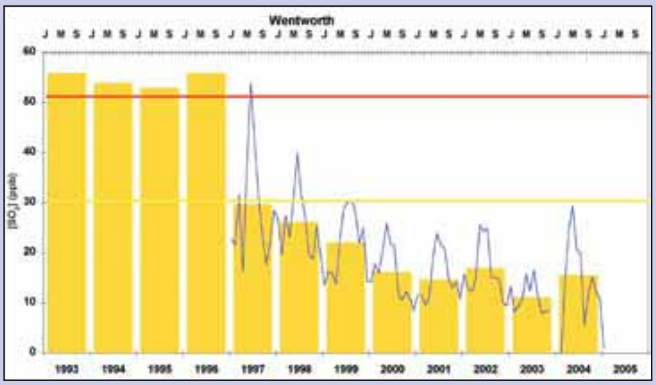
Figure 4.2.3.3: Long-term SO_2 levels around Umkomaas

Long-term SO_2 levels at Durban are indicated in Figure 4.2.3.4.

Location of SO_2 monitoring stations at Durban







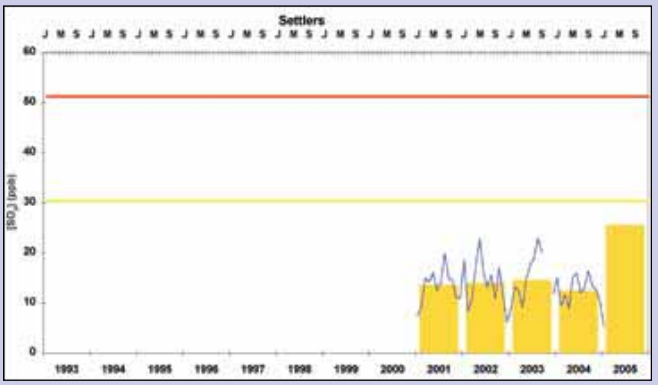
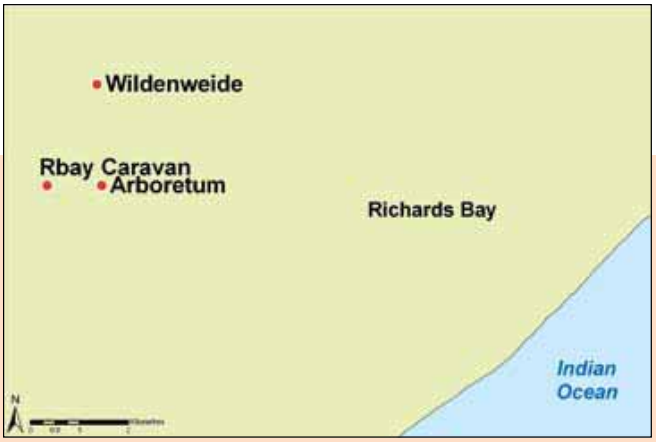
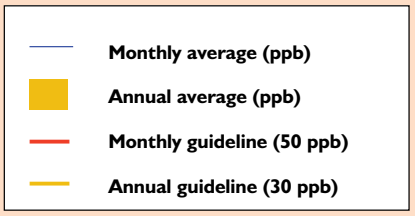


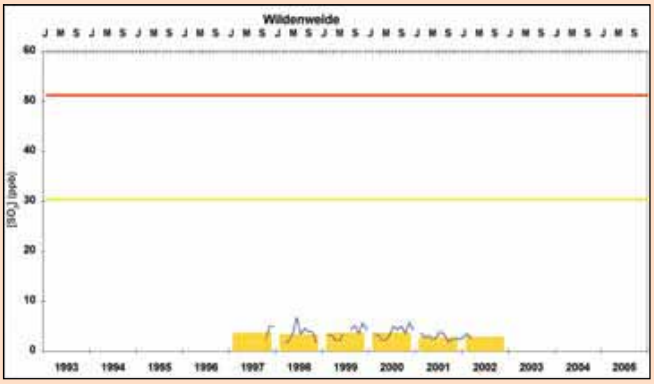
Figure 4.2.3.4: Long-term SO_2 levels at Durban

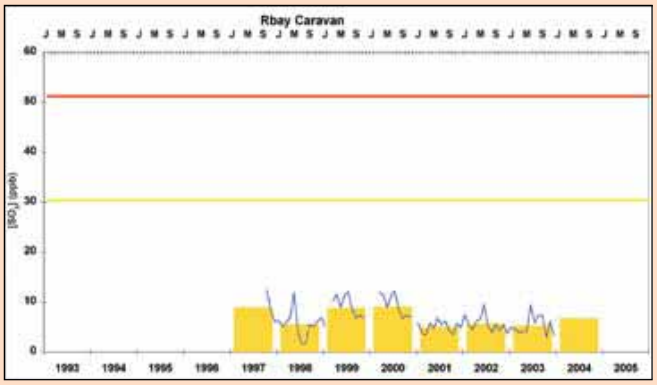
Figure 4.2.3.5 indicates the long-term trends of SO_2 at Richards Bay.



Location of SO_2 monitoring stations at Richards Bay







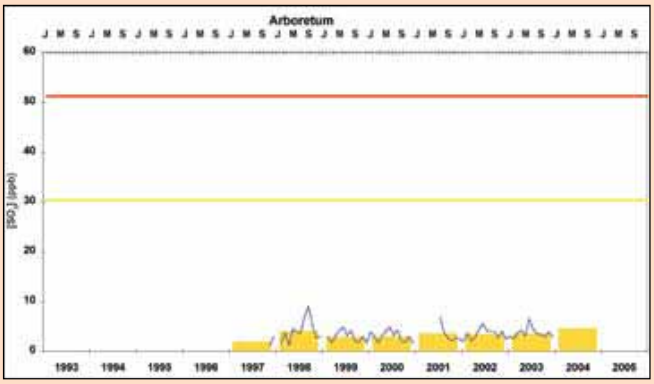
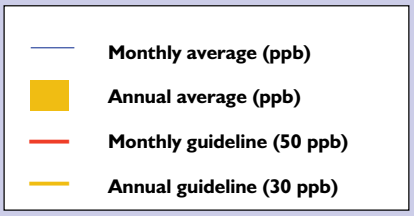
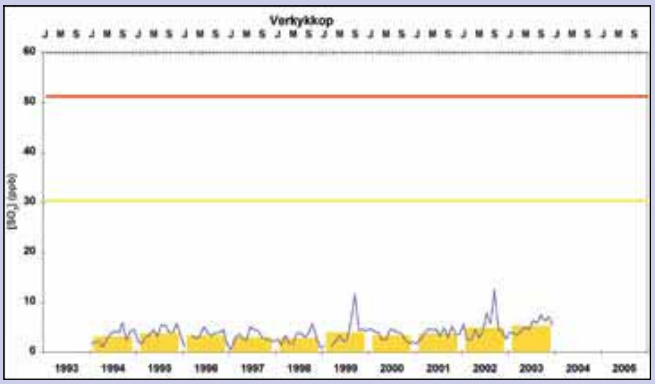


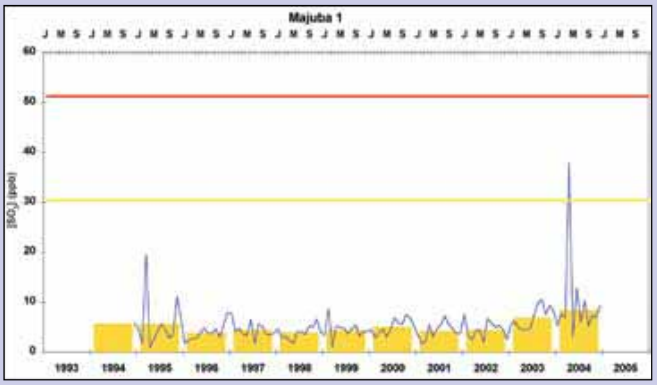
Figure 4.2.3.5: Long-term SO_2 levels at Richards Bay

Figure 4.2.3.6 Indicates the long-term trends of SO_2 near Volksrust.

Location of SO_2 monitoring stations near Volksrust







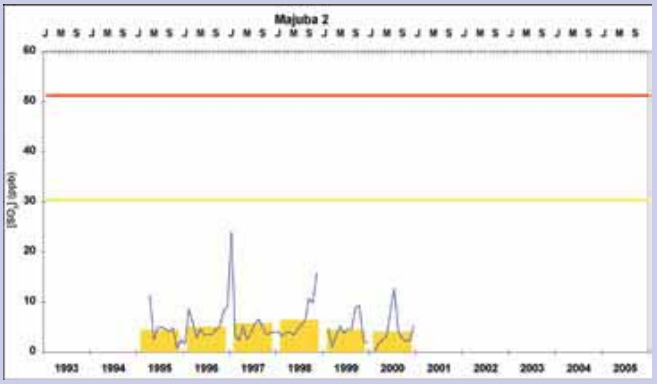
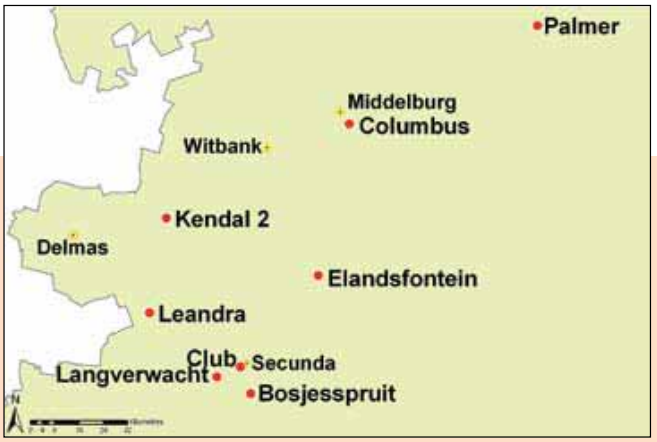
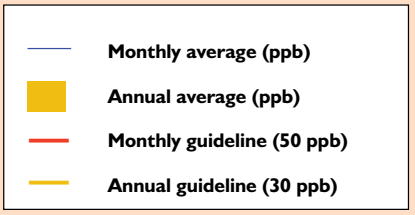


Figure 4.2.3.6: Long-term SO_2 levels near Volksrust

Figure 4.2.3.7 Indicates the long-term trends of SO_2 near Mpumalanga.



Location of SO_2 monitoring stations in Mpumalanga



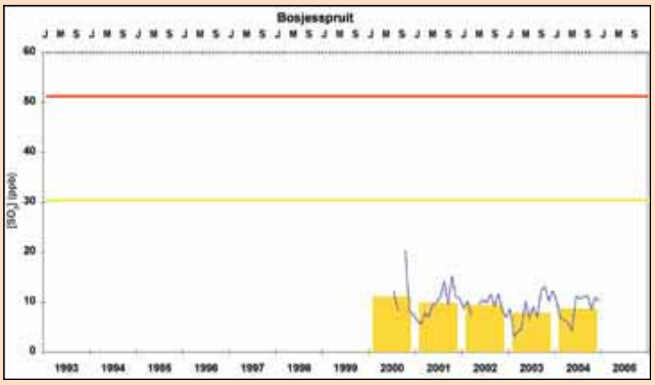


Figure 4.2.3.7: Long-term SO_2 levels in Mpumalanga

Continued next page

Figure 4.2.3.7: Long-term SO_2 levels in Mpumalanga

Location of SO_2 monitoring station near Sasolburg

Figure 4.2.3.8 Indicates long-term trends of SO_2 near Sasolburg.

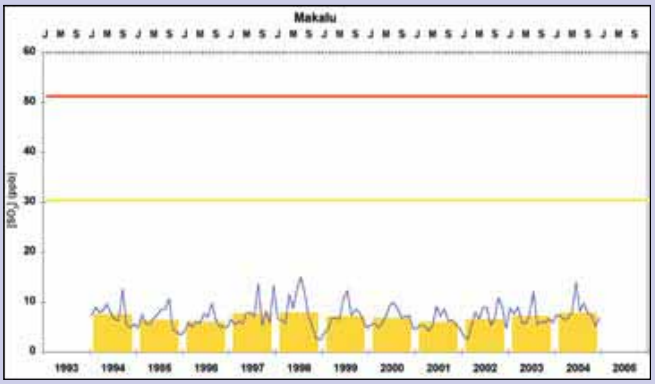


Figure 4.2.3.8: Long-term SO_2 levels near Sasolburg

The following can be derived from Figure 4.2.3.1–4.2.3.8 (refer also to Table 4.2.3.1):

- SO_2 levels at Cape Town and Port Elizabeth - No monthly or annual standards have been exceeded.
- SO_2 levels at Umkomaas - the trends are downwards at Drift station. Monthly averages showed significant fluctuation with the monthly average of 50 ppb being exceeded at three stations.
- SO_2 levels at Durban - a downward trend is seen at two of the three stations, with significant monthly fluctuations. The monthly standard was exceeded once at Southern Works and Wentworth.
- SO_2 levels at Richards Bay - levels are very low, with no exceedances of either of the monthly or annual standards.
- SO_2 levels near Volksrust - levels are relatively low, with no exceedances of either the monthly or annual standards. The levels in Verkykkop are steadily increasing.
- SO_2 levels in Mpumalanga - with the exception of Palmer, the levels indicate moderate to high pollution at Club and Columbus stations. There is a decreasing trend at Club station, but increasing at Langverwacht.
- SO_2 levels at Makalu station (background station near Sasolburg) - levels are relatively low, with no exceedances of either the monthly or annual standards.

4.2.4 Lead

The monthly data for the stations that had at least 5 years of lead data were further analyzed to determine possible trends and the results are shown in Table 4.2.4.1.

Table 4.2.4.1: Trend analysis* of monthly data for Pb (µg/m³)

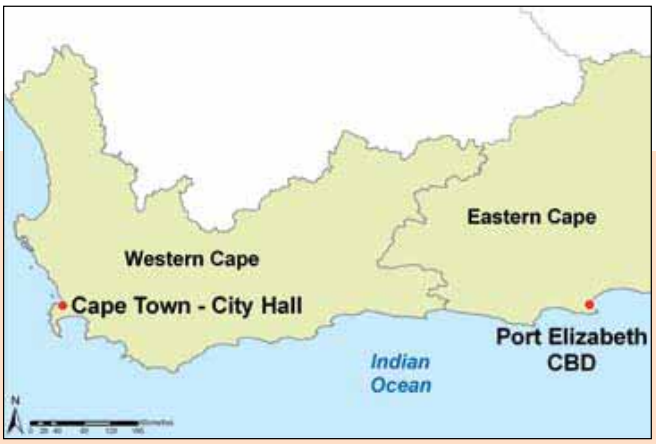
Province	Name	Period	Num.	Avg	Slope	Intercept	RSq	growth%
EC	Port Elizabeth – CBD	1992-04 to 1997-03	47	0.28	–0.0048	0.4101	0.120	–1.73
WC	Cape Town (City Hall)	1992-04 to 1997-01	44	0.89	–0.0168	1.3134	0.345	–1.89
GAU	Johannesburg City Hall	1992-04 to 1998-02	55	0.49	–0.0062	0.7008	0.120	–1.26
GAU	Pretoria: Beatrix St	1992-04 to 1997-06	49	0.68	–0.0118	1.0318	0.228	–1.73
GAU	Vereeniging – CBD	1992-04 to 1998-03	58	0.30	–0.0058	0.502	0.256	–1.91
KZN	Durban – City Hall	1992-04 to 1998-03	58	0.43	–0.0043	0.5802	0.131	–1.00
KZN	Pietermaritzburg City Hall	1994-02 to 1998-01	33	0.54	–0.0279	1.7433	0.581	–5.18

* See explanations on the meaning of columns in section 4.1.1

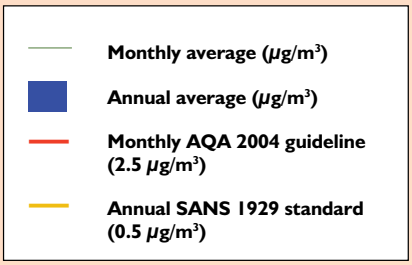
Although correlation coefficients for the trends are low, the growth percentage indicates a downward trend in the Pb concentrations. The biggest reduction, of about 5%, was measured at Pietermaritzburg and this result has the highest correlation coefficient.

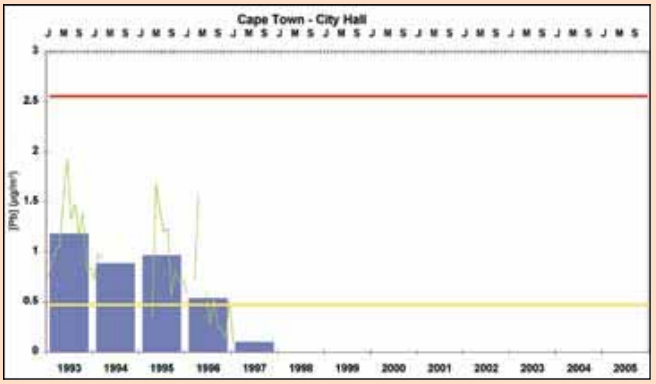
The downward trends in Pb concentrations are also noticeable in the graphs that follow (Figures 4.2.4.1–4.2.4.3). However, the lack of data for later years (only 2003 data are available for the period 1998–2004), reduces confidence in this analysis.

The long-term monthly and annual average Pb levels for the Western and Eastern Cape are shown in Table 4.2.4.1.



Location of Pb monitoring stations in the Western and Eastern Cape





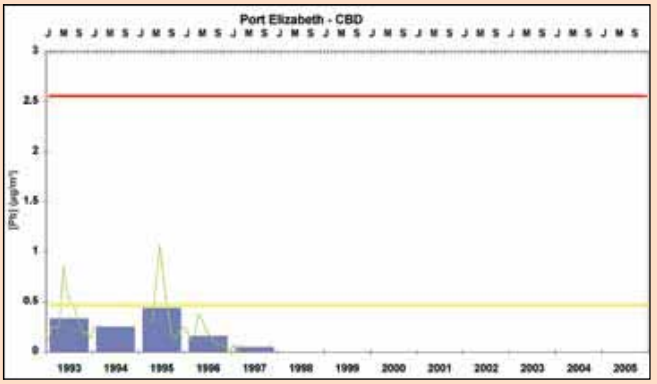
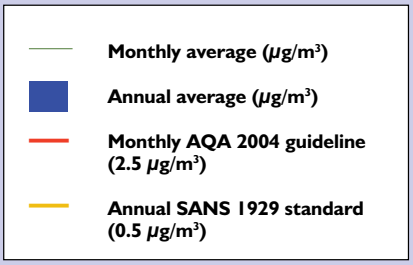
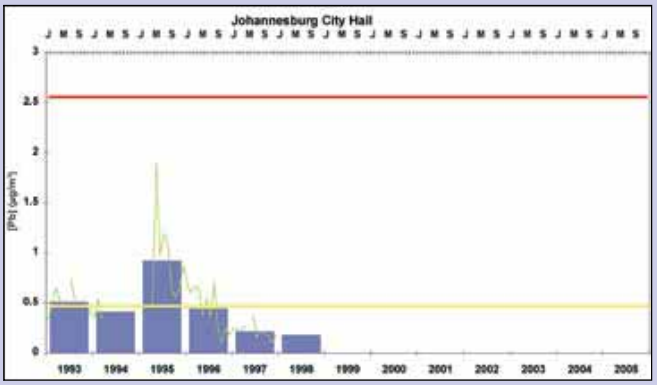


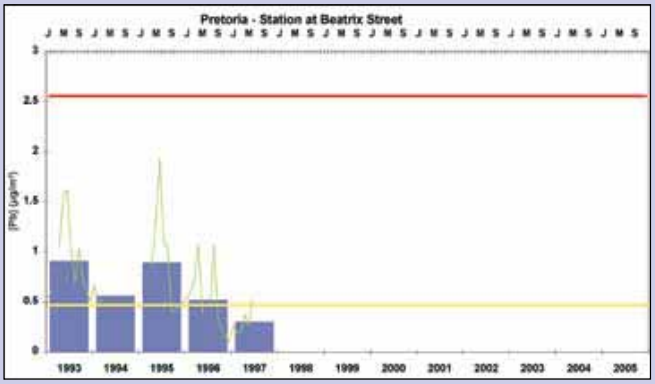
Figure 4.2.4.1: Lead (Pb) trends in the Western and Eastern Cape

Figure 4.2.4.2 indicates trends in Pb levels for Gauteng

Location of Pb monitoring stations in Gauteng







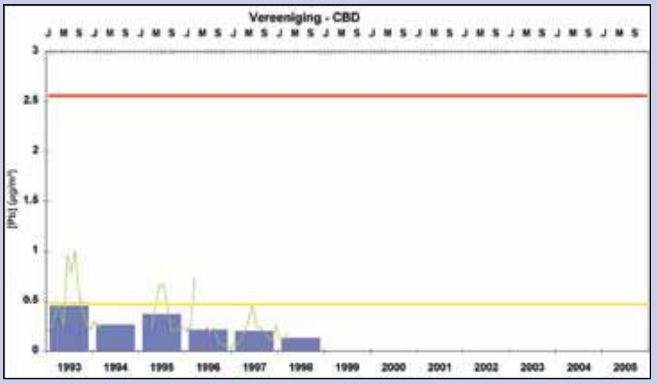
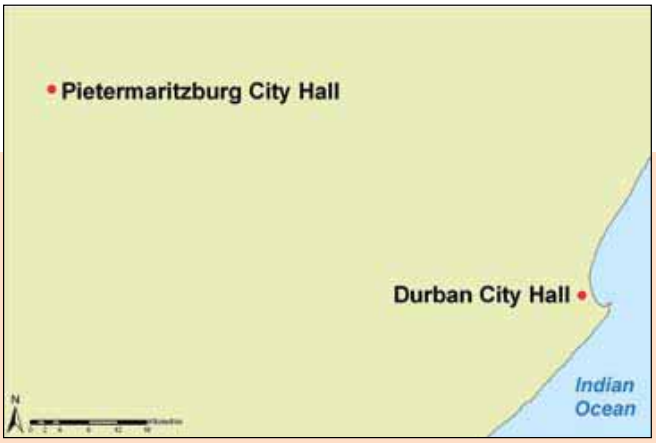
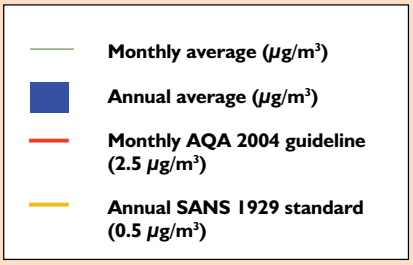


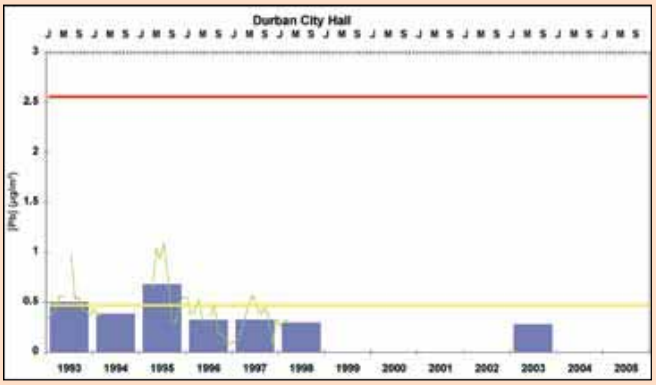
Figure 4.2.4.2: Trends in lead levels in Gauteng

Figure 4.2.4.3 indicates the trends in Pb levels in KwaZulu-Natal.



Location of Pb monitoring stations in KwaZulu-Natal





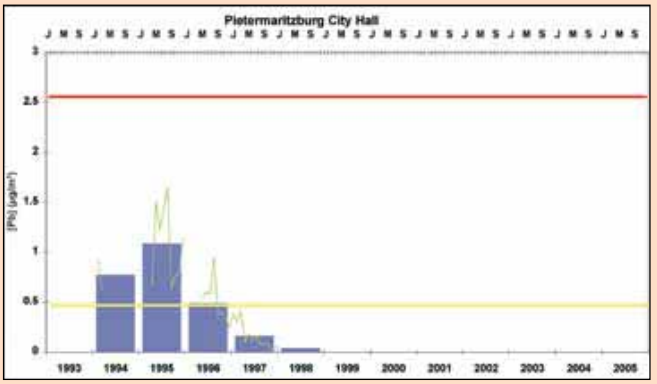


Figure 4.2.4.3: Trends in Pb levels in KwaZulu-Natal

The following can be derived from Figures 4.2.4.1–4.2.4.3 (refer also to Table 4.2.4.1):

- Pb in the Western and Eastern Cape - a downward trend was detected. The annual SANS 1929 standard of 0.5 $\mu g/m^3$ was exceeded 3 times at Cape Town City Hall.
- Pb in Gauteng - again a downward trend, with the annual SANS 1929 standard exceeded 3 times at the Beatrix Street station in Pretoria.
- Pb in KwaZulu-Natal - a downward trend was observed, with the SANS 1929 standard exceeded once at the Durban City Hall station, and twice at the Pietermaritzburg station.

The new proposed standards are much stricter, but because no data for 2004 are available, it is impossible to conclude how they would compare with the new limit of 0.5 $\mu g/m^3$.

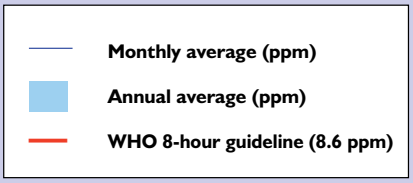
The measured reduction of ambient levels reflects emission reduction from vehicles as a result of improved fuel efficiency, incorporation of emission control in new vehicles, and changes in fuel composition. From 1 January 2006, leaded petrol has been phased out and this will further reduce lead pollution. It should also be noted that the reduced influence of lead pollution on health shifted recently from the effect of ambient pollution to that resulting from contact with objects treated with lead-based paints.

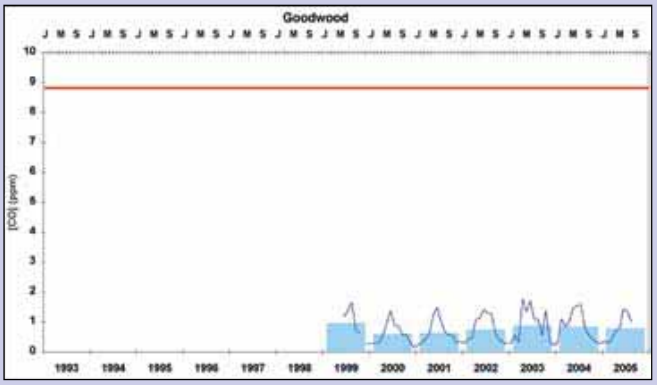
4.2.5 Carbon monoxide

The monthly data for the stations with at least 5 years of CO data were further analyzed to determine possible trends but no statistically significant ones were detected.

The long-term trends in CO levels near Cape Town are illustrated in Figure 4.2.5.1.

Location of CO monitoring stations near Cape Town





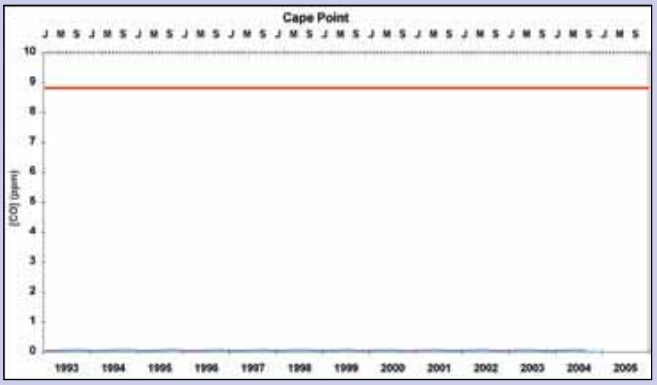
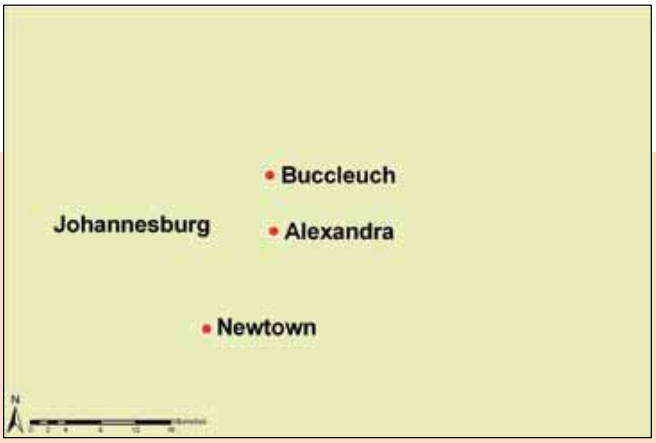
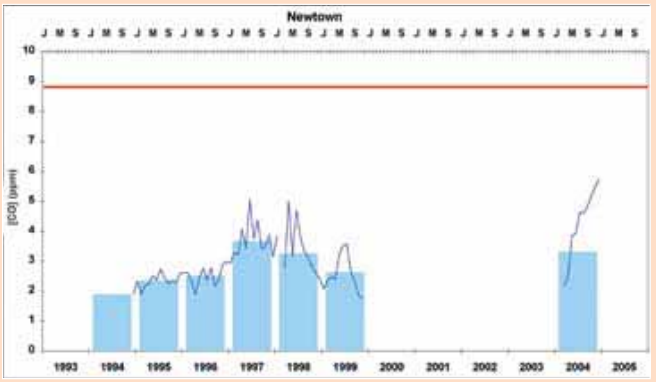


Figure 4.2.5.1: Trends in CO levels near Cape Town

The long-term trends in CO levels near Johannesburg are as in Figure 4.2.5.2.



Location of CO monitoring stations around Johannesburg



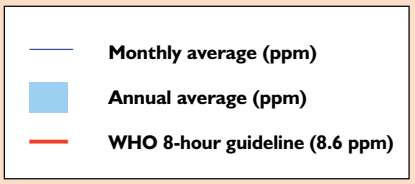


Figure 4.2.5.2: Trends in CO levels in central Johannesburg

No conclusions could be derived from Figures 4.2.5.1 and 4.2.5.2 because there are no CO monthly or annual standards, but the monthly averages at all stations are much lower than the 8-hour standard.

4.2.6 Particulate matter

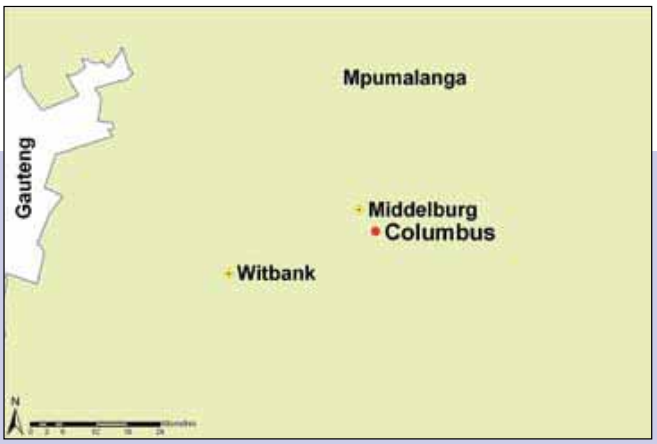
The monthly data for the stations that had at least 5 years of PM_{10} data were further analyzed to determine possible trends and the results are shown in Table 4.2.6.1.

Table 4.2.6.1: Results of the trend analysis for PM_{10}

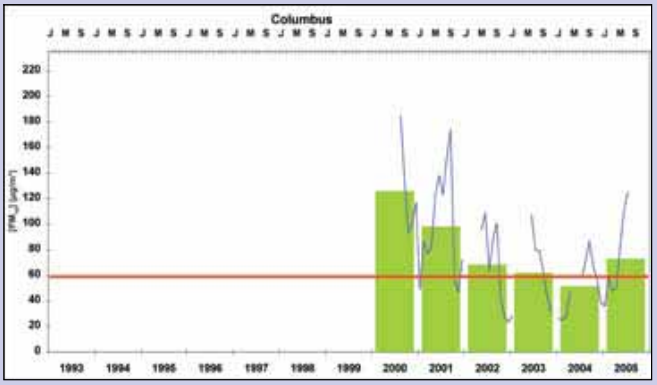
Province	Station Type	Name	Period	No. of Points	Avg	Slope	Intercept	RSq	Growth %
MPU	I	Columbus	2000-08-01 to 2005-07-01	52	77.02	–0.9954	198.18	0.221	–1.29
W Cape	RI	Table View	1994-11-01 to 2005-08-01	130	25.45	0.084	18.108	0.333	0.33

The growth % indicates a negative trend in PM_{10} levels at Columbus station in Mpumalanga and an increasing trend at Table View.

These trends are also noticeable in the graphs that follow (Figures 4.2.6.1–4.2.6.3).



Location of PM_{10} monitoring station near Middelburg

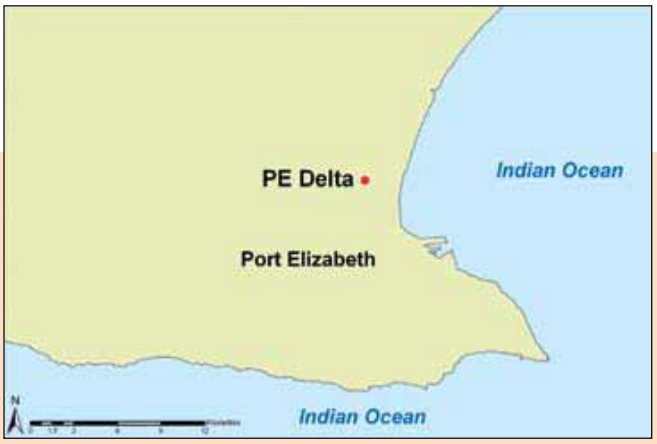


Monthly average ($\mu g/m^3$)

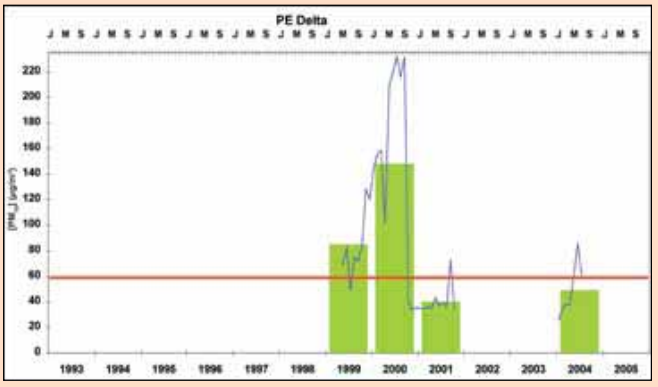
Annual average ($\mu g/m^3$)

Annual APPA guideline (60 $\mu g/m^3$)

Figure 4.2.6.1: Monthly and annual averages of PM_{10} concentrations near Middelburg



Location of PM_{10} monitoring station at Port Elizabeth



Monthly average ($\mu g/m^3$)

Annual average ($\mu g/m^3$)

Annual APPA guideline (60 $\mu g/m^3$)

Figure 4.2.6.2: Monthly and annual averages of PM_{10} concentrations in Port Elizabeth

Location of PM_{10} monitoring stations at Cape Town

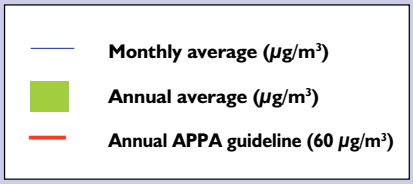


Figure 4.2.6.3: Monthly and annual averages of PM_{10} concentrations in Cape Town

The following can be derived from Figures 4.2.6.1–4.2.6.3:

The pollution levels in Mpumalanga (Columbus, near Middelburg) and in Port Elizabeth (PE Delta) are relatively high, but the downward trend can be clearly seen for the Columbus station. The monthly standards were exceeded with high monthly averages in the winter of 2000.

PM_{10} in Cape Town - an upward trend is evident at Table View and Khayelitsha. No exceedance of the annual standard was found.

4.2.7 Carbon dioxide

The monthly data at Cape Point were further analyzed to determine possible trends and the results are shown in Table 4.2.7.1. A clear upward trend is observed, which demonstrates a contribution to global warming.

Table is 4.2.7.1: Results of the trend analysis for CO_2 concentrations at Cape Point

Province	Type	Name	Period	No. of Points	Average	Slope	Intercept	RSq	Growth %
WC	B	Cape Point	1993-09-01 to 2004-12-31	131	365.3	0.152	353.4	0.99	0.04

The monthly and annual average CO_2 concentrations are shown in Figure 4.2.7.1.

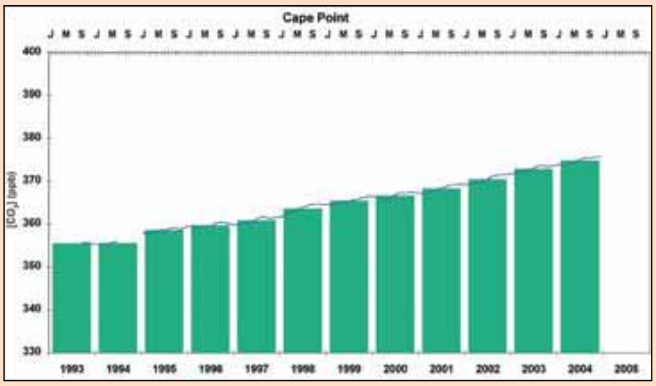
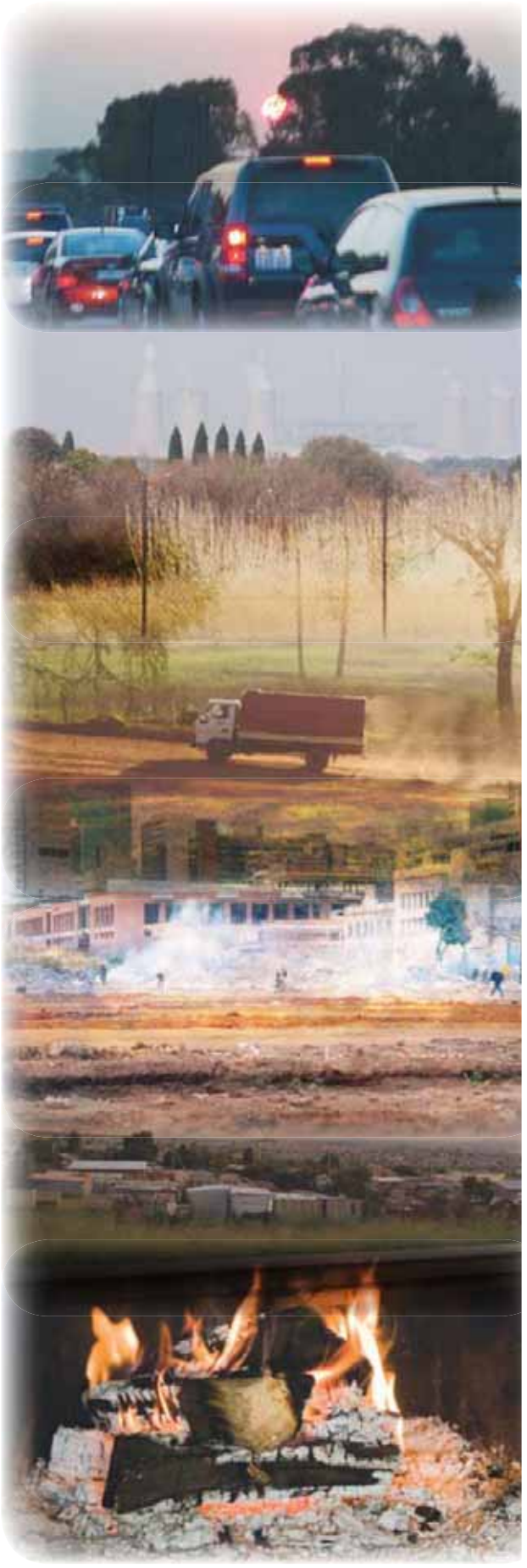


Figure 4.2.7.1: Monthly (thin line) and annual averages of (filled bars) CO_2 concentrations in Cape Point



4.3. COMPLIANCE ANALYSIS FOR CRITERIA POLLUTANTS

4.3.1 Compliance analysis of O_3

The results for the stations analyzed for O_3 compliance are given in Tables 4.3.1.1 (monthly) and Table 4.3.1.2 (annual).

Table 4.3.1.1: Statistical analysis of O_3 results for South Africa (monthly concentrations in ppb)

Province	Station type	Station	Num.*	Num. (all)**	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
EC	B	Ben McDhui	16	16	31.1	31.1	26.0	10.9	52.3	53.0
LMP	B	Louis Trichardt	12	12	33.3	33.3	32.5	9.5	48.3	56.0
MPU	B	Skukuza	2	2	12.5	12.5	12.5	2.1	13.9	14.0
NWP	B	Lichtenburg	6	6	20.2	20.2	20.5	1.2	21.0	21.0
WC	B	Cape Point	132	144	23.8	23.6	24.3	5.6	31.5	32.6
EC	I	PE Delta	49	52	25.4	25.7	21.5	11.9	46.3	55.9
FS	I	Bosjesspruit	42	42	29.5	29.5	28.3	6.1	41.1	47.0
GAU	I	350 site	0	9		26.5				0.0
GAU	I	620 site	0	9		21.5				0.0
GAU	I	Bedworth Park	11	11	16.9	16.9	17.6	3.0	21.0	22.3
GAU	I	Mobile Caravan station	1	9	29.3	17.8	29.3			
MP	I	Amersfoort	38	38	28.8	28.8	29.1	6.6	37.3	46.0
FS	P	Makalu	132	132	22.1	22.1	22.3	5.9	30.9	48.5
MP	P	Kendal 2	132	132	27.7	27.7	26.4	6.3	38.0	45.7
MP	P	Palmer	119	119	29.6	29.6	30.1	8.6	43.4	49.1
MPU	P	Elandsfontein	116	116	22.5	22.5	21.2	6.5	34.1	42.1
MPU	P	Verkykkop	119	119	30.8	30.8	30.7	9.2	45.9	56.0
MPU	P	Warden	7	7	18.3	18.3	18.0	3.7	22.4	23.0
MP	R	Houtbosrand	2	2	18.5	18.5	18.5	4.9	21.7	22.0
WC	R	Goodwood	96	102	13.5	13.6	13.2	4.0	20.2	26.4
WC	R	Oranjezight	131	139	20.4	20.4	19.8	4.0	27.7	34.1
FS	RI	Club	71	71	30.6	30.6	29.2	10.7	49.8	73.0
FS	RI	Steam Station	11	23	26.6	27.9	26.3	7.8	38.7	38.7
GAU	RI	Delta Park	8	8	25.2	25.2	28.2	7.4	33.4	34.6
KZN	RI	Wentworth	10	11	15.3	14.6	15.4	4.1	21.0	24.3
MP	RI	Langverwacht	12	12	24.2	24.2	22.8	7.8	35.1	35.4
FS	T	Leitrum	17	29	30.1	31.3	31.2	5.8	37.0	38.8
GAU	T	Alexandra	32	39	34.4	33.2	31.6	8.5	47.8	53.5
WC	T	Athlone	79	86	13.6	13.4	14.0	3.6	19.1	22.5
GAU	U	Buccleuch	10	10	85.6	85.6	54.4	98.9	262.8	271.3
GAU	U	City Deep	37	37	21.6	21.6	23.0	6.2	32.2	33.5
GAU	U	JHB City Hall	4	16	17.8	19.2	17.7	7.4	26.7	28.6
GAU	U	Newtown	70	70	14.9	14.9	14.3	5.7	25.1	31.6
GAU	U	Rosslyn	5	5	9.9	9.9	5.9	9.4	22.6	25.0
GAU	W	Northern Works	29	29	19.8	19.8	20.1	6.8	29.4	30.2

* Num., number of monthly averages available in the database for the period 1994–2004 – see Section 4.2.1

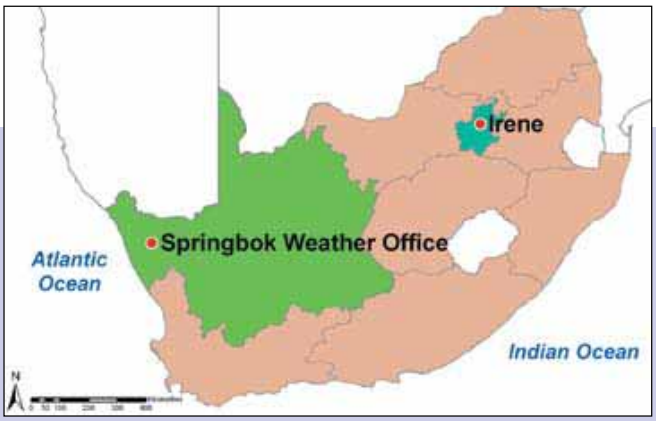
**Num. (all), number of monthly averages available in the database for the full survey period

Average background concentrations of surface level O_3 in the northeastern parts of the country ranged from 20.2 ppb at Lichtenburg to 33.3 ppb at Louis Trichardt, and as low as 12.5 ppb at Skukuza in the lowveld. Both Lichtenburg and Louis Trichardt are influenced by a range of sources on a regional scale, including industry on the Highveld and Vaal Triangle and activities in towns and cities in the northern parts of the country. Skukuza is somewhat shielded by the eastern escarpment. Over the southern parts of the country, concentrations ranged between 23.8 ppb at Cape Point and 31.1 ppb at Ben McDhui in the southern Drakensberg. The greatest variance was recorded at Ben MacDhui, a site that is well positioned to monitor the regional scale transport of air from the interior towards the Indian Ocean.

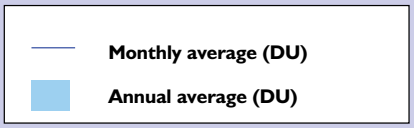
Ozone concentrations measured at all other stations apart from Alexandra and Buccleuch are lower or in the same range as those at the background stations, regardless of the stations' classification. Although the average levels at residential and urban sites (with the exception of Buccleuch) are lower than at industrial sites, those affected by power generation or residential sites are affected by industries. This confirms that elevated O_3 concentrations are found some distance from the sources of precursors. Alexandra and Buccleuch are both located in the vicinity of the busy road networks of the N3 and M1 highways with high emissions of NO_x from traffic. With hydrocarbons in the atmosphere and stagnant meteorological conditions, particularly in winter, O_3 will form close to the source and traffic should be considered to be the main contributor to the relatively high concentrations at these sites.

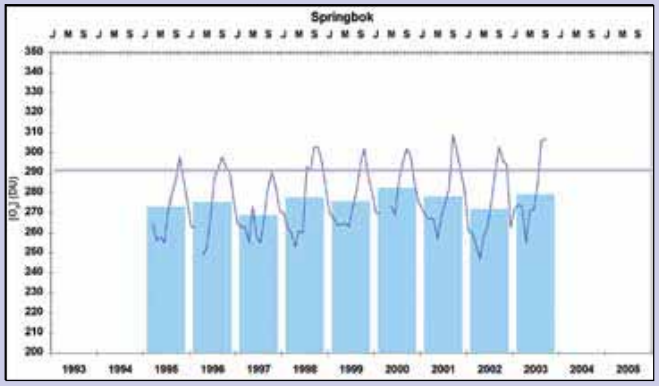
There is no O_3 guideline or standard for the monthly or annual averages (see Table 2.2.1). No compliance analysis could therefore be made. However, the 8-h limit is 56 ppb and the monthly averages should be significantly lower than this limit. Twelve stations recorded maximum monthly averages of more than 40 ppb. It is therefore possible that for most days during that particular month, the 8-h limit would have been exceeded. Compliance analysis of the hourly data would probably show a large number of the stations that exceeded the APPA limit.

The annual compliance analysis was not conducted, as only short-term concentrations are important for such analysis.



Location of ozone monitoring stations in South Africa





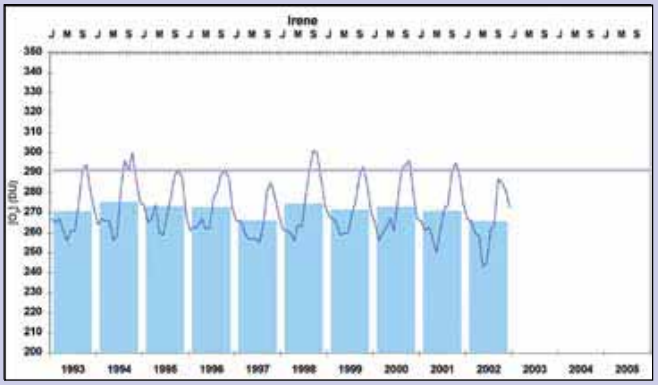


Figure 4.3.1.1: Monthly and annual total column O_3 levels at two sites in South Africa

Table 4.3.1.2: Statistical analysis of O_3 concentrations (monthly totals in Dobson units)

Station type	Province	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5 %	Max.
R	GAU	Irene	108	120	271.7	271.6	267.0	13.2	294.7	301.0
B	NC	Springbok	100	100	275.8	275.8	272.5	15.6	303.0	309.0

Total column O_3 is measured at the South African Weather Service stations at Irene and Springbok. This is a measure of the amount of O_3 present in the vertical column above the site, extending from ground level to the top of the atmosphere. It is measured in Dobson units (DU), which is equivalent to the thickness of the ozone layer at standard temperature and pressure (STP), where 1 DU = 0.01 mm at STP. Total column varies with latitude and season from values of more than 400 DU at polar latitudes in early summer, to about 240 DU at the equator where seasonal variation is limited.

The natural decrease in total column O_3 towards the equator over South Africa is evident in the 4 DU difference between the average at Springbok and Irene, approximately 6 degrees further north. The standard deviation calculated at both sites accounts for the seasonal variation, with the maximum in spring (September/October) and the minimum in early winter (May/June). The measured values of total column O_3 at the two sites are typical for these latitudes. Long-term monthly and annual averages in total column O_3 in South Africa are indicated in Figure 4.3.1.2.

The two observing stations provide a good record of total column O_3 and the latitudinal separation provides a measure that may be regarded as representative of South Africa. These data may be augmented with daily total column O_3 measurements from the NASA Total Ozone Mapping Spectrophotometer (TOMS) on the Earth Probe satellite (see http://jwocky.gsfc.nasa.gov/).

It should be noted that the ozone hole is mostly restricted to polar latitudes and would therefore not be detected at the Irene and Springbok observing stations.

4.3.2 Compliance analysis of oxides of nitrogen

Tables 4.3.2.1 and 4.3.2.2 indicate the monthly and annual results of the stations that were analyzed for NO_2 compliance. Monthly averages and the top 5% (95th percentile) values are also compared to AQA standards in Figure 4.3.2.1.

Table 4.3.2.1: Statistical analysis of NO_2 (monthly concentrations in ppb)

Province	Station type	Station	Num.	Num. (all)	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
EC	B	Ben McDhui	14	14	0.5	0.5	0.4	0.5	1.3	2.0
LMP	B	Louis Trichardt	12	12	0.5	0.5	0.5	0.3	1.0	1.2
MP	B	Houtbosrand	2	2	0.70	0.70	0.70			0.80
MPU	B	Skukuza	2	2	0.5	0.5	0.5			0.6
NWP	B	Lichtenburg	6	6	4.5	4.5	4.3	1.7	6.7	7.2
WC	B	Cape point	15	15	0.8	0.8	0.8	0.3	1.3	1.4
EC	I	PE Delta	49	52	11.5	12.7	7.4	9.4	29.6	41.2
GAU	I	350 Site	0	9		15.2				
GAU	I	620 Site	0	9		16.6				
GAU	I	Bedworth Park	11	11	13.7	13.7	12.2	5.5	23.4	26.8
GAU	I	Mittal Mobile Caravan	8	17	12.3	13.6	14.6	7.4	20.9	22.5
KZN	I	Southern Works	13	14	14.6	14.7	11.1	8.0	29.2	32.1
MP	I	Bosjesspruit	41	41	9.6	9.6	9.6	3.8	16.0	20.5
MPU	I	Amersfoort	11	11	2.9	2.9	2.6	1.1	4.6	4.7
MPU	I	Columbus	44	51	6.7	6.3	7.0	5.5	16.0	17.0
WC	I	Bothasig	100	104	10.7	10.6	9.9	5.2	20.5	32.5
FS	P	Makalu	132	132	8.9	8.9	8.3	2.6	13.6	17.0
FS	P	Warden	8	8	6.2	6.2	6.1	1.8	8.9	9.8
MP	P	Kendal 2	132	132	7.5	7.5	6.9	4.3	10.4	50.4
MP	P	Palmer	121	121	2.7	2.7	2.2	2.0	5.0	18.8
MPU	P	Elandsfontein	113	113	5.6	5.6	5.1	2.2	9.5	15.3
MPU	P	Verkykkop	118	118	3.8	3.8	3.3	2.1	6.9	17.2
GAU	R	Delta Park	4	4	16.7	16.7	15.3	6.2	24.0	25.3
WC	R	Goodwood	114	121	15.1	15.0	13.8	6.5	27.6	32.9
FS	RI	A J Jacobs	0	12		15.0				
KZN	RI	Settlers	32	32	13.2	13.2	12.0	5.8	23.3	28.8
KZN	RI	Siza Centre	33	33	2.2	2.2	1.5	1.9	6.2	8.2
KZN	RI	Wentworth	11	12	12.7	12.0	11.2	6.2	23.5	24.2
MP	RI	Club	66	66	13.1	13.1	11.5	6.2	25.2	40.3
WC	RI	Table View	118	126	11.2	11.0	10.1	4.5	18.6	32.9
FS	T	Leitrum	17	29	14.4	13.3	11.9	5.8	24.9	28.8
GAU	T	Alexandra	33	40	29.4	29.7	25.6	13.2	51.5	82.0
GAU	U	Buccleuch	10	10	34.6	34.6	38.3	7.0	40.8	42.0
GAU	U	Jhb City Hall	4	16	20.2	23.5	23.3	1.6	21.6	21.6
GAU	U	Newtown	68	68	29.4	29.4	29.3	6.7	42.4	46.5
GAU	U	Rosslyn	5	5	21.8	21.8	21.9	17.7	44.2	48.6
WC	U	Cape Town City Hall	129	137	25.6	25.3	25.3	8.2	41.4	47.7

As can be seen from the table and the graphs, there have been no exceedances of the AQA standard of 83 ppb. The station with the highest levels of NO_2 is Alexandra township. However, long-term averages in Buccleuch and Newtown (Johannesburg) are even higher than Alexandra. This may indicate that traffic-related pollution and domestic fuel use are important sources of NO_2 pollution in South Africa.

The urban stations in Johannesburg have higher levels than Cape Town and just slightly higher than in Pretoria (Rosslyn station). However, Rosslyn station has only 5 months' data available and therefore this value is not representative.

The Eskom stations show relatively low average concentrations and only one station has a relatively high maximum of 50.4 ppb (Kendal 2 station in January 1999). But the 95% level for this station is only 10.4 ppb. The 2nd highest value is less than 20 ppb, which means that this peak is not typical.

All of the industrial sites also have relatively low levels of NO_2 pollution, which are similar to residential sites.

There are background stations in 4 different provinces: Eastern Cape (Ben McDhui), Mpumalanga (Skukuza), Western Cape (Cape Point), and Limpopo (Louis Trichardt). All background NO_2 concentrations are low (below 1 ppb) and very similar.

Table 4.3.2.2: Statistical analysis of annual NO_2 concentrations (ppb)

Province	Type	Name	Num.	Avg	Max.	% Limit
EC	B	Ben McDhui	3	0.50	0.55	0.9
EC	I	PE Delta	7	10.89	22.63	20.6
FS	P	Makalu	11	8.89	10.99	16.8
FS	P	Warden	2	5.98	6.47	11.3
FS	T	Leitrim	2	14.54	15.08	27.4
GAU	I	Bedworth Park	2	12.55	13.99	23.7
GAU	I	Mittal Mobile Caravan	1	12.25	12.25	23.1
GAU	R	Delta Park	1	17.13	17.13	32.3
GAU	T	Alexandra	3	28.51	35.44	53.8
GAU	U	Buccleuch	1	33.51	33.51	63.2
GAU	U	Johannesburg City Hall	1	20.75	20.75	39.1
GAU	U	Newtown	5	28.34	32.79	53.5
GAU	U	Newtown	6	28.25	33.51	53.3
GAU	U	Rosslyn Air Quality Monitoring Station	2	28.67	31.33	54.1
KZN	I	Southern Works	2	11.10	13.40	20.9
KZN	RI	Settlers	3	13.18	16.25	24.9
KZN	RI	Siza Centre	4	2.03	2.63	3.8
KZN	RI	Wentworth	1	12.16	12.16	22.9
MPU	B	Houtbosrand	1	0.70	0.70	1.3
MPU	B	Louis Trichardt	2	0.61	0.70	1.1
MPU	B	Skukuza	1	0.50	0.50	0.9
MPU	I	Amersfoort	2	3.49	4.45	6.6
MPU	I	Bosjesspruit	4	9.27	11.34	17.5
MPU	I	Columbus	5	9.82	23.00	18.5
MPU	P	Elandsfontein	10	5.57	6.94	10.5
MPU	P	Kendal 2	11	7.46	11.54	14.1
MPU	P	Palmer	11	2.57	4.52	4.9
MPU	P	Verkykkop	10	3.78	6.61	7.1
MPU	RI	Club	7	13.74	24.21	25.9
NWP	B	Lichtenburg	2	4.50	4.55	8.5
WC	B	Cape point	3	0.89	1.15	1.7
WC	R	Goodwood	10	15.38	24.03	29.0
WC	RI	Bothasig	10	10.78	16.54	20.3
WC	RI	Table View	11	11.01	18.23	20.8
WC	U	Cape Town City Hall	11	25.50	38.30	48.1

No exceedances of the annual NO_2 standard of 52 ppb were evident for the available data.

There are 17 stations that also measure NO and the results are presented in Table 4.3.2.3 (monthly) and Table 4.3.2.4 (annual).

Table 4.3.2.3: Statistical analysis of monthly NO concentrations (ppb)

Province	Station type	Station	Num	Num (all)	Avg	Avg (all)	Median	Std dev.	Top 5 %	Max
FS	P	Makalu	132	132	3.6	3.6	3.1	1.8	7.0	9.3
GAU	I	Bedworth Park	11	11	15.6	15.6	11.5	11.5	33.7	46.2
GAU	R	Delta Park	9	9	3.1	3.1	1.6	3.3	8.5	11.6
GAU	U	Buccleuch	10	10	134.4	134.4	125.4	53.9	215.7	231.3
GAU	U	Jhb City Hall	4	16	30.3	34.7	35.2	11.2	39.9	41.0
GAU	U	Newtown	68	68	55.4	55.4	52.5	20.1	93.7	114.7
GAU	U	Rosslyn	5	5	17.9	17.9	8.8	17.2	37.9	38.7
KZN	I	Southern Works	13	14	20.4	25.1	15.0	16.0	48.5	52.1
KZN	RI	Settlers	32	32	11.2	11.2	7.6	8.6	26.6	30.9
KZN	RI	Siza Centre	28	28	1.5	1.5	1.3	0.9	2.9	3.0
KZN	RI	Wentworth	11	12	9.9	9.3	6.9	6.7	21.0	22.9
MP	I	Bosjesspruit	17	17	4.3	4.3	3.1	2.7	8.0	12.5
MP	P	Elandsfontein	112	112	3.0	3.0	2.7	1.5	5.4	11.6
MP	P	Kendal 2	132	132	5.2	5.2	4.8	2.1	8.4	17.0
MP	P	Palmer	121	121	1.3	1.3	1.0	1.0	3.0	7.2
MP	P	Verkykkop	118	118	1.7	1.7	1.4	1.0	3.9	5.2
MP	RI	Club	27	27	12.0	12.0	10.8	6.2	21.1	25.8

The highest NO levels were measured at Buccleuch station, which is the only station where pollution exceeds the standard (according to AQA standards, the monthly and annual limits are 200 and 150 ppb respectively). There was 1 month during this period (less than a year) when the monthly limit was exceeded. The 2nd highest concentrations are measured in the urban centre of Johannesburg, Newtown station. Similarly to the situation with NO_2, the low levels in Rosslyn could be explained by a limited number of values being available for the study period.

The Southern Works station has the highest concentrations in the Durban area. The high volume of heavy vehicle traffic past the Southern Works station is likely to contribute to the observed NO concentrations.

The concentrations at all stations in the Mpumalanga province are quite low, because the emissions sources are high above ground and there is enough time for conversion of NO to NO_2.

Table 4.3.2.4: Statistical analysis of NO monitoring (annual concentrations in ppb)

Province	Type	Name	Num.	Avg	Max.	% Limit
FS	P	Makalu	11	3.6	5.0	2.4
GAU	I	Bedworth Park	2	13.7	16.0	9.2
GAU	R	Delta Park	1	3.4	3.4	2.3
GAU	U	Buccleuch	1	150.0	150.0	100.0
GAU	U	Johannesburg City Hall	1	34.7	34.7	23.1
GAU	U	Newtown	5	58.4	66.1	38.9
GAU	U	Newtown	6	55.2	66.1	36.8
GAU	U	Rosslyn	2	19.4	34.8	12.9
KZN	I	Southern Works	2	15.4	19.2	10.2
KZN	RI	Settlers	3	11.2	14.5	7.5
KZN	RI	Siza Centre	4	1.4	2.1	1.0
KZN	RI	Wentworth	1	10.1	10.1	6.7
MP	I	Bosjesspruit	2	3.6	4.3	2.4
MP	P	Elandsfontein	10	3.0	4.1	2.0
MP	P	Kendal 2	11	5.2	6.6	3.5
MP	P	Palmer	11	1.3	2.2	0.9
MP	P	Verkykkop	10	1.7	3.6	1.2
MP	RI	Club	4	12.4	19.5	8.3

The analysis of annual averages shows the same patterns as monthly data.

Table 4.3.2.5 (monthly) and 4.3.2.6 (annual) indicates the results of the compliance analysis for the 11 stations that measure NO_x.

Table 4.3.2.5: Statistical analysis of NO_x monitoring (monthly concentrations in ppb)

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.
FS	P	Makalu	12	12	12.1	12.1	10.2	3.7	17.8	20.7
FS	RI	Steam Station	3	13	12.3	17.7	16.1	7.1	16.7	16.8
GAU	R	Delta Park	9	9	8.1	8.1	2.6	8.9	21.3	22.9
GAU	U	Buccleuch	10	10	167.7	167.7	154.4	58.9	257.0	274.0
GAU	U	Newtown	10	10	59.6	59.6	50.5	18.0	85.5	86.8
GAU	U	Rosslyn	5	5	36.3	36.3	43.0	24.8	62.0	64.1
KZN	RI	Siza Centre	28	28	3.3	3.3	3.1	2.0	7.0	7.8
MPU	I	Bosjesspruit	17	17	17.1	17.1	9.7	22.9	49.4	101.6
MPU	P	Kendal 2	12	12	14.4	14.4	15.1	2.5	17.4	17.4
MPU	P	Palmer	1	1	2.0	2.0				
MPU	RI	Club	27	27	21.8	21.8	20.0	11.4	42.0	55.8

No exceedances of monthly limits were found, but pollution levels at Buccleuch station were found to be the highest.

Table 4.3.2.6: Statistical analysis of NO_x monitoring (annual concentrations in ppb).

Province	Type	Name	Num.	Avg	Max.	% Limit
FS	P	Makalu	1	12.1	12.1	6.1
FS	RI	Steam Station	1	12.3	12.3	6.2
GAU	R	Delta Park	1	9.9	9.9	4.9
GAU	U	Buccleuch	1	182.9	182.9	91.4
GAU	U	Newtown	1	52.7	52.7	26.4
GAU	U	Rosslyn	2	46.3	56.9	23.1
KZN	RI	Siza Centre	4	3.5	5.0	1.7
MPU	I	Bosjesspruit	2	11.2	12.5	5.6
MPU	P	Kendal 2	1	14.5	14.5	7.2
MPU	P	Palmer	1	2.0	2.0	1.0
MPU	RI	Club	4	23.6	35.0	11.8

Most of the NO_x data is only available for a short period of less than a year, but the geographical variations are very similar to the pollution levels of NO_2.

4.3.3 Compliance analysis of sulphur dioxide

The SO_2 data are the most comprehensive, compared to other pollutants. The results of the compliance analysis for SO_2 are indicated in Tables 4.3.3.1 and 4.3.3.2 for continuous monitoring and 4.3.3.3 for passive monitoring.

Table 4.3.3.1: Statistical analysis of continuous monthly SO_2 concentrations (ppb)

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.	Exceed
EC	B	Ben McDhui	15	15	0.5	0.5	0.4	0.3	0.9	1.0	0
LMP	B	Louis Trichardt	12	12	0.5	0.5	0.5	0.2	0.7	0.8	0
MP	B	Houtbosrand	2	2	0.8	0.8	0.8	0.1	0.8	0.8	0
MP	B	Skukuza	2	2	1.0	1.0	1.0	0.2	1.1	1.1	0
NWP	B	Lichtenburg	5	5	2.4	2.4	2.8	0.9	3.2	3.2	0
WC	B	Cape Point	15	15	0.5	0.5	0.5	0.3	1.0	1.1	0
EC	I	Amsterdam Plein	44	44	1.2	1.2	1.1	0.6	2.3	2.6	0
EC	I	PE Delta	60	63	14.8	14.9	12.5	6.8	27.8	32.3	0
GAU	I	350 site	0	9		10.9					0
GAU	I	620 site	0	9		15.4					0
GAU	I	Bedworth Park	11	11	11.2	11.2	7.8	9.6	26.3	38.0	0
GAU	I	Mittal Caravan	8	17	15.5	17.1	16.8	7.0	23.1	24.2	0
KZN	I	Dlambula School	43	52	21.3	21.1	18.0	13.6	46.8	49.0	0
KZN	I	Drift	123	129	15.3	14.8	12.0	11.2	34.9	58.0	2
KZN	I	Hillside	13	13	9.4	9.4	9.3	2.3	12.9	14.2	0
KZN	I	Ilfracombe	96	107	7.3	7.0	3.0	12.1	37.3	65.0	1
KZN	I	Naidooville School	46	53	4.2	4.1	4.0	1.7	7.0	8.0	0
KZN	I	Scorpio	9	9	6.9	6.9	6.9	2.1	9.9	11.2	0
KZN	I	Southern Works	95	95	25.0	25.0	23.9	8.1	40.0	51.7	1
KZN	I	TLC	53	59	3.1	3.1	3.0	2.6	5.0	20.0	0
KZN	I	Umkomaas	112	121	12.7	12.4	10.0	10.3	33.9	53.0	1
MP	I	Amersfoort	17	17	5.0	5.0	4.4	2.0	7.4	12.0	0
MP	I	Bosjesspruit	53	53	9.4	9.4	9.6	3.0	13.5	20.3	0
MP	I	Columbus	34	39	16.0	15.2	10.5	14.0	43.4	53.0	1
NWP	I	Hexrivier	20	20	9.3	9.3	8.3	3.2	16.6	17.8	0
NWP	I	L5 Sewerage Plant	0	9		19.3					0
NWP	I	L6- K4 Shaft	0	7		7.9					0
NWP	I	Paardekraal	19	19	14.5	14.5	13.9	5.3	24.7	26.5	0
WC	I	Mittal Steel Saldanha	47	47	1.1	1.1	1.0	0.5	1.9	2.3	0
FS	P	Makalu	132	132	7.0	7.0	6.6	2.4	12.2	15.0	0
FS	P	Warden	6	6	1.7	1.7	1.8	0.6	2.4	2.5	0
MP	P	Elandsfontein	118	118	9.4	9.4	9.4	3.1	15.1	18.5	0
MP	P	Kendal 1	8	8	7.2	7.2	5.9	3.2	12.6	14.6	0
MP	P	Kendal 2	130	130	13.2	13.2	12.6	4.9	22.2	34.5	0
MP	P	Kendal 3	7	7	9.3	9.3	7.0	6.0	18.8	21.7	0
MP	P	Leandra	100	100	11.4	11.4	10.1	5.4	20.5	33.4	0
MP	P	Majuba 1	121	121	5.3	5.3	4.6	3.9	9.8	38.0	0
MP	P	Majuba 2	66	66	5.1	5.1	4.2	3.7	11.1	24.0	0
MP	P	Majuba 3	47	47	5.1	5.1	4.7	2.9	10.2	10.7	0
MP	P	Palmer	116	116	3.4	3.4	2.6	2.9	8.4	17.3	0
MP	P	Verkykkop	118	118	3.7	3.7	3.7	1.8	6.3	12.5	0
WC	P*	Athlone	62	68	3.5	3.5	3.0	1.7	6.4	8.6	0
KZN	R	Arboretum	67	67	3.4	3.4	3.1	1.4	6.2	9.0	0
KZN	R	Arboretum Ext	17	17	3.3	3.3	2.7	1.7	6.2	6.8	0
KZN	R	Brackenham	10	10	3.0	3.0	3.1	0.7	3.8	3.8	0
KZN	R	Veldenvlei	10	10	3.1	3.1	2.8	1.4	5.5	5.9	0
KZN	R	Wildenweide	47	47	3.5	3.5	3.3	1.2	5.5	6.8	0
NWP	R	Bergsig School	20	20	12.2	12.2	11.4	3.3	15.7	23.8	0
NWP	R	Kroondal Station	10	10	11.2	11.2	11.3	2.6	14.9	16.1	0
WC	R	Goodwood	115	127	5.7	5.6	5.3	2.9	11.0	16.0	0
FS	RI	AJ Jacobs	26	38	16.6	15.7	15.3	7.2	23.1	48.3	0

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Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.	Exceed
FS	RI	Boiketlong	26	38	15.9	16.2	14.0	8.8	21.4	55.9	1
FS	RI	Hospital	26	38	15.3	14.4	14.6	6.6	20.5	43.1	0
KZN	RI	Settlers	46	48	13.7	13.8	13.3	3.9	20.1	22.9	0
KZN	RI	Siza Centre	36	36	4.4	4.4	4.4	1.8	7.2	8.5	0
KZN	RI	Wentworth	95	96	18.7	18.5	16.2	8.9	31.7	53.9	1
MP	RI	Club	69	69	13.5	13.5	9.1	11.5	37.7	58.2	3
MP	RI	Grootvlei	1	1	4.8	4.8					0
MP	RI	Langverwacht	72	72	10.6	10.6	10.2	5.7	19.2	32.7	0
NWP	RI	Waterval	20	20	21.4	21.4	19.5	7.0	34.2	38.9	0
WC	RI	Bothasig	116	124	3.5	3.6	3.1	1.6	6.5	7.2	0
WC	RI	Table View	121	129	5.1	5.0	5.0	2.2	9.5	12.2	0
EC	T	Motherwell	22	22	1.1	1.1	1.0	0.7	2.0	2.8	0
FS	T	Leitrum	17	29	9.7	10.4	9.5	2.7	14.9	16.3	0
GAU	T	Alexandra	33	40	8.2	8.0	7.5	3.0	12.7	17.3	0
GAU	T	Orange Farm	9	17	9.3	7.9	5.6	6.8	19.4	19.4	0
KZN	T	Esikhawini	33	33	2.1	2.1	1.9	1.0	3.8	4.3	0
KZN	T	Umhlatuze	34	34	2.7	2.7	2.6	1.2	4.5	5.2	0
EC	U	Coega Salt Works	37	37	1.0	1.0	1.0	0.6	2.0	2.8	0
GAU	U	Buccleuch	10	10	13.6	13.6	13.1	4.1	19.4	19.6	0
GAU	U	Rosslyn	5	5	5.0	5.0	3.7	3.6	9.9	11.1	0
KZN	U	Rbay Caravan	71	71	6.5	6.5	6.0	2.6	12.0	12.4	0
WC	U	Cape Town City Hall	86	92	5.6	5.6	5.3	2.0	9.2	11.1	0

SO_2 is measured in eight provinces and it seems that the worst SO_2 pollution is in Durban, but this could be misleading because Durban has the largest monitoring network. Out of 20 monitoring stations with long-term monthly averages between 3 and 25 ppb, the monthly limit of 50 ppb is exceeded at 5 stations (Southern Works, Wentworth, Drift, Ilfracombe, and Umkomaas).

The other station with exceedances is Boiketlong in the Free State (max. 55.9 ppb), which is in close proximity to the Vaal Triangle Industrial complex and could also be affected by domestic fuel-burning. Out of 17 stations in Mpumalanga province, exceedances were found at two stations; the Club (max. of 58.2 ppb) in Secunda and the Columbus station near Middelburg (max. of 53 ppb) in close proximity to industrial sources. The longest exceedance period (over 3 months) was found at the Club station in Mpumalanga (max. of 58.2 ppb).

There were large variations amongst stations located in industrial areas. For example, a station in Saldanha has a long-term average of 1.1 ppb and in KwaZulu-Natal some of the stations in industrial areas, such as Ilfracombe, Naidooville School, and Scorpio, had average concentrations between 4.1 and 7 ppb.

Low levels of SO_2 were found in township stations at the East Coast and KwaZulu-Natal (max. 2.8 and 5.2 ppb), while in Gauteng these were higher (max. 17.3 and 19.4 ppb), but are still low compared to the AQA standard of 50 ppb.

All five background stations have low averages ranging from 0.5 to 2.4 ppb at the Lichtenburg station.

Table 4.3.3.2: Statistical analysis of continuous annual SO_2 concentrations (ppb)

Province	Type	Name	Num.	Avg	Max.	% Limit	Exceed
EC	B	Ben McDhui	3	0.4	0.5	1.3	0
EC	I	Amsterdam Plein	4	1.2	1.5	4.0	0
EC	I	PE Delta	7	14.7	26.4	48.9	0
EC	T	Motherwell	5	5.5	17.1	18.4	0
EC	U	Coega Salt Works	4	0.8	1.5	2.7	0
FS	P	Makalu	10	7.0	7.9	23.2	0
FS	P	Makalu	11	7.0	7.9	23.5	0
FS	P	Warden	2	1.9	2.3	6.3	0
FS	T	Leitrim	2	10.3	11.0	34.3	0
FS	RI	AJ Jacobs	3	17.5	23.2	58.3	0
FS	RI	Boiketlong	3	15.6	19.8	51.9	0
FS	RI	Hospital	3	16.3	21.3	54.2	0
GAU	I	Bedworth Park	2	8.6	11.8	28.5	0
GAU	I	Mittal Mobile Caravan	1	15.5	15.5	51.6	0
GAU	T	Alexandra	3	8.0	8.9	26.7	0
GAU	T	Orange Farm	1	9.6	9.6	32.0	0
GAU	U	Buccleuch	1	12.6	12.6	41.8	0
GAU	U	Rosslyn air quality monitoring station	2	5.5	8.1	18.2	0
KZN	I	Dlambula School	4	21.1	24.3	70.4	0
KZN	I	Drift	11	15.9	30.3	53.1	1
KZN	I	Hillside	6	8.8	10.7	29.4	0
KZN	I	Ilfracombe	10	7.5	22.4	25.0	0
KZN	I	Naidooville School	4	4.2	4.8	14.0	0
KZN	I	Scorpio	2	8.7	10.6	29.1	0
KZN	I	Southern Works	8	25.0	32.3	83.4	2
KZN	I	TLC	5	3.1	3.7	10.3	0
KZN	I	Umkomaas	10	12.9	26.6	42.9	0
KZN	R	Arboretum	8	3.4	4.6	11.4	0
KZN	R	Arboretum Extension	3	3.1	4.2	10.5	0
KZN	R	Brackenham	3	3.4	4.0	11.5	0
KZN	R	Veldenvlei	3	3.0	3.1	10.0	0
KZN	R	Wildenweide	6	3.4	3.7	11.2	0
KZN	RI	Settlers	4	13.7	14.6	45.7	0
KZN	RI	Siza Centre air quality monitoring station	4	4.3	5.4	14.4	0
KZN	RI	Wentworth	11	28.7	56.0	95.7	4
KZN	T	Esikhawini	4	1.8	2.4	6.0	0
KZN	T	Umhlatuze	4	2.8	3.6	9.5	0
KZN	U	Richards Bay Caravan	8	6.9	9.1	23.0	0
LMP	B	Louis Trichardt	2	0.5	0.6	1.7	0
MPU	B	Houtbosrand	1	0.8	0.8	2.5	0
MPU	B	Skukuza	1	1.0	1.0	3.2	0
MPU	I	Amersfoort	2	4.5	4.6	15.1	0
MPU	I	Amersfoort	2	2.8	3.4	9.3	0
MPU	I	Bosjesspruit	5	9.4	11.2	31.4	0
MPU	I	Columbus	5	15.4	34.6	51.4	0
MPU	P	Elandsfontein	10	9.4	11.6	31.5	0
MPU	P	Kendal 1	1	7.2	7.2	24.0	0
MPU	P	Kendal 2	10	13.2	17.9	44.0	0
MPU	P	Kendal 2	11	13.2	17.9	44.1	0
MPU	P	Kendal 3	1	9.3	9.3	31.1	0
MPU	P	Leandra	9	11.1	15.9	36.9	0
MPU	P	Majuba 1	10	4.8	6.9	16.1	0
MPU	P	Majuba 1	11	5.2	8.4	17.2	0

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Province	Type	Name	Num.	Avg	Max.	% Limit	Exceed
MPU	P	Majuba 2	6	5.1	6.4	16.9	0
MPU	P	Majuba 3	4	5.0	7.7	16.6	0
MPU	P	Majuba 3	3	4.1	5.3	13.6	0
MPU	P	Palmer	10	3.3	5.6	11.0	0
MPU	P	Palmer	11	3.2	5.6	10.7	0
MPU	P	Verkykkop	10	3.7	5.3	12.5	0
MPU	RI	Club	7	15.2	37.5	50.7	1
MPU	RI	Grootvlei	1	4.8	4.8	16.1	0
MPU	RI	Langverwacht	7	10.6	15.2	35.5	0
NWP	B	Lichtenburg	2	2.5	3.0	8.4	0
NWP	I	Hexrivier	2	9.4	10.2	31.3	2
NWP	I	Paardekraal	2	14.7	14.9	48.9	1
NWP	R	Bergsig School	2	12.1	12.7	40.2	0
NWP	R	Kroondal Station	2	10.1	11.7	33.8	0
NWP	RI	Waterval	2	20.4	24.9	68.0	0
WC	B	Cape Point	3	0.5	0.7	1.6	0
WC	I	Mittal Steel Saldanha	4	1.2	1.4	3.8	0
WC	P*	Athlone	7	3.6	5.6	12.0	0
WC	R	Goodwood	11	5.9	9.2	19.6	0
WC	RI	Bothasig	10	3.6	4.6	11.9	0
WC	RI	Table View	11	5.2	6.5	17.2	0
WC	U	Central Cape Town City Hall	8	5.6	8.0	18.5	0

Analysis of annual averages shows a similar geographical distribution, but fewer stations have pollution levels exceeding the annual interim standard. Three stations in KZN (Wentworth, Drift, and Southern Works) and two stations in Mpumalanga (Club and one in Middelburg) have exceedances of the annual standard of 30 ppb.

Table 4.3.3.3: Statistical analysis of SO_2 concentrations (passive monitoring) (ppb)

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.	Exceed
NWP	I	Stack & tailings dam (C5)	10	20	9.8	12.9	9.6	2.7	13.6	14.0	0
NWP	I	L2 BMR	10	12	20.2	18.9	20.0	6.8	31.0	35.0	0
NWP	I	Rowland Shaft (C10)	5	16	10.7	13.3	8.3	4.5	15.8	16.0	0
NWP	I	Substation: Marikana Road (C8)	8	19	75.0	81.1	80.0	24.0	99.7	100.0	6
NWP	I	WPL Offices (C4)	11	19	9.1	8.5	8.8	4.0	16.0	16.0	0
NWP	RI	End of town (C3)	10	21	3.5	3.8	3.9	1.4	4.7	4.9	0
NWP	RI	Karee K4 (C9)	5	16	6.0	6.8	6.4	1.0	6.8	6.9	0
NWP	RI	Middle of town (C2)	11	22	4.3	4.5	4.6	0.9	5.4	5.6	0
NWP	RI	Tlhapi Supermarket (C1)	11	22	5.1	5.0	4.5	1.8	7.7	7.8	0
NWP	T	Selokwaneng (301 C6)	8	19	5.8	5.1	5.6	1.9	8.9	9.9	0
NWP	T	Selokwaneng (355 C7)	10	20	5.5	5.1	4.8	1.8	8.6	10.0	0

The comprehensive passive sampling data from Lonmin Platinum mine show that in the vicinity of the smelter, high SO_2 levels are measured. The station at Marikana Road showed consistently high values. All the other stations in the residential and township areas around Lonmin showed relatively low SO_2 concentrations.

4.3.4 Compliance analysis of Lead (Pb)

Detailed statistical analysis was performed on the monthly and annual data from all stations and these are presented in Tables 4.3.4.1 and 4.3.4.2 respectively.

Table 4.3.4.1: Statistical analysis of Pb concentrations (monthly data) ($\mu g/m^3$)

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.
EC	U	Port Elizabeth - CBD	27	39	0.25	0.28	0.22	0.24	0.71	1.07
GAU	U	Fordsburg	22	22	1.14	1.14	1.05	0.31	1.62	1.82
GAU	U	Germiston	15	27	0.23	0.45	0.47	0.22	0.67	0.71
GAU	U	Johannesburg City Hall	36	46	0.49	0.49	0.47	0.37	1.11	1.90
GAU	U	Newtown	24	24	0.75	0.75	0.68	0.36	1.42	1.71
GAU	U	Pretoria - Beatrix Street	29	40	0.60	0.68	0.54	0.41	1.25	1.93
GAU	U	Vereeniging - CBD	37	49	0.25	0.30	0.23	0.17	0.66	0.74
KZN	B	Cowies Hill	6	6	0.17	0.17	0.05	0.27	0.56	0.71
KZN	I	Congella Fire Station	9	9	0.28	0.28	0.25	0.12	0.49	0.54
KZN	I	Southern Roof	9	9	0.25	0.25	0.22	0.18	0.54	0.64
KZN	R	Gillits Road	9	9	0.19	0.19	0.15	0.14	0.42	0.55
KZN	R	Hosley Road	9	9	0.20	0.20	0.16	0.17	0.49	0.52
KZN	RI	Brighton Beach Reservoir	9	9	0.21	0.21	0.16	0.16	0.48	0.52
KZN	RI	Isipingo	9	9	0.25	0.25	0.24	0.08	0.36	0.38
KZN	RI	Merewent	9	9	0.20	0.20	0.19	0.10	0.34	0.40
KZN	RI	South Bluff	9	9	0.14	0.14	0.13	0.09	0.27	0.27
KZN	RI	Wentworth	9	9	0.13	0.13	0.05	0.10	0.27	0.28
KZN	U	Cato Manor	9	9	0.28	0.28	0.24	0.13	0.49	0.49
KZN	U	Chatsworth	8	8	0.18	0.18	0.15	0.10	0.32	0.33
KZN	U	Durban City Hall	38	49	0.41	0.43	0.39	0.24	0.96	1.09
KZN	U	Palmfield Road	9	9	0.28	0.28	0.26	0.13	0.48	0.53
KZN	U	Pietermaritzburg City Hall	33	33	0.54	0.54	0.40	0.45	1.46	1.65
KZN	U	Pinetown Civic Centre	9	9	0.18	0.18	0.16	0.10	0.32	0.33
WC	U	Cape Town City Hall	23	35	0.73	0.89	0.83	0.45	1.55	1.68

There are no exceedances of the monthly AQA standard of 2.5 $\mu g/m^3$ for Pb at any of the stations.

The highest monthly averages were measured in Johannesburg and Pretoria urban city centres (1.9 $\mu g/m^3$). Cape Town and Pietermaritzburg have slightly lower maxima, while Durban and Port Elizabeth city centres have much lower maxima of about 1 $\mu g/m^3$. The long-term averages have a different distribution, the highest being in Cape Town, followed by Pretoria, Pietermaritzburg, and Johannesburg. The rest of the stations have significantly lower monthly averages.

An extensive lead survey was done in Durban, but there are only 9 months of data for these stations. It is interesting to note that the background station had the same long-term average as most of the residential stations, while stations in residential areas affected by industrial pollution had lower levels than background stations. However the median at the background station (Cowies Hill) is very low, 0.05 $\mu g/m^3$, which means that half of the time the concentrations are much lower than the average at this station.

Most of the standard deviations are similar to the averages or even lower, which shows that the range of the concentrations is not very wide.

C&M Consulting Engineers conducted Pb monitoring from April 1994 to March 1995 in Pretoria (no data are available for Pretoria station in our database for this period). The monthly averages ranged from 0.22 to 1.74 $\mu g/m^3$ with an annual average of 0.84 $\mu g/m^3$ which exceeds the SANS 1929 limit of 0.5 $\mu g/m^3$ (Liebenberg-Enslin and Petzer, 2005). These results agree with the monitoring results presented above.

Table 4.3.4.2: Compliance with annual standards for Pb concentrations ($\mu g/m^3$)

Province	Type	Name	Num.	Avg	Max.	% Limit
EC	U	Port Elizabeth - CBD	4	0.23	0.44	45.21
GAU	U	Fordsburg	2	1.13	1.28	225.48
GAU	U	Germiston	3	0.29	0.64	58.22
GAU	U	Johannesburg City Hall	5	0.44	0.92	87.17
GAU	U	Newtown	3	0.74	0.97	148.02
GAU	U	Pretoria - Beatrix Street	4	0.57	0.90	114.11
GAU	U	Vereeniging - CBD	5	0.24	0.37	47.45
KZN	B	Cowies Hill	1	0.17	0.17	34.33
KZN	I	Congella Fire Station	1	0.28	0.28	56.67
KZN	I	Southern Roof	1	0.25	0.25	49.33
KZN	R	Gillits Road	1	0.19	0.19	37.78
KZN	R	Hosley Road	1	0.20	0.20	40.89
KZN	RI	Brighton Beach Reservoir	1	0.21	0.21	42.44
KZN	RI	Isipingo	1	0.25	0.25	49.78
KZN	RI	Merewent	1	0.20	0.20	39.33
KZN	RI	South Bluff	1	0.14	0.14	28.89
KZN	RI	Wentworth	1	0.13	0.13	26.22
KZN	U	Cato Manor	1	0.28	0.28	56.44
KZN	U	Chatsworth	1	0.18	0.18	35.00
KZN	U	Durban City Hall	6	0.38	0.68	76.34
KZN	U	Palmfield Road	1	0.28	0.28	55.33
KZN	U	Pietermaritzburg City Hall	5	0.51	1.09	102.29
KZN	U	Pinetown Civic Centre	1	0.18	0.18	36.67
WC	U	Cape Town City Hall	4	0.62	0.97	124.56

The compliance analysis for the annual averages shows a different situation. The annual averages range from 0.17 to 1.13 $\mu g/m^3$. Many urban stations have long-term annual averages above the annual interim standard of 0.5 $\mu g/m^3$, such as Fordsburg and Newtown in Johannesburg, Beatrix Street in Pretoria, Pietermaritzburg and Cape Town City Hall stations. The information for stations that have a long monitoring record is presented graphically in section 4.2.4 on long-term trend analysis.

4.3.5 Compliance analysis of particulate matter

4.3.5.1 PM_{10} and $PM_{2.5}$

The statistical analysis of monthly PM_{10} is indicated in Table 4.3.5.1.

Table 4.3.5.1: Statistical analysis of monthly PM_{10} ($\mu g/m^3$) monitoring (maxima are highlighted)

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.	Exceed
EC	I	P E Delta	37	37	86.6	86.6	61.9	65.1	221.9	232.2	5
GAU	I	350 site	0	9		91.7				0.0	
GAU	I	620 site	0	8		88.2				0.0	
GAU	I	Mittal Mobile Caravan	8	17	132.0	114.9	132.5	15.3	151.0	152.7	
MPU	I	Columbus	44	51	77.7	77.0	71.5	40.3	149.9	185.0	1
NWP	I	Paardekraal	2	2	32.7	32.7	32.7	11.7	40.1	41.0	
WC	I	Mittal Steel Saldanha	40	40	36.0	36.0	34.6	7.2	50.1	54.8	
MP	P	Palmer	1	1	38.6	38.6					
GAU	R	Delta Park	8	8	32.2	32.2	34.1	9.2	41.5	41.6	
NWP	R	Bergsig School	17	17	61.7	61.7	58.3	11.2	78.8	93.8	
WC	R	Goodwood	118	126	28.0	28.2	28.0	4.7	35.2	41.0	
KZN	RI	Settlers	33	33	41.0	41.0	33.8	16.5	64.2	101.8	
KZN	RI	Wentworth	11	12	36.8	34.9	30.6	14.9	59.9	64.6	
NWP	RI	Waterval	19	19	50.6	50.6	50.3	10.5	66.2	73.2	
WC	RI	Table View	122	130	25.1	25.5	24.0	5.2	35.0	40.0	
EC	T	Motherwell	22	22	43.0	43.0	38.0	19.1	83.6	96.0	
FS	T	Leitrum	17	28	76.9	90.1	71.4	55.4	165.1	182.8	1
GAU	T	Alexandra	32	39	42.9	45.9	40.8	19.3	78.5	109.0	
GAU	T	Diepsloot	6	6	113.6	113.6	100.4	58.4	197.8	217.6	1
GAU	T	Orange Farm	10	15	76.7	80.2	77.8	29.7	115.9	127.2	
WC	T	Khayelitsha	55	63	44.9	45.0	45.0	10.3	60.9	82.0	
EC	U	Publicity House	3	3	46.0	46.0	41.9	11.6	57.3	59.1	
GAU	U	Buccleuch	10	10	60.4	60.4	58.2	19.3	89.3	100.0	
GAU	U	Newtown	17	17	48.2	48.2	48.0	10.0	64.1	67.3	
WC	U	Drill Hall	118	124	23.6	23.7	23.2	4.5	31.6	38.3	
EC	W	B	3	4	18.0	16.5	16.8	5.8	23.5	24.3	

The highest PM_{10} levels were measured at the **industrial** site of PE Delta, on the East Coast (maximum of 232.2 $\mu g/m^3$), but the highest average over the period was measured at another industrial site, Mittal, Gauteng (132 $\mu g/m^3$). It should be noted that not all industrial sites recorded high levels of PM_{10} pollution. Much lower averages (32.7 and 36 $\mu g/m^3$) were in the North West and Western Cape provinces. Unfortunately the measurements near Vereeniging

(350 and 620 sites) started recently and no data were available prior to 2005. The data for the 8–9 months in 2005 show averages typical for industrial sites (around 90 $\mu g/m^3$).

The **township** of Diepsloot has a maximum monthly concentration almost as high as at PE Delta and an average almost as high as at Mittal (both industrial sites). Although there are only 6-monthly averages available for Diepsloot, it shows that it is practically the most polluted site in the country. Averages recorded at other township sites are lower, but townships in Gauteng and Free State are more polluted than in the Eastern and Western Cape because of the domestic coal combustion (the lower PM_{10} pollution in Alexandra is a result of poor siting of the station, which does not represent the true pollution in the area). One of the reasons why the Diepsloot site has such a high average concentration, is because the period for which measurements are available was only from May until November and during winter the pollution is normally highest. For other township stations, the average was reduced by less polluted summer months.

Not enough information is available for assessing the impact of power generation.

The two **residential** stations in Durban affected by industrial pollution also have relatively high maxima, but the residential site in Cape Town, Goodwood, has better air quality from a PM perspective.

There are three stations representing **urban** pollution, Publicity House in Port Elizabeth (EC), Drill Hill in Cape Town (WC), and Newtown in Johannesburg (GAU). They have similar levels of pollution that do not vary much from month to month. The averages in Gauteng and the East Coast are just below 50 $\mu g/m^3$, while air quality in Cape Town is better (average of only 23 $\mu g/m^3$).

The on-site waste station next to the highway in the EC has the lowest average of all sites, as it currently represents **background** pollution, with the waste site not being operational yet.

No compliance analysis can be made on the monthly data as the AQA standards for PM_{10} are daily (180 $\mu g/m^3$) and annual (60 $\mu g/m^3$). However, when the maximum monthly average is compared to the daily standards, there are 4 stations where this standard is exceeded for at least a whole month or more. If the results are compared to the new proposed standard of 75 $\mu g/m^3$ then at least 7 more stations will be non-compliant (see maximum value highlighted).

Compliance analysis of annual data is presented in Table 4.3.5.2.

Table 4.3.5.2: Statistical analysis of annual PM_{10} and $PM_{2.5}$ ($\mu g/m^3$) monitoring

Province	Station Type	Station	Parameter	Num	Avg	Max.	% Limit	Exceedances
EC	I	PE Delta	PM_{10}	4	80.66	148.02	134.43	2
EC	T	Motherwell	PM_{10}	4	37.57	53.14	62.62	
EC	U	Publicity House	PM_{10}	1	46.19	46.19	76.98	
EC	W	B: adjacent to highway	PM_{10}	1	16.39	16.39	27.32	
FS	T	Leitrum	PM_{10}	2	98.20	143.55	163.67	2
GAU	I	Mittal Mobile Caravan	PM_{10}	1	132.04	132.04	220.06	2
GAU	R	Delta Park	PM_{10}	1	34.22	34.22	57.03	
GAU	T	Alexandra	PM_{10}	3	43.59	46.41	72.66	1
GAU	T	Diepsloot	PM_{10}	1	117.27	117.27	195.44	1
GAU	T	Jabavu	PM_{10}	1	78.48	78.48	130.80	1
GAU	T	Orange Farm	PM_{10}	1	79.50	79.50	132.50	2
GAU	U	Buccleuch	PM_{10}	1	62.42	62.42	104.04	1
GAU	U	Newtown	PM_{10}	2	47.31	48.84	78.86	
KZN	I	Hillside	PM_{10}	2	35.00	40.00	58.33	
KZN	RI	Settlers	PM_{10}	3	39.61	39.96	66.01	
KZN	RI	Wentworth	PM_{10}	1	33.36	33.36	55.59	
KZN	U	Siza Centre	PM_{10}	3	0.07	0.09	0.12	
MP	I	Columbus	PM_{10}	5	81.18	125.80	135.30	5
MP	P	Palmer	PM_{10}	1	38.60	38.60	64.34	
NWP	I	Paardekraal	PM_{10}	1	25.98	25.98	43.29	
NWP	R	Bergsig School	PM_{10}	2	62.19	62.92	103.64	2
NWP	RI	Waterval	PM_{10}	2	52.18	52.71	86.97	
WC	I	Mittal Steel Saldanha	PM_{10}	4	36.23	42.21	60.38	
WC	R	Goodwood	PM_{10}	10	27.97	33.17	46.62	
WC	RI	Table View	PM_{10}	11	24.92	31.17	41.53	
WC	TU	Khayelitsha	PM_{10}	6	46.15	51.75	76.92	
WC	UC	Drill Hall	PM_{10}	10	23.63	26.64	39.39	
GAU	U	Buccleuch	$PM_{2.5}$	1	48.38	48.38		

The annual AQA PM_{10} standard of 60 $\mu g/m^3$ was compared with annual averages and it was exceeded during four out of five years as measured at an industrial site in Mpumalanga (Columbus). There were also exceedances during two years at the PE Delta industrial site and one year at Mittal (Vereeniging, Gauteng). The latter has only 8 months' available data for 2004, but the average for this period was 132 $\mu g/m^3$, which is more than double the standard value.

It must be noted that if the new proposed annual standard of 40 $\mu g/m^3$ is accepted, then practically all stations will be non-compliant with this standard.

The measurements of $PM_{2.5}$ at Buccleuch station show that about 70% of PM_{10} at this station was smaller than 2.5 μm.

4.3.5.2 TSP

The annual AQA TSP standard of 100 $\mu g/m^3$ was exceeded only at Diepsloot station (Table 4.3.5.3). This comparison is not strictly valid, because data were available only for 6 months, mainly for winter (June–November 2004). As for most of the other pollutants, the TSP at this **township** station showed the highest concentrations in the country.

Statistical analysis of monthly TSP is indicated in Table 4.3.5.3.

Table 4.3.5.3: Statistical analysis of monthly TSP ($\mu g/m^3$) monitoring

Province	Station type	Station	Num.	Num. (all)	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
EC	I	Amsterdam Plein	34	34	29.6	29.6	28.5	12.5	46.5	79.0
KZN	R	Arbor Park School	79	86	34.9	35.1	28.0	20.1	69.2	86.0
EC	U	Coega Salt Works	43	43	33.3	33.3	28.0	17.6	75.7	98.0
GAU	T	Diepsloot	6	6	229.3	229.3	209.0	105.0	379.2	413.4
KZN	I	Karbochem Effluent Plant	79	86	44.1	43.6	38.5	22.4	87.5	109.0
KZN	U	Keyway Motors	78	85	52.8	52.9	50.5	23.5	90.5	105.0
KZN	UC	Newcastle Airport	77	84	39.8	39.9	39.0	21.6	74.2	111.0

All four sites in KwaZulu-Natal (Newcastle) show low variability between different types of sites. The **residential station** at Arbor Park recorded a slightly lower maximum monthly average (86 $\mu g/m^3$) compared to the three other stations (105–111 $\mu g/m^3$).

However, the comparison between the Eastern Cape (East London) and KwaZulu-Natal shows that for both station types (**industrial** and **urban**) the levels of pollution in East London are on average about half the levels in Newcastle, while maximum concentrations are similar. It is important to note that the pollution levels in both areas are below AQA annual standard, indicating no cause for concern, although it should be noted that AQA standards were not based solely on human health outcomes.

4.3.6 Carbon monoxide

Since CO has acute health impacts, there are no long-term standards. The new proposed SA standard is 10 mg/m^3 (8.6 ppm) for 8-h averages, which is the same as the WHO guideline or US standard. Stations and areas may therefore be compared, but the number of exceedances cannot be determined because no relevant (i.e. monthly) standard is available. The statistical analysis of monthly CO is indicated in Table 4.3.6.1.

Table 4.3.6.1: Statistical analysis of CO (ppm) monitoring

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.
GAU	I	350 site	0	9		0.51				
GAU	I	620 site	0	8		1.11				
GAU	I	Mittal Mobile Caravan	0	10		0.79				
GAU	T	Alexandra	31	39	1.52	1.39	0.87	2.15	6.46	9.09
GAU	U	Buccleuch	10	10	11.28	11.28	6.53	18.40	38.35	63.35
GAU	U	City Deep	23	23	1.36	1.36	1.42	0.38	1.92	1.99
GAU	U	Jhb City Hall	5	16	1.52	1.59	1.61	0.18	1.74	1.77
GAU	U	Newtown	69	69	3.08	3.08	2.77	0.97	5.03	5.72
GAU	U	Rosslyn	5	5	0.96	0.96	0.39	0.99	2.19	2.31
KZN	RI	Settlers	33	33	1.09	1.09	1.11	0.33	1.63	1.85
MPU	RI	Langverwacht	8	8	0.77	0.77	0.70	0.44	1.30	1.31
WC	R	Goodwood	65	74	0.77	0.77	0.61	0.46	1.57	1.76
WC	U	Cape Town City Hall	62	71	1.95	1.97	1.84	0.58	3.07	3.45
WC	B	Cape Point	128	140	0.05	0.05	0.05	0.01	0.07	0.07

The highest CO levels were measured at the Buccleuch station, with a maximum of 63.35 ppm and long-term average of 11.28 ppm. This means that the SANS limit is exceeded most of the time at this station. Since this station represents a busy highway, it shows that the motor vehicle pollution is the most important source of CO. The 2nd highest level was measured in the **township** station of Alexandra (maximum monthly value of 9.09 ppm). This means that during this month the 8-h limit of 8.6 ppm has been consistently exceeded. The 2nd highest long-term average of 2.86 ppm was recorded in Newtown (**urban** station). The max. for this station was 5 ppm. For this station, hourly data were provided and further analyzed. During the 10 years (1994–2004) the 1-h limit was exceeded 42 times. It must be noted that only a 60% data recovery was achieved for that period, which may bias results.

Comparison of City Hall stations (**urban**) in Johannesburg and Cape Town shows that levels in Cape Town are slightly higher than in Johannesburg. Similar CO pollution levels were measured at **residential** stations in Cape Town and Durban.

There is published information on CO measurements at Warwick station in Durban. This station was commissioned on 25 March 2004 and represents urban pollution (eThekwini Health Department, 2004). The 1-h maximum for 2004 at this station was 17.8 ppm, but the 8-h maximum was 6.9 ppm, which is close to, but still below the new proposed standard of 8.6 ppm. The annual average for 2004 was 1.7 ppm. The only station available in this database for Durban is Settlers, which shows a relatively low monthly maximum of 1.85 ppm and a long-term average of 1.09 ppm.

Three new **industrial** sites were added in 2005 around Vereeniging and the averages for the last 8–10 months are similar to concentrations measured at residential sites.

The only site available in Mpumalanga represents a residential area affected by industrial pollution in Langverwacht, and the concentrations are low with an average of 0.77 ppm. However, only 8 months of data are available and, again, the 8-h peaks are not known.

The most comprehensive dataset for CO is available for 13 years at the background station of Cape Point. As expected, the concentrations are low (max. of 0.07 ppm) with the range of variation also being low (Std dev. of 0.01 ppm).

4.4 OTHER POLLUTANTS

4.4.1 BTEX

The only places where total BTEX is measured is at the regional waste disposal sites in East London (Table 4 4 1.1).

There were only 4 months' data available. However, significant variation is found among sites.

Table 4.4.1.1: Statistical analysis of total BTEX concentrations (µg/m³)

Station	Num. (all)	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
B: On-site adjacent to highway	4	17.06	17.06	2.75	29.80	52.91	61.75
C: Background site in Nqonqweni residential area	4	14.93	14.93	2.55	25.12	45.12	52.60
D: Background site at Border Technikon entrance	4	10.86	10.86	5.68	12.53	26.13	29.30
E: Background site at Thorn Hill farm	3	3.42	3.42	2.40	2.21	5.60	5.95
F: Background site at Lily Stone farm	4	9.05	9.05	2.96	12.91	24.64	28.40

Some of these variations could be explained by site location, as the highest values were found at the site adjacent to the highway. However, concentrations at the residential site are also much higher than at other background sites. There is no limit for total BTEX, so it is difficult to interpret these results.

The statistical analysis of benzene monitoring results is indicated in Table 4.4.1.2.

Table 4.4.1.2: Statistical analysis of benzene (ppb) monitoring

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.
FS	T	Leitrim	17	23	1.43	1.57	0.96	1.33	3.30	3.30
GAU	I	350 site	0	9		1.06				
GAU	I	620 site	0	9		2.23				
GAU	U	Buccleuch	7	7	1.75	1.75	1.74	1.33	3.45	3.69

The station at Buccleuch (near highway), Leitrim (Sasolburg), and two industrial sites near Vereeniging measure benzene, toluene, and xylene. The concentrations measured are much lower than the RfC limits of 9.4 ppb, 1330 ppb, and 23 ppb. However, if compared to new proposed standards for benzene of 5 µg/m³ (1.56 ppb), then all (except the 350 site) are non-compliant. The variation between stations is not high.

According to the eThekwini Annual 2004 report, the highest annual benzene concentration of 8.1 µg/m³ was measured at Settlers, exceeding the new proposed standard of 5 µg/m³. This station is impacted by pollution from refineries. Warwick, a station affected by traffic pollution, is next in line with an annual average of 7 µg/m³. These annual averages are comparable to values measured in Gauteng and the Free State.

The statistical analysis of toluene monitoring results is indicated in Table 4.4.1.3.

Table 4.4.1.3: Statistical analysis of toluene (ppb) monitoring

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.
FS	T	Leitrim	5	5	2.20	2.20	2.12	0.84	3.25	**3.40**
GAU	I	350 site	0	9		5.66				
GAU	I	620 site	0	9		2.56				
GAU	U	Buccleuch	7	7	3.40	3.40	2.75	2.86	7.23	**7.32**

The statistical analysis of xylene monitoring results are indicated in Table 4.4.1.4.

Table 4.4.1.4: Statistical analysis of xylene (ppb) monitoring

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.
FS	T	Leitrim	5	5	0.29	0.29	0.22	0.22	0.59	0.67
GAU	I	350 Site	0	9		0.23				
GAU	I	620 Site	0	9		0.63				
GAU	U	Buccleuch	9	9	7.35	7.35	2.62	10.49	25.99	28.20

4.4.2 Methane

Methane, a greenhouse gas, is monitored at two locations in Johannesburg and one in Cape Town. Statistical analysis of the long-term trends at the Cape Point site is indicated in Table 4.4.2.1. The annual and monthly averages for the available data are indicated in Figure 4.4.2.1 (Johannesburg) and Figure 4.4.2.2 (Cape Town).

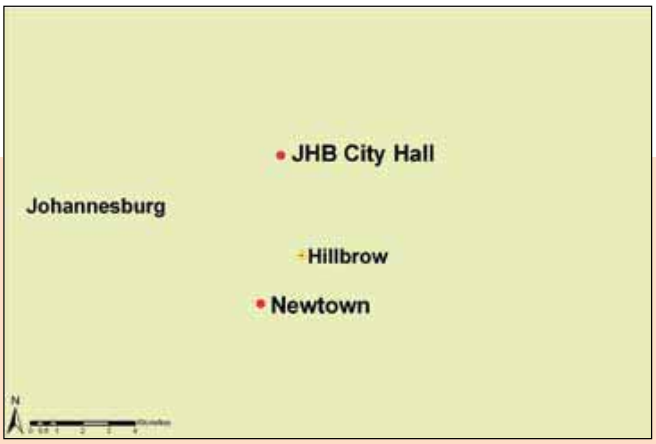
Table 4.4.2.1: Results of the trend analysis for CH_4

Province	Station Type	Name	Period	No. of Points	Avg	Slope	Intercept	RSq	Growth %
W Cape	B	Cape Point	(1991-01-16 to 2004-12-16)	144	1.69	0.0003	1.6676	0.629	0.02

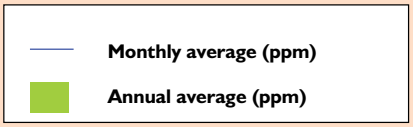
The % growth indicates a slight upward trend in methane concentrations. This can also be seen in Figures 4.4.2.1–4.4.2.2.

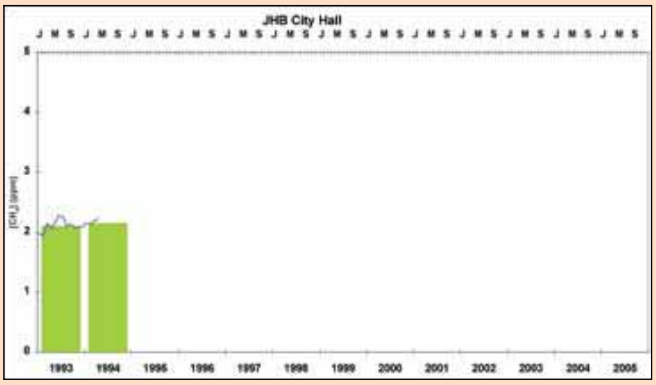
The following can be derived from Figures 4.4.2.1–4.4.2.2:

- CH_4 levels in Johannesburg are very low, especially if one considers that the ACGIH-TLV is 1000 ppm.
- Background CH_4 levels have remained stable over the 10-year period, with a small upward trend (compare Table .4.4.2.1).



Location of CH_4 monitoring stations in Johannesburg





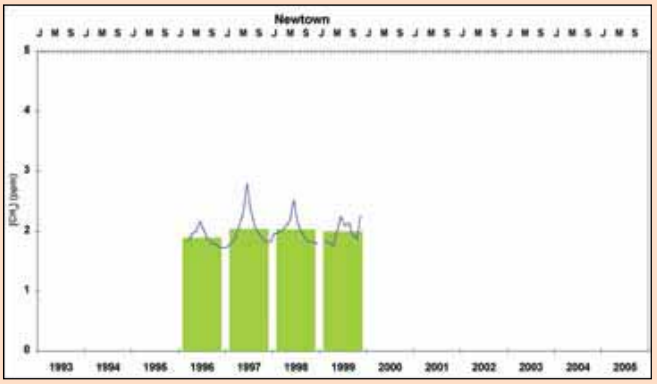
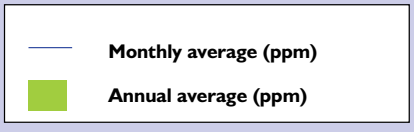


Figure 4.4.2.1: Monthly and annual averages of CH_4 concentrations in Johannesburg

Location of CH_4 monitoring station at Cape Point



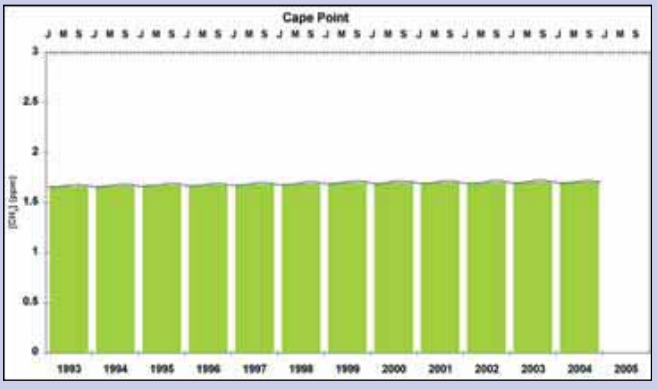


Figure 4.4.2.2: Monthly and annual averages of CH_4 concentrations at Cape Point

4.4.3 Smoke and SO_2

As previously explained, the DEAT's support for the smoke and SO_2 (bubbler) network was withdrawn in 1998.

The results obtained by the sampling and analytical methods used must be interpreted with care. The method used is neither specific to airborne particulates nor sulphur dioxide. At best, the method is useful only to investigate trends in these two pollutants. It must be borne in mind that the effects of any error, because of the sampling and analytical methods, are nullified if the same techniques are used continuously and are not deviated from. Furthermore, the methods are not referenced to internationally accepted monitoring methods. Current international trends are towards the use of sophisticated automatic analyzers. Such analyzers provide real-time data and are capable of detecting particulates and SO_2 at very low ranges.

The shortcomings of these methods are as follows:

- Smoke - The permeation of light through a filter on which particles have been collected is dependent on various factors, i.e. mass of the particles, particle size distribution, colour of the particles, etc.

- The soiling index is not a reliable indication of the concentration of particulates in ambient air. Ambient air quality concentrations are defined as the number of micrograms per cubic metre. This implies that the mass of particulates must be determined, which was not done in the smoke monitoring method developed by the CSIR as used by the CTMM.

- Sulphur dioxide - As the analytical technique is based on a pH adjustment of the solution exposed to the air sample, any airborne component that can affect the pH of the solution will bias the result. It is not uncommon to end up with "negative" SO_2 results, as any alkaline gas, e.g. ammonia, will change the pH of the solution. The results obtained, therefore, were more of an indication of the acidity of the air, of which SO_2 is a contributing factor, than of the SO_2 itself.

Although the shortcomings of the methods have been explained above, the same methods were used from 1996 to 2002 and these data were used to give an indication of the long-term trends in the air quality of the CTMM.

With more than 50% of the data missing, the data for the three stations in Tshwane were discarded.

Table 4.4.3.1 indicates the statistical analysis of available SO_2 data that were gathered as part of the smoke and SO_2 network.

Table 4.4.3.1: Statistical analysis of SO_2 (ppb) monitoring (bubbler)

Province	Station type	Station	Num.	Num. (full period)	Avg	Avg (full period)	Median	Std dev.	Top 5%	Max.	Exceed
EC	I	Uitenhage Stores	27	36	11.9	13.8	10.8	6.7	19.2	30.6	0
EC	R	Despatch	32	40	77.4	85.1	69.2	56.1	137.0	321.0	22
EC	R	Uitenhage Parks	27	36	14.7	13.9	11.8	12.0	35.4	55.5	1
KZN	B	Cowies Hill	8	8	9.4	9.4	7.6	6.6	19.8	25.0	0
KZN	I	Congella Fire Station	9	9	20.2	20.2	18.9	3.2	24.5	24.6	0
KZN	I	Southern Roof	9	9	47.5	47.5	43.3	10.7	63.4	66.4	3
KZN	R	Gillits Road	9	9	15.8	15.8	14.8	5.8	25.7	28.7	0
KZN	R	Hosley Road	9	9	23.9	23.9	21.9	10.4	40.0	46.8	1
KZN	RI	Brighton Beach Reservoir	9	9	24.3	24.3	17.9	13.7	47.3	51.2	1
KZN	RI	Isipingo	9	9	17.1	17.1	17.5	4.4	22.3	22.4	0
KZN	RI	Merewent	9	9	33.6	33.6	32.0	10.3	49.7	57.8	1
KZN	RI	South Bluff	9	9	17.2	17.2	12.6	11.4	36.1	42.4	0
KZN	U	Cato Manor	9	9	7.8	7.8	7.4	2.7	10.9	11.0	0
KZN	U	Chatsworth	9	9	6.8	6.8	6.4	2.6	10.3	10.5	0
KZN	U	Durban City Hall	9	9	17.0	17.0	19.5	4.3	21.9	22.9	0
KZN	U	Palmfield road	9	9	7.2	7.2	6.7	1.9	10.5	11.2	0
KZN	U	Pinetown Civic Centre	9	9	17.1	17.1	17.8	4.3	23.4	25.0	0

Very high levels were measured at Despatch station in the Eastern Cape and need to be verified by continuous SO_2 monitoring.

4.4.4 Total reduced sulphur

The statistical analysis of TRS is indicated in Table 4.4.4.1.

Table 4.4.4.1: Statistical analysis of TRS (ppb) monitoring

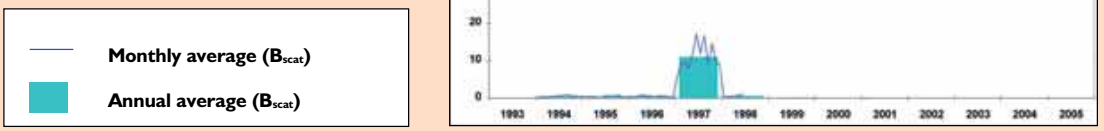
Station	Type	Num.	Num. (all)	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
Settlers	I	42	44	4.34	4.26	4.58	1.62	6.86	7.70
Southern Works	RI	6	6	3.84	3.84	3.29	1.36	5.79	6.12

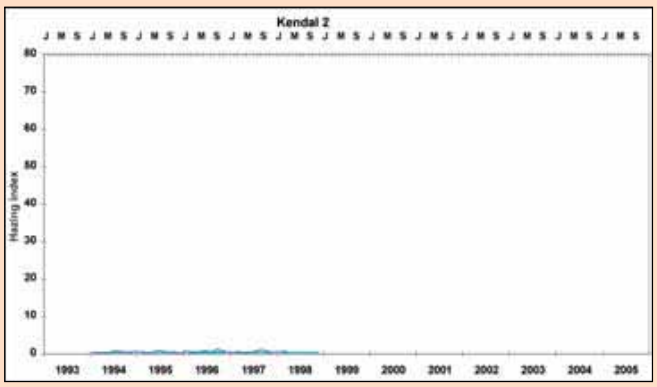
All measured monthly values are lower than the limits of 7.8 ppb, suggested by the South Durban Steering Committee, but the maximum measured at Settlers station is very close to this limit.

4.4.5 Hazing

Hazing is largely attributed to the backscattering of light by small airborne particles. The degree of hazing can therefore be related to the concentration of such particles through an index, namely a hazing index. In Mpumalanga, the hazing index is used to access the impact of air pollution ($PM_{2.5}$) on visibility. Figure 4.4.5.1 shows the hazing index ($B_{scat} \times 30 = PM_{2.5}$) for Mpumalanga.

Location of stations that monitor hazing index in Mpumalanga





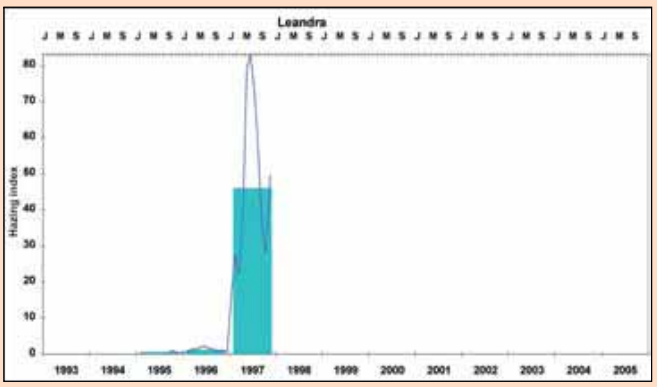


Figure 4.4.5.1: Monthly and annual averages of hazing index for Mpumalanga

Hazing was determined at just three stations on the Mpumalanga Highveld between 1994 and 1997. During this time, relatively low hazing values were reported at both stations except in 1997. At Elandsfontein and Leandra a significant increase in haze was reported, particularly in winter. The reason for this is not clear.

4.4.6 Hexavalent chromium

Hexavalent chromium (Cr^{6+}) pollution is monitored only in Newcastle. The monitoring network consists of 4 stations and has been in operation since April 1998, with monitoring of Cr^{6+} commencing at the end of June 1998. The network was designed based on results of air quality modelling, accessibility and feasibility. The monitoring frequency is about 3 weeks (to allow for the collection of mass sufficient for analysis on the filters). A summary of the monitoring results is presented in Table 4.4.6.1. The reference concentration (RfC) of 0.1 $\mu g/m^3$ has never been exceeded. There is not much variation in the long-term averages between the sites.

Table 4.4.6.1: Statistical analysis of Cr^{6+} ($\mu g/m^3$) monitoring

Station	Type	Num	Num. (all)	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
Arbor Park School	R	71	77	0.005	0.005	0.003	0.005	0.013	0.026
Karbochem Effluent Plant	I	73	79	0.005	0.005	0.003	0.005	0.016	0.027
Keyway Motors	U	74	80	0.007	0.007	0.005	0.008	0.016	0.062
Newcastle Airport	UC	72	78	0.004	0.004	0.003	0.004	0.011	0.025

The most recent (2005) health risk assessment indicates that no non-cancer effects are expected because levels are lower than the reference concentration (RfC) of 0.1 $\mu g/m^3$ for Cr^{6+} (Oosthuizen, *et. al.*, 2005).

Total chromium was also measured, to be used for additional interpretation of the Cr^{6+} concentrations, but the results are not presented here because there is no guideline to which a comparison may be made.

4.4.7 Manganese

Manganese is currently monitored in the Northern Cape. The monitoring network has been operational since 1999 and was initiated by the manganese mines to provide sound scientific data for decision support on environmental activities. A summary of monitoring results at two sites (both residential) is presented in Table 4.4.7.1. Neither of the sites exceeds the WHO annual average guideline of 0.15 $\mu g/m^3$. The fraction of Mn in airborne dust was consistently less than 2% at these sites.

Table 4.4.7.1: Statistical analysis of Mn ($\mu g/m^3$) monitoring

Station	Type	Num.	Num. (all)	Avg	Avg (all)	Median	Std dev.	Top 5%	Max.
Site D-Van Zyls Rus	R	45	45	0.007	0.007	0.004	0.012	0.024	0.074
Site E-Kuruman	R	49	49	0.110	0.110	0.115	0.037	0.168	0.204

4.4.8 Mercury

According to a 1999 EPA report (P. E-5), 80% of all anthropogenic Hg loadings are from air pollution. Atmospheric Hg concentrations are relatively homogeneous and generally range between 1.2 and 1.4 ng/m^3 with peaks in the summers of 2000, 2001, 2003, and 2004, and peaks later in 2000 (Figure 4.4.8.1). Brunke and Labuschange (2001) attributed the January 2000 peak to the direct impact of a wild-fire plume on the monitoring site, and suggest that biomass burning is a significant source of atmospheric total gaseous mercury. The other peaks may also relate to biomass burning, but this has not been verified. There is no significant diurnal variation in total gaseous mercury (Baker *et al.*, 2002).

5. Conclusions

A wide range of air quality information has been collected across the country for several years and is currently ongoing. However, there is no coordinated approach at provincial or national level to archive and evaluate air quality data for reporting the status of air quality. The approach that was therefore adopted in compiling this *Technical Compilation to Inform the State of Air Report 2005* was to describe ambient air quality in terms of national standards and to assess trends in air quality where sufficient data were available. The ambient air quality data collected during the *Air Quality Information Review* (DEAT, 2006a) activity, which requested monthly and annual average data for the 10-year period 1994–2003 was utilized (Phase II Transition Project: Output c.1.). The scope was subsequently extended to include 2004 in order to conduct more meaningful statistical analyses of data.

It should be borne in mind when reporting on ambient air quality that it is only possible to report where data are available. Although there is a significant amount of ambient air quality monitoring activity, and this is increasing, it is mostly concentrated in urban and industrial centres. Limited monitoring data in background, township and smaller urban centres makes comprehensive evaluation of ambient air quality impossible. Data coverage in all provinces, other than Gauteng, is inadequate to facilitate effective air quality management. In Gauteng, the additional monitoring planned for Vaal Triangle area will supplement coverage for the southern part of the province.

The available data indicate that there are occurrences of a poor state of air in parts of South Africa, particularly when considering SO_2 and particulates near industrial areas and in townships. Some downward trends in pollutants such as Pb, NO_2 and SO_2 have been detected. The major findings regarding the state of air for each of the pollutants are listed here.

For ozone (O_3):

Surface O_3 is monitored at 44 stations in the country, and two stations monitor total column O_3. Average background concentrations of O_3 range between 12 and 33 ppb, depending on the location of the stations. Ozone concentrations measured at all other sites are typically within the same range as the background stations, or lower, except at the Johannesburg station, Buccleuch. This station is specifically sited to measure traffic influences amongst others and the monthly maximum reaches 271 ppb.

There is no monthly or annual guideline or standard for O_3, but the 8-h limit is 56 ppb. In some cases maximum monthly averages of 40 ppb or more occur. In these cases the 8-h limit could have been exceeded.

The longest uninterrupted O_3 records exist at Cape Point, Kendal, Amersfoort, Elandsfontein, Palmer, Verkykkop, and Makalu. A clear seasonal variation is evident at all stations, with a maximum in spring and a minimum prior to winter. The negative trend of about 1.3%, measured at PE Delta in the Eastern Cape, also has the highest correlation coefficient. A smaller negative trend of 0.36% is measured at the Mpumalanga station of Elandsfontein. The positive trend of 0.3% occurs at the Cape Town stations of Athlone and Goodwood.

Total column O_3 is measured at Irene and Springbok. Total O_3 column thickness is greater at the higher latitude station (Springbok) and both stations exhibit clear seasonal variations with maxima in spring.

For oxides of nitrogen (NO and NO_2):

There are 43 monitoring stations that measure NO_2. Monitoring is performed in four main cities: Cape Town, Durban, Johannesburg (including Alexandra) and Tshwane, and, of these, only 24 stations measure NO. Most of these stations represent urban and industrial pollution.

No exceedances of the monthly AQA standard of 83 ppb for NO_2 occur at any monitoring stations and no exceedances of the annual standard of 52 ppb occur. Background NO_2 concentration are typically less than 1 ppb. The highest maximum concentration occurs at Alexandra (51 ppb) in Johannesburg, while the highest average concentrations occur at Newtown and Buccleuch (29 and 35 ppb, respectively).

NO_2 in Cape Town exhibits a seasonal trend with maxima in winter and minima in summer. A downward trend is evident in annual average NO_2 concentrations at Cape Town stations since 1997. The same seasonal variation is also evident in the NO_2 record elsewhere, but there is little or no trend in annual averages over time.

The only station where NO concentrations exceed standards is Buccleuch. Newtown records relatively high average concentrations. Both stations indicate the high contribution of traffic emissions.

For sulphur dioxide (SO_2):

SO_2 is the most commonly measured pollutant and there are 81 continuous monitoring stations and 8 stations that measure the gas using passive sampling. There are stations in 4 main cities, a few industrial sites and a number of stations on the Mpumalanga Highveld to monitor power station pollution. There are 7 background stations and 7 stations in townships. Despite the relatively large number of SO_2 monitoring stations, there are still areas where monitoring is limited or non-existent. For example, all monitoring in the Western Cape is located only in the City of Cape Town, there is no monitoring in East London, and limited monitoring occurs in the greater Vaal Triangle area. There is no monitoring in the Northern Cape or Limpopo provinces.

Background concentrations of SO_2 are typically less than 2 ppb. SO_2 concentrations in Durban are reported to be the highest. Out of 20 monitoring stations with long-term monthly averages between 3 and 25 ppb, the monthly limit is exceeded at 5 stations (Southern Works, Wentworth, Drift, Ilfacombe, and Umkomaas).

Other stations where exceedances occur are Boiketlong in the Free State and the Club station near Secunda and Columbus at Middelburg.

Marked downward trends were evident at Drift (since 1994), at Southern Works and Wentworth (since 1997) and at Umkomaas (since 1999). The biggest reduction of about 3.1% was measured at the Columbus Station in Mpumalanga, while the biggest upward trend of 0.89% was seen at Langverwacht in Mpumalanga.

For particulate matter (PM):

PM is a critical parameter with regard to the impact on health. The size and composition of particulate matter, and therefore the impact, vary greatly depending on the type of source and distance from the source. Considering the importance of PM (and particularly the finer fraction) to human health, only 32 stations measure PM_{10} (and three stations measure $PM_{2.5}$).

The highest PM_{10} levels were measured at the **industrial** site of PE Delta, in EC (maximum of 232.2 $\mu g/m^3$), but the highest long-term average was measured at another industrial site, Mittal, Gauteng (132 $\mu g/m^3$). It should be noted that not all industrial sites recorded high levels of particulate pollution. A much lower average (43 $\mu g/m^3$) was recorded at Motherwell, located in PE (Eastern Cape).

The **township** of Diepsloot has a maximum monthly concentration almost as high as at PE Delta and an average almost as high as at Mittal. Although there are only 6-monthly averages available for Diepsloot, it shows that it is practically the most polluted site in the country with respect to PM_{10}. Averages recorded at other township sites are lower, but townships in Gauteng and Free State are more polluted than in the Eastern and Western Cape because of the domestic combustion of coal.

The **residential sites, residential affected by industries, and urban sites** have similar levels ranging from 20 to 60 $\mu g/m^3$.

No compliance analysis can be made on the monthly data as the AQA standards for PM_{10} are daily (180 $\mu g/m^3$) and annual (60 $\mu g/m^3$). However, when the maximum monthly average is compared to the daily standards there are 4 stations where this standard is exceeded for at least a whole month or more. If the results compared to the new proposed standard of 75 $\mu g/m^3$ then at least 7 more stations will be non-compliant. **It must be noted that if the new proposed annual standard of 40 $\mu g/m^3$ is accepted then practically all stations will be non-compliant.**

The percent growth indicates a negative trend in PM_{10} levels at three of the 5 stations, although correlation coefficients for the trends are very low. The biggest reduction of about 1.29% was measured at the Columbus station in Mpumalanga.

For lead (Pb):

The highest monthly averages occurred in Johannesburg and Pretoria city centres, with Cape Town and Pietermaritzburg **urban** pollution somewhat lower. Maximum concentrations typically occurred in winter. There were no exceedances of the monthly AQA standard of 2.5 $\mu g/m^3$ for Pb at any of the stations, but at 8 out of 24 stations the annual AQA standard of 0.5 $\mu g/m^3$ was exceeded.

Strong downward trends were evident at all monitoring sites from 1993, and in Johannesburg and Pretoria from 1995. Although some exceedances of lead standards were observed, it is expected that these will decrease further after the enforcement of unleaded petrol use (from 1 January 2006).

For carbon monoxide (CO):

CO is monitored at 16 stations. The highest CO levels were measured at the Buccleuch station, with a maximum of 63 ppm and long-term average of 11 ppm. The 2nd highest level was measured in the **township** station of Alexandra (maximum monthly value of 9 ppm). The 2nd highest long-term average of 3 ppm was recorded in Newtown (**urban** station). Comparison of City Hall stations (**urban**) in Johannesburg and Cape Town shows that levels in Cape Town were slightly higher than in Johannesburg. Very similar CO pollution levels were measured at residential stations in Cape Town and Durban.

The correlation coefficients for the trends are very low and no statistically significant trends were measured.

For greenhouse gases (GHGs):

CO_2, CH_4 and N_2O are monitored at Cape Point. N_2O and CH_4 levels are stable around 300 ppb and 1.7 ppm, respectively, and a small upward trend was detected for both of them. The CO_2 levels increased steadily and reached 380 ppm in 2004. The CH_4 was also monitored in Johannesburg and the values ranged between 2–3 ppm. This monitoring was discontinued.

For volatile organic compounds (VOCs):

Monitoring for volatile organic compounds focused mainly on benzene, toluene, ethylbenzene and xylene (BTEX). Very little data are available since monitoring started only in 2004. The measured levels of benzene in 1 out of 3 stations in Gauteng (Buccleuch), 1 station in Free State (Leitrim), and 5 out of 7 stations in Durban show non-compliance with the proposed standard of 5 $\mu g/m^3$.

For metals (Cr, Mn and Hg):

Very limited data were obtained for Cr, Mn and Hg. The Cr and Mn were measured around relevant industries and Hg at the background site of Cape Point. The Cr^{6+} levels ranged between 0.004 and 0.007 $\mu g/m^3$, the Mn levels ranged between 0.007 and 0.11 $\mu g/m^3$, and neither present significant health risk. The background level of Hg was around 1.5 ng/m^3, with a single peak of 5 ng/m^3. It could have been caused by biomass burning.

For hydrogen sulphide and total reduced sulphur (H_2S and TRS):

H_2S and TRS are regarded mainly as a nuisance and they do not have ambient standards. Monitoring is only conducted in cases when there are complaints. No national or regional network is required.

6. Limitations of this technical compilation

This assessment considers ambient air quality for the period 1993–2004. There are a number of limitations in this assessment.

- Several ambient air quality monitoring initiatives have commenced subsequent to 2004 and are therefore not included in this report.
- It is only possible to report on the state of the air where data are available. Although there is a significant amount of ambient air quality monitoring activity, and this is increasing, it is mostly concentrated in urban and industrial centres. Limited monitoring data in background, township, and smaller urban centres makes comprehensive evaluation of the state of air impossible.
- The lack of a standard approach to data quality assurance and quality control is evident and the authors at times had to make assumptions regarding data. For example, it was assumed that all negative and zero values represented zero concentrations. If this assumption is incorrect it will have an effect on the calculated statistical results. There is a clear need for national norms and standards on data quality assurance, quality control and data validation.

There are limitations related to assessments of compliance with the ambient air quality standards:

- The current South African ambient air quality standards listed in AQA were used for compliance analysis of criteria pollutant, but much stricter standards have been proposed by DEAT. The implications of the new standards on compliance have been demonstrated to a limited degree.
- There is a need to incorporate the permit number of exceedances into proposed standards to allow for more effective reporting.
- The section on compliance analysis used the SO_2 standard accepted in January 2002, as latest data represent the period after changes to the standard. This is considered to be an unfair treatment of historical data.
- In accordance with the initial objectives of the study, the data that were originally requested and collected were monthly averages. Although some organisations provided data at higher frequencies (sometimes at a few minutes' intervals), all the data were converted to, and analyzed using, monthly and annual averages to ensure consistency. This approach could not accommodate comprehensive compliance analysis, as, for many of the criteria pollutants, AQA standards refer to shorter intervals – 10 min, 1-h, 8-h and 24-h. This also means that the exceedances of these standards are not shown in this report and therefore the compliance analysis is less accurate. This limitation was addressed to some extent in the *State of Air Report 2005*, which analyzed data at hourly intervals for selected sites.
- Many datasets had long gaps in the data, which affect the validity of the statistical analysis, particularly compliance analysis.

7. Recommendations

Information in the *Assessment of Ambient Air Quality (1994–2004)* was used in this compilation to inform the *State of Air Report 2005*. Future revisions of the information in this report should, in turn, be used to inform future state of air reporting on a routine basis. It is important to consider the following recommendations in order to facilitate this process.

- The ambient air quality database that has been developed through the *Assessment of Ambient Air Quality (1994–2004)* provides the most comprehensive integrative ambient air quality database to date. This database should be used as input into the National Air Quality Information System (NAQIS). NAQIS should, in turn, be kept current and used in all future state of air reporting.
- The monitoring collected in scientific campaign studies could be centrally stored as a part of NAQIS. Alternatively the links to the sources of the campaigns reports/results could be provided. A comprehensive inventory of the research outputs (theses, research reports, journal papers and conference papers) of all air quality related studies is available in the DEAT's air quality research database (DEAT, 2006b). It is a useful source of information, supplementing air quality data and supporting data interpretation.
- The monitoring network should be extended to enable regional characterization of air quality and identification of potential priority areas. The monitoring outside of major cities and in environmentally sensitive areas should be added. Where old smoke and SO_2 measurements indicated high level of pollution (e.g. Despatch station in the Eastern Cape), the modern equipment should be installed to verify these findings. A cost-effective approach is recommended. Passive sampling and/or biomonitoring should be used for spatial screening of regional pollution and for baseline characterization in small municipalities and less polluted areas. Remote sensing represents an important emerging tool for spatial screening and regional characterization. Finally, emissions inventory and atmospheric dispersion modelling represent critical components of cost-effective, ongoing air quality characterization. These techniques supplement monitoring by facilitating the prediction of spatial variations in air pollutant concentrations. Dispersion modelling also allows the projection of air quality

changes, given new developments or the implementation of planned emission reduction strategies.

- The number of the air quality parameters monitored should also be extended. To quantify the potential impacts described in the *State of Air Report 2005* additional pollutants should be monitored, and more extensive monitoring is recommended for pollutants that are monitored at present at a very limited number of locations. In particular, these should include cancer risk pollutants, such as volatile organic compounds, and specifically benzene, as well as O_3 (potential damage to vegetation). $PM_{2.5}$ may be considered in future reporting initiatives, as this follows the global trend.

- Considering the importance of climate change impacts, the need for quantification of mitigation and adaptation options, and general lack of GHG ambient data for southern Africa, GHG monitoring should also be extended.

- The data collected were not sufficient to access the impact of waste disposal on air pollution.

- There is a need to link the EIA data and Waste Management Information System to the NAQIS.

- A quality control process by the respective data holding agencies is necessary before data is collated into the NAQIS. It is recommended to implement consistent QA and QC procedures and a uniform validation protocol. A further process of data ratification could also be considered.

- There are currently no national norms and standards for collecting ambient air quality data, nor for its storing, sharing, archiving, reporting and distribution. As a result, data were received in many different formats. In future, data should be drawn from the National Air Quality Information System (NAQIS). In order to standardize reporting, it is recommended that the requirements of the reports should be defined by the NAQIS. Concurrent development of the National Framework under AQA will provide a uniform and consistent solution for this and the above issue of quality control. More detailed recommendations on the improvement of the quality of data are provided in section 3.2.4.

This report and its consequent revisions will be an important source of information for decision-making processes related to air quality in South Africa, specifically for air quality management plans currently being initiated or developed by municipalities and provinces.

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APPENDIX A: Summary of available monitoring data

Organization	Station Name	Parameters in questionnaire
City of Johannesburg	Buccleuch	CO, O_3, SO_2
	Delta Park	O_3, PM
	Jabavu	PM_{10}, SO_2
	Orange Farm	PM_{10}, SO_2
	Newtown	CO, NO_2, O_3, PM_{10}
	Northern Works	O_3
	Alexandra	O_3, PM_{10}, CO, Met data, NO_2, SO_2
	City Deep	none
	City Hall	none
	South Hills	none
	Tambo Clinic	none
	Diepsloot	none
City of Tshwane Metropolitan	Rosslyn	CO, Met, O_3, PM, SO_2
	Pretoria West	CO, Met, O_3, PM, SO_2,
	Mamelodi Clinic	NA
Ekurhuleni Metro	All stations	SO_2
City of Cape Town	Athlone	NO_X, SO_2, O_3
	Bellville South	PM_{10}, SO_2, O_3
	City Hall (CBD)	NO_X, SO_2, O_3, CO
	Drill Hall City Centre (CBD)	PM_{10}, O_3
	Goodwood	PM_{10}, NO_X, SO_2, CO, O_3
	Khayelitsha	PM_{10}, NO_X, SO_2, CO, O_3
	Killarney	PM_{10}, NO_X, SO_2, H_2S
	Pinelands	SO_2, O_3
	Tableview	PM_{10}, NO_X, SO_2, H_2S
	Oranjezight/Molteno (CBD)	O_3
	Potsdam	H_2S
	Bothasig	PM_{10}, NO_X, SO_2, H_2S
	Plattekloof	PM_{10}, NO_X, SO_2, H_2S
eThekwini Municipality	City Hall	NO_X, PM_{10}, SO_2
	Ganges	NO_X, PM_{10}, SO_2
	Grosvenor	Met, SO_2
	Harbour	Met
	Jacobs	NO_X, SO_2
	Jacobs Met	Met
	King Edward	NO_X, PM
	Prospecton	SO_2
	Southern Works	Met, NO_X, SO_2, other
	Sapref	Met
	Settlers	SO_2, other
	Warwick	CO, NO_X
	Wentworth	Met, NO_X, O_3, PM_{10}, SO_2
	Alverstone	O_3
	Riverside	none
	Palmfield	none
	Cowies Hill	none
	Civic	none
	Gillitts	none
	Cato Manor	none
	Congella	none
	Brighton Beach Reservoir	none
	South Bluff	none
	Hosley Road	none
	Southern Roof	none
	Merewent	none
	Isipingo	none
	Chatsworth	none
Nelson Mandela Metropolitan	Central (CML)	Smoke, SO_2
	Automotive (Deal Party?)	Smoke, SO_2
	Perseverance	Smoke, SO_2
	Neave Industrial	Smoke, SO_2
	Dora Nginzi	Smoke, SO_2
	Markman Industrial	Smoke, SO_2
	Bluewater Bay	Smoke, SO_2
	Motherwell	Smoke, SO_2
	Despatch	Smoke, SO_2
	Uitenhage Stores	Smoke, SO_2
	Uitenhage Parks	Smoke, SO_2
	PE Delta	NO_X, O_3, PM_{10}, SO_2
Air Pollution Liaison Committee (APOLCOM)	APOLCOM	NO_X, PM_{10}, SO_2

Continued next page

Organization	Station Name	Parameters in questionnaire
Annegarn Environmental	Bank, Goedehoop, Kriel, Kleinkopje, Greenside, Landau, New Vaal, New Denmark, Mafube & Isibonelo	115 dust deposition (PM) monitoring sites at Anglo Coal mines
	Durban Roodepoort Deep	PM for Project Sam
East London Regional Waste	A: Central location on East London Regional Waste Site, Berlin	PM, VOC
	B: On-site location adjacent to highway (Berlin)	PM, VOC
	C: Background site in Nqonqweni residential area (Berlin)	PM, VOC
	D: Background site at Border Technikon entrance (Berlin)	PM, VOC, Met
	E: Background site at Thorn Hill farm (Berlin	PM, VOC
	F: Background site at Lily Stone farm (Berlin	PM, VOC
Msunduzi Air Quality Forum	Publicity House	Met, NO_X, O_3, SO_2
	Mason's Mill	Smoke, SO_2
	Bayer, Willowton	-
Richards Bay Clean Air Association (RBCAA)	Arboretum	SO_2
	Arboretum Extension	SO_2
	Brackenham	SO_2
	Caravan (Civic Centre)	SO_2, PM_{10}
	Scorpio	SO_2
	Esikhawini	SO_2
	Umhlatuze	SO_2
	Wildenweide	SO_2
	Veldenvlei	SO_2
	Hillside	SO_2
C & M Consulting Engineers	Pretoria – station at Beatrix Street	Pb
	Germiston – CBD	Pb
	Johannesburg City Hall	Pb
	Vereeniging – CBD	Pb
	Durban City Hall	Pb
	Pietermaritzburg City Hall	Pb
	Port Elizabeth – CBD	Pb
	Cape Town City Hall	Pb
	Sandton – CBD	Pb

Organization	Station Name	Parameters in questionnaire
Kiepersol Joint Venture	Amersfoort	Acid rain
	Louis Trichardt	Acid rain
	Cathedral Peak	Acid rain
	CSIR Pretoria	Acid rain
	Kliprivier	Acid rain
	Blyde	Acid rain
	Vryheid	Acid rain
	Warden	Acid rain
	Bloemfontein	Acid rain
	Hoedspruit	Acid rain
	Lichtenberg	Acid rain
North-West University (DEBITS pgm)	Cape Point	NO_X, O_3, SO_2, other
	Louis Trichardt	NO_X, O_3, SO_2, other
	Amersfoort	NO_X, O_3, SO_2, other
	Skukuza	NO_X, O_3, SO_2, other
	Namibia	NO_X, O_3, SO_2, other
SourAWS	Baseline Surface Radiation Network site, De Aar	Met, other
	Irene	Met, O_3
	Springbok Weather Office	Met, O_3
	Cape Point GAW Station (CPT)	Met, NO_X, O_3, VOC, other
AEL for Airkem	Esther Park	Met, PM, SO_2
Chrome International	Karbochem Effluent Plant	PM, Cr, Cr (VI)
	Keyway Motors Filling station	PM, Cr, Cr (VI)
	Arbor Park School	PM, Cr, Cr (VI)
	Newcastle Airport at Newcastle airport	PM, Cr, Cr (VI)
Columbus Stainless Steel	Columbus, Hendrina Road	PM, SO_2
EL IDZ Corporation	Siyakha Air Quality station	PM, PM_{10}, SO_2, VOC
Eskom	Bergsig School	PM_{10}, SO_2
	Bedworth Park	NO_X, O_3, SO_2
	Elandsfontein	NO_X, O_3, SO_2
	Kendal 3	SO_2
	Kendal 1	SO_2
	Kendal 2	NO_X, O_3, SO_2
	Leandra	SO_2
	Majuba 1	SO_2
	Majuba 2	SO_2
	Majuba 3	SO_2
	Makalu	NO_X, O_3, SO_2
	Palmer	NO_X, O_3, SO_2
	Verkykkop	NO_X, O_3, SO_2

Continued next page

Organization	Station Name	Parameters in questionnaire
Mittal Steel	Siza Centre, Newcastle	NO_X, PM_{10}
	Deep Throat (Mittal Steel Saldanha)	Met, PM_{10}, SO_2, H_2S
	620 site, Delfos blvd, VdBPark	CO, Met, NO_X, O_3, SO_2, VOC, H_2S
	350 site, Delfos blvd, VdBPark	CO, Met, NO_X, O_3, SO_2, VOC, H_2S
	Mobile Caravan station, Delfos blvd, VdBPark	CO, Met, NO_X, O_3, SO_2, VOC, H_2S
Mondi Packaging	MPSA Felixton mill	SO_2, other
	Mondi Packaging Piet Retief Mill	PM
Natref	Sasolburg Municipal Works	other
Palabora Mining Company	Station 2	NO_X, O_3, PM, SO_2
PetroSA	Refinery Site VoorBay Tankfarm	NO_X, O_3, PM, SO_2, VOCs, Mn, Pb
	Logistics Base Assembly Point	NO_X, O_3, PM, SO_2, VOCs, Mn, Pb
	Total Tanks	NO_X, O_3, PM, SO_2, VOCs, Mn, Pb
	Engen Tanks Residential Areas	NO_X, O_3, PM, SO_2
Sappi Saiccor	Drift	SO_2
	Ilfracombe	SO_2
	Umkomaas	SO_2
	TLC	SO_2
	Dlambula School	SO_2
	Naidooville School	SO_2
	Magabheni LC	SO_2
	Saiccor Village	SO_2
Sasol Synfuels	Amersfoort	Met, O_3, other
	Bosjesspruit	Met, SO_2, other
	Grootvlei	Met, other
	Langverwacht	CO, Met, NO_X, O_3, PM_{10}, SO_2, VOCs, other
	Rosebank	Met, other
	Club	CO, Met, NO_X, O_3, PM, SO_2, VOCs, other
	Springs Girls' High School	Met, other
Coega Development Corporation	Motherwell	SO_2, NO_X, PM
	Amsterdam Plein	SO_2, NO_X, PM
	Coega Salt Works	SO_2, NO_X, PM
Eskom (for AngloPlats)	Waterval	SO_2, Met, PM
	Brakspruit	Met, PM
	Hexrivier	SO_2
	Paardekraal	SO_2
Dow Chemicals		NA

APPENDIX B: Full list of contacts & contributors to the *State of Air Report*

Agency/organization	City/town	Tel no.	E-mail	AQ contact person
Nelson Mandela Metropolitan Municipality	Port Elizabeth	041 506 5210/5400; 083 393 5423	kslabbert@mandelametro.gov.za	Kobus Slabbert
City of Johannesburg Metropolitan Municipality	Johannesburg	011 407 6727/6445*	gideons@joburg.org.za	Gideon Slabbert*
Ekurhuleni Metropolitan Municipality	Ekurhuleni	011 255 4852/4848; 083 305 1488	flipv@ekurhuleni.com	Flip Visser
City of Tshwane Metropolitan Municipality	Pretoria	012 358 3759	JuanM@tshwane.gov.za	Juan Mostert
Pietermaritzburg Metropol	Pietermaritzburg	083 387 2507	andrews@mweb.co.za	Andrew Simpson
Ethekwini Department of Health	Durban	031 3113690	chettysiva@durban.gov.za	Siva Chetty
City of Cape Town	Cape Town	021 684 1012/4	grant.ravenscroft@capetown.gov.za	Grant Ravenscroft, Hans Linde
Coega Development Corporation	Port Elizabeth	041 507 9111	fezile.ndema@coega.co.za	Fezile Ndema
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C&M Engineering - Pb	Pretoria	012 803 5124		Riaan Kruger
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Eskom Acid rain				Gerhardt de Beer
Parabola Mining Company	Palaborwa	015 780 2281	gabe.vandenberg@palabora.co.za	Gabe van den Berg
Anglo Platinum (Amplats)	Rustenburg	014 5914262; 083 455 2783	sbullock@angloplat.com; jmalan@amplats.co.za	Jacobus Malan
Iscor - Mittal Steel, Vanderbijlpark	Vanderbijlpark+E67	016 889 4597/3126	Patrick.vandenbon@mittalsteel.com; Johan.Hattingh@mittalsteel.com	Johan Hattingh, Patrick vd Bonn
Sappi Saiccor		039 973 8153	derek.airey@sappi.com	Derek Airey
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Lonmin Platinum	Rustenburg	014 5713215; 084 555 7589	trusha.fakir@lonplats.com	Trusha Fakir
Saldanha Steel (Mittal Steel)	Saldanha	083 3007903	siegfried.spanig@iscor.com	Siggie Spanig
Impala Platinum	Rustenburg	014 569 7075/0000	suan.mulder@implats.co.za	Suan Mulder
Columbus Stainless Steel/Billiton, Middelburg	Middelburg	013 247 9111/2417; 247 3413	peter.scurr@bhpbilliton.com	Heather Booysen, Pieter Scurr
Anglo Coal/New Vaal Colliery	Three Rivers	016 450 7291	ncrawshaw@coal.anglo.co.za	Mark Aken
Petro SA	Mossel Bay	044 601 2748	eileen.green@petrosa.co.za	Eileen Green
Chrome International, Newcastle	Newcastle	034 370 1641	jacque.hunlun@lanxess.com	Jacque Hunlun
Mittal Steel, Newcastle	Newcastle	034 314 7911/8839	sipho.mntambo@mittalsteel.com	Sipho Mntambo; Thokozani Mdluli
MetAlloys, Meyerton Division	Meyerton	016 360 2308	jaco.vanwyk@bhpbilliton.com	Jaco Van Wyk

APPENDIX C: Locations of some monitoring sites in the North West province measuring only fallout dust

Area	Station description	Type
City Council of Klerksdorp	Hostel Karee	RI
Local Municipality of Madibeng	#5 Return water pumpstation	I
Local Municipality of Madibeng	#6 Return pumpstation	I
Local Municipality of Madibeng	1 East liftshaft	I
Local Municipality of Madibeng	2 Shaft crusher	I
Local Municipality of Madibeng	3 Shaft	I
Local Municipality of Madibeng	B3 Inclined Shaft	I
Local Municipality of Madibeng	EPL office TEOM	I
Local Municipality of Madibeng	Erasmus farm	RI
Local Municipality of Madibeng	ESKOM Substation	I
Local Municipality of Madibeng	Explosive South	I
Local Municipality of Madibeng	Hossey Shaft	I
Local Municipality of Madibeng	Itireleng Farm	T
Local Municipality of Madibeng	Liftshaft tailings east	I
Local Municipality of Madibeng	Liftshaft tailings north	I
Local Municipality of Madibeng	Liftshaft tailings south	I
Local Municipality of Madibeng	Lonmin Main offices	I
Local Municipality of Madibeng	Machadam Combined School	T
Local Municipality of Madibeng	Middlekraal Hostel	RI
Local Municipality of Madibeng	Mr C Theledi	RI
Local Municipality of Madibeng	Professional services	I
Local Municipality of Madibeng	Railway crossing bridge S1	RI
Local Municipality of Madibeng	Rowland Shaft #4 Sump	I
Local Municipality of Madibeng	Roy Qibi	RI
Local Municipality of Madibeng	Smelter Sewage Works	I
Local Municipality of Madibeng	Tailing 5 North S22	I
Local Municipality of Madibeng	Tailing 5 South West	I
Local Municipality of Madibeng	Tailing 5 WBH5	I
Local Municipality of Madibeng	Tailing South West	I
Local Municipality of Madibeng	Tailings #6 South east	I
Local Municipality of Madibeng	Tailings 5 South East	I
Local Municipality of Madibeng	Tailings North West S2	I
Local Municipality of Madibeng	Thabamurudi Village	RI
Local Municipality of Madibeng	Visvang Plek	I
Local Municipality of Madibeng	Weighbridge Concentration	I
Local Municipality of Madibeng	Wonderkop Village	RI
Local Municipality of Madibeng	Wonderkop Workshop	RI
Rustenburg Local Municipality	1 Shaft west fans	I
Rustenburg Local Municipality	4 Inclined Shaft	I
Rustenburg Local Municipality	De Beer farm	I
Rustenburg Local Municipality	K3 Karee Offices	I
Rustenburg Local Municipality	K4 Concentrator	I
Rustenburg Local Municipality	Koppie south of 2 Shaft	I
Rustenburg Local Municipality	Marikana Kukame	RI
Rustenburg Local Municipality	Peters Farm	RI
Rustenburg Local Municipality	Shaft 3 TEOM	I
Rustenburg Local Municipality	Sonnenblom Park	RI
Rustenburg Local Municipality	U1 Opencast	I





State of Air Report 2005
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Published by
Department of Environmental Affairs
Private Bag X447
Pretoria, 0001
South Africa

ISBN 978-0-621-38726-7

Published in 2009