# AN AIR QUALITY MANAGEMENT STRATEGY FOR THE VAAL TRIANGLE PART II

H J ANNEGARN and Y SCORGIE

SCHONLAND RESEARCH CENTRE
UNIVERSITY OF THE WITWATERSRAND
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FINAL REPORT ON THE VAAL TRIANGLE INTERVENTION PROJECT
DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM

PROJECT LEADERS
A P TERBLANCHE, ENVIRONMENTEK, CSIR
H J ANNEGARN, SRCNS, UNIVERSITY OF THE WITWATERSRAND

## INTRODUCTION

The purpose of this investigation was to develop intervention strategies applicable to improving poor air quality over the Vaal Triangle region. The recognition of the need for such an intervention strategy arose out the Vaal Air Pollution Health Study (VAPS). The air quality problem in the Vaal Triangle and the resultant adverse impacts on human health have been widely documented arising from the VAPS and other studies [VA95, TE94, MU92].

The starting point for the investigation was to examine the policies, legislation and implementation of air quality control in countries that could serve as a role model for South Africa. In Part I of this report (AN97) we reviewed urban air management stratefgies in the European Union, the United Kingdom and the United States of America. The review section concluded with an evaluation of air pollution control and legislation in South Africa.

This contribution constitutes Part II of the report, in which we develop a proposed air quality management strategy for the Vaal Triangle. Although this report was completed before the finalisation of the White Paper on Environemntal Management Policy for South Africa (GO97), it is still directly relevant. The White Paper sets the policy. This paper proposes a way of implementing air quality management systems under this policy, and under the broad environmental rights of the new Constitution.

We start off by describing the physical and air pollution characteristics of the Vaal Triangle region. From a synthesis of ideas from the international review in Part I (AN97), we propose the formation of a Metropolitan Air Quality Authority, a council of elected representatives, industry and community groups. The area of jurisdiction would span the entire Vaal Triangle region. The structure and functions of the MAQA are explored in detail.

Existing baseline studies in the Vaal Triangle are discussed. Actual implementation strategies from the US State Implementation Plan (SIP) documents are analysed as a basis for a Particulate Matter SIP for the Vaal Triangle. Administrative issues and community involvement issues relating to the proposed SIP are discussed in the concluding section.

The ideas in this document have been developed over a period of time, and presented to several different audiences of municipal and central government regulators. While there has by no means been universal acceptance of the proposed regulatory model, we are convinced that the approach presented here for urban air quality management is basically sound, appropriate for South Africa now. Either these proposals, or something essentially similar, will in due course be adopted as official policy within the Environmental Management Policy framework (GO97).

## AIR QUALITY IN THE VAAL TRIANGLE REGION

### PHYSICAL CHARACTERISTICS

Located sixty kilometers to the southwest of Johannesburg, the Vaal Triangle is a highly industrialised and densely populated region. The region encompasses an area of approximately 2,500 km2, and is characterised by fairly uniform terrain, situated at elevations of between 1,425 and 1,500 m above mean sea level. Vereeniging, Vanderbijlpark, Sasolburg and Meyerton are the main commercial centers in the region. The majority of the population is, however, accommodated in the townships of Lekoa, Evaton and Sharpeville. Other residential townships include Boipatong, Bophelong, Orange Farm, Sebokeng, and Zamdela. The area surrounding these townships is of a semi-rural nature and extensively used for low level pastoral farming [VA95, MU92].

Industrial activities in the region include iron and steel industries, an oil refinery, under ground and open cast coal mines, coal fired power plants, various other large metallurgical and chemical plants, and numerous small industries.

### GENERAL CLIMATIC CONDITIONS AND WIND CHARACTERISTICS

An understanding of the potential of the atmosphere to disperse pollutants is essential to the development of effective control strategies for the Vaal Triangle. Changes in pollution levels occur not only as a result of variations in the extent of source emissions. The dynamics of the atmosphere is largely responsible for temporal and spatial trends in pollution concentration levels.

Located on the Highveld, the synoptic scale circulation of the Vaal Triangle is dominated by anticyclonic subsidence. Such subsidence results in the occurrence of elevated inversions, and consequently limited mixing depths and poor atmospheric dispersion potentials. Dispersion potentials are particularly poor in winter months during which subsidence inversions have a high frequency of occurrence (80%) [MU92].

The large scale surface airflows over the region are determined primarily by the prevailing high pressure circulation. During summer, northerly to northwesterly winds are prevalent. During winter, westerly to southwesterly winds prevail. The occurrence of low wind speeds during winter months, limits the potential for the horizontal transport of pollutants [MU92]. During August to October, episodic high winds occur, often associated with frontal disturbances. These events may be associated with dust storms from the arid regions to the south, plowed agricultural land and localised dust clouds from mining and industrial waste dumps.

In addition to the synoptic circulation, the dispersion potential of pollutants is further limited by meso-scale meteorological phenomenon. The frequent occurrence of radiation inversions, particularly during the winter, results in extremely stable nocturnal conditions within the first 250 meters of the atmosphere [MU92]. These ground based inversions substantially reduce the mixing depth; low-level pollution emissions accumulate within the boundary layer and ground level pollution concentrations are increased.

The dynamics of the atmosphere emphasizes the importance of taking episodic peaks in pollution concentrations into account in the development of control strategies. Domestic coal combustion is, for example, estimated to have contributed only 2% of the total TSP emissions in the Vaal Triangle in 1992. Despite low annual emissions (relative to industrial emissions in the region), episodic peaks in ambient pollution concentrations which occur as a result of domestic coal burning represent a substantial threat to human health and welfare. Such peaks occur frequently in winter, when poor atmospheric dispersion potentials coincide with maximum coal burning activity. Should control strategies be based exclusively on annual average contributions of sources, the need to control domestic coal during emissions might be overlooked. Strategies aimed at controlling domestic coal burning emissions would substantially reduce exposure levels, despite contributing only marginally to reductions total coal fuel use or in annual average concentrations.

An assessment of atmospheric dynamics may further aid air quality management strategies by facilitating the identification of background pollutants. The Vaal Triangle lies within the Vaal River basin, and forms a shallow depression for the possible accumulation of pollutants. Vereeniging and Vanderbijlpark lie downstream along the Klipriver Valley from the Witwatersrand. During stable nocturnal conditions, katabatic flow occurs along the Klipriver Valley, carrying the Witwatersrand urban plume into the Vaal Triangle region [MU92]. Atmospheric pollutants emitted from domestic coal burning in Soweto and from industrial emissions in Klipriver and Meyerton similarly drift southwards with the dominant wind direction along the Klipriver valley and into the Vaal Triangle [MU92]. Air quality management in the Vaal Triangle may thus include negotiation with air pollution control authorities in adjacent regions should background emissions be found to contribute significantly to elevated pollution concentrations.

**EXISTING AIR QUALITY IN THE VAAL TRIANGLE**

The Vaal Triangle Air Pollution Health Study (VAPS) was initiated in 1990 in response to widespread concerns regarding the potential impacts of air pollution on the human health in the Vaal Triangle. The study involved an assessment of the extent of indoor, outdoor, and personal exposure to air pollutants and the determination of the resultant health effects.

Following four years of intensive data collection, several conclusions were reached:

Air pollution in the Vaal Triangle, specifically particulate matter, exceeds health standards up to 2.5 times on an average annual basis.

- Children residing in the Vaal Triangle have significantly higher risks of developing respiratory tract symptoms and illnesses compared with children living in less polluted control areas.
- Domestic coal burning is the single most significant risk factor for respiratory tract illness in black children.
- Domestic coal burning is the major contributor to ground level concentrations of particulate matter.
- The health of approximately 2 million people is at risk as a result of air pollution in the Vaal Triangle.
- The situation in the Vaal Triangle is likely to be similar in other areas where coal is utilized as the household energy source.

Recommendations made by the VAPS Steering Committee were:

- A holistic approach to air quality management for the region need be adopted.
- Intervention strategies should be developed, tested and evaluated as a matter of urgency.
- Sufficient resources should be allocated to intervention and on-going monitoring to manage the risk identified.

The conclusions and recommendations of VAPS form the basis of the current desktop study. The challenge in undertaking the study is to identify an intervention strategy for the Vaal Triangle which is not only technically feasible, but also economically feasible and socially acceptable. For despite widespread acknowledgment of the need for intervention, there are few ideas and little agreement on how to proceed without threatening jobs, wealth creation and economic development.

## SOURCES OF AIR POLLUTION IN THE VAAL TRIANGLE

Particulate matter is regarded as the pollutant of greatest concern in the region [VA95, TE94, MU92, EN95]. In light of this a source inventory of particulate air pollution for the Vaal Triangle for the year 1992 was compiled [VA95]. All sources of airborne particulate matter in the region were identified, and their emissions quantified. The main sources of particulates were found to be:

- fugitive dust from paved and unpaved roads;
- fugitive wind blown dust from ash dumps, material stock piles and agricultural activities;
- area sources, including domestic coal combustion and veld fires;
- industrial stack emissions; and
- surface mining.

A receptor based source apportionment study has recently been undertaken by Mintek [EN95]. This study incorporated ambient particulate sampling in three of the commercial centers of the Vaal Triangle (Vereeniging, Vanderbijlpark and Sasolburg). Receptor modelling based on a chemical analysis of the samples revealed that soil dust, domestic coal combustion, secondary ammonium sulphate, iron arc furnaces and power station fly ash were the major sources. Sinter plant emissions, secondary ammonium nitrate, coking furnaces, petrol vehicle and ferro-managanese arc furnace emissions were responsible for smaller contributions.

## COMMITTEES AND PROGRAMS CONCERNED WITH AIR QUALITY OF THE VAAL TRIANGLE

### *AIR POLLUTION PREVENTION ACTION COMMITTEE*

The Vaal Triangle Air Pollution Action Committee (APAC) was created on the initiative of Chief Air Pollution Control Officer (CAPCO), as an open forum at which industrial air pollution issues of the Vaal Triangle could be shared and aired. Scheduled industries are required by CAPCO to attend and report the four-monthly meetings. Other participants are invited representatives from local authorities, the National Association for Clean Air (NACA), and research organisations including the Environmentek, CSIR and the Schonland Research Centre for Nuclear Sciences (SRCNS), University of the Witwatersrand. Although media representatives and the public are also invited, participation by this sector has been infrequent. While APPAC has provided a forum to receive reports on air quality research projects, the emphasis has been and continues to be on the air emissions (problems and associated complaints) of individual industries.

### *STEERING COMMITTEE OF THE VAPS PROJECT*

Management of the Vaal Air Pollution Study health study was supervised by a Steering Committee, which brought together a broad based representation of national and local air pollution regulators, senior industrial representatives, community representatives and researchers. The Steering Committee provided an effective forum for planning, financing, reporting and coordinating air quality issues on a regional basis in the Vaal Triangle. The Steering Committee was disbanded on completion of the VAPS project in 1994.

### *NATIONAL ASSOCIATION FOR CLEAN AIR, VAAL TRIANGLE BRANCH*

NACA is an NGO focused on air quality issues. Membership comprises individuals, corporate and local authority members. The strength of the organisation lies in providing a platform for presentation of technical and policy discussions relating to air pollution, at local seminars and annual conferences. On a rotational basis, the NACA Annual Conference is held in the Vaal Triangle every fourth year. NACA has also been responsible for arranging visits on a regular basis by air quality experts from abroad to address specific problem areas in the region. Membership in the region consists mainly of company members, predominantly the larger smoke stack industries, local authority members, and individual members who join as a result of their job positions as environmental officers in the larger companies.

### *BLUE SKIES OVER THE VAAL BY THE YEAR 2000*

This project was initiated by the Vaal Triangle Branch of the National Association for Clean Air in 1992, to create a holistic framework for improving the air quality of the Vaal Triangle region. The promotion of public participation and communication represented one of the main aims of the campaign. The campaign did not receive initial enthusiastic support from key industries, and NACA allowed the initiative to languish.

### *CITIZEN ENVIRONMENTAL GROUPS AND FORUMS*

Air quality issues have been raised in citizen forums and reports of the existence of Environmental discussion groups have been received on occasion. There are individual members of environmental groups such as Earth Life Africa and Group for Environmental Monitoring (GEM) resident in the region. Participation of these groups has not led to a sustained involvement in air quality issues.

In summary, despite the wide spread awareness of poor air quality, and the now proven adverse health effects, it has not proved possible to create a sustainable public interest in bodies or campaigns to improve the situation in the Vaal Triangle.

## A NEW AIR QUALITY MANAGEMENT STRATEGY FOR THE VAAL TRIANGLE

### INTRODUCTION

Two common features have emerged from the review of international trends in air quality management (Part I ). Firstly has been a shift from source based control approach to an effects-based air quality management approach. Secondly, there has been a shift from centralised national control, to decentralised management by local government. The management of urban air quality by local government under a uniform set of national air quality standards has been practiced in the USA for almost two decades, and has recently been introduced in the United Kingdom [SC93, AI95b]. The experience of such countries provides valuable models for South African atmospheric environmental management.

The new Constitution has devolved environmental control to the provincial level. Principals of transparency, public participation in environmental decision making, local empowerment are promoted as desirable values. In this section we propose a system of urban air quality management for the Vaal Triangle, based on an effects-based, metropolitan-centered approach, which is consistent with the principles enshrined in the new constitution. The proposed system is founded on the European and proven US systems. Argument is presented on why metropolitan, rather than provincial level management is preferable. The development of a functional structure for air quality management in the Vaal Triangle necessitates an assessment of the most effective levels at which plans may be made, and at which actions may be undertaken [MA95]. Suggestions are offered on the composition and functions of a to be created controlling structure, and existing environmental health departments.

**METROPOLITAN AIR QUALITY AUTHORITY (MAQA)**

On the basis of the examination of international trends (Section 2), it is recommended that air quality management in the Vaal Triangle be administered by a Metropolitan Air Quality Authority (MAQA).

*PURPOSE*

The Metropolitan Air Quality Authority would be responsible for preparation, coordination and implementation of an Air Quality Strategy Implementation Plan (SIP) for the Vaal Triangle. This plan will show how the region will comply with national standards. In the development of the plan, the MAQA is primarily responsible for identifying, analysing and recommending control measures to include in the plan. This is to be accomplished by working with implementing organisations, including provincial legislatures and local government, to obtain commitment to implement and enforce the control measures. MAQA staff would assist the Provincial Environment Departments with portions of the technical analysis and provide review of the technical results and reports.

*AREA OF JURISDICTION*

The area of jurisdiction of the Vaal MAQA would comprise the physical area that comprises what is commonly understood by the Vaal Triangle. This area spans sections of two provinces (Gauteng and Free State) and multiple metropolitan authorities. The proposed area includes the residential, business and industrial suburbs/towns that traditionally have formed part of the Vaal Triangle region: Boipatong, Bophelong, Evaton, Lekoa, Meyerton, Orange Farm, Randvaal, Sebokeng, Sasolburg, Sharpeville, Vaalpark, Vanderbijlpark, Vereeniging and Zamdela.

The MAQA would of necessity be a coordinating governmental body, with representatives from the government structures lying within the air basin, and with authority derived by delegation from the appropriate provincial and metropolitan structures.

*COMPOSITION*

The Metropolitan Air Quality Authority would be composed of:

- elected officials from local government;
- business and community leaders;
- clean air advocates and public interest groups
- the professional officer (project leader) from one of the environmental health departments, employed to develop and execute the programmes approved by the MAQA;
- representatives of the metropolitan transportation and land use planning agencies.

In view of the primacy given to the Provincial Governments in environmental affairs under the 1996 Constitution, local government representation should be taken to include, in all further discussion, both provincial and local representation, as appropriate.

*TECHNICAL IMPLEMENTATION*

The air pollution control divisions within the local government environmental health departments would have responsibility for developing, administering and enforcing air quality control programmes adopted by the MAQA, including Strategy Implementation Plans. In addition to implementing programmes these departments would collect and analyse data and conduct research.

These departments would be primarily responsible for performing the technical analysis that serves as the basis of strategy development and demonstration of attainment of compliance with national standards. The Departments may also assist the MAQA with identifying and analysing effectiveness of control measures. The departments reviews MAQA recommended measures and provides oversight of the SIP development process.

To perform these technical functions, local government departments will require full time professional staff. Based on the precedent of the United States experience, such staff would be employed by and housed in the environmental health department of one of the participating metropolitan councils (or provinces). (It is not envisaged that MAQA would become an employer in its own right.) Where such functions could not be performed by council staff, consultants would have to be contracted.

For the Vaal region, it is suggested that the following staff complement might be appropriate to carry out the tasks: one or two graduate professionals, a data manager, an administrative assistant and other technical staff (x3). Specific tasks of these staff would include preparation of emission inventories, ambient air quality monitoring and exposure assessment; air quality modeling; receipt and evaluation of industry environmental reports relating to emission permits; analysis of air quality data; and provision of technical assistance and advice.

Due to the potential absence at both local and regional levels of the technical, administrative and management capabilities needed for the implementation of the air quality strategies proposed, it is suggested that capacity building be undertaken to create the abilities needed.

## FUNCTIONS OF THE METROPOLITAN AIR QUALITY AUTHORITY

### *DEVELOPMENT OF A STRATEGY IMPLEMENTATION PLAN*

A Strategy Implementation Plan (SIP) is needed to show how a region will come into compliance with ambient air quality standards. (The modification of the US State Implementation Plan title is intentional.) The development of such a plan involves the formulation of regulatory policies which achieve the greatest improvements in the levels of a pollutant, at the lowest cost and over the shortest time period. The establishment and maintenance of an emission inventory for the region, ambient monitoring, receptor and dispersion modelling and exposure assessment form the basis and integral part for the development and evaluation of air pollution reduction strategies. The final strategy implementation plan may include various control measures, programs and regulations that provide for necessary emission reductions.

A recommended structure for the Strategy Implementation Plan is adapted from the EPA PM10 SIP Development Guide [PM87]:

1. Identification of pollutants to be controlled
2. Identification of all sources of each pollutant - and for each source determine:
   - 2.1. quantity of emissions (including temporal patterns in extent of emissions)
   - 2.2. percentage contribution to total emissions of a pollutant
   - 2.3. the height of emission - e.g. ground, medium elevated or high elevated source
   - 2.4. likelihood of human exposure to emissions (exposure index) - e.g. emissions near population concentrations
3. Identification of air pollution reduction strategies
   - 3.1. list and description of possible strategies for each source
   - 3.2. explanation of implementation of each measure
   - 3.3. quantification of ambient concentration reductions from implementation of each strategy by use of dispersion model analysis
   - 3.4. Cost-benefit analysis of controlling each source with each strategy. Cost-benefit analyses should include the consideration of:
     - source characteristics (i.e. percent contribution, height of emission, and exposure index) - to select the sources to be controlled
     - reduction of ambient concentrations as a result of implementation of each strategy - identify most effective strategies for ambient pollution abatement
     - technical feasibility of each strategy
     - socio-economic impacts of each strategy - determine the feasibility of strategies within the socio-economic context
4. Following final evaluation of strategies, recommend the most cost-effective strategies which may be adopted to minimise emissions.
5. Demonstrate how and when standards may be attained should the recommended strategies be undertaken, through the use of dispersion model analysis.
6. Indicate the effect of future emissions from growth and development (industry, transport, population growth) on ambient air quality and demonstrate how compliance will be maintained.
7. Contingency measures may have to be included in the strategy implementation plan. These measures need only be implemented should the recommended control strategies not be successful in achieving and maintaining compliance within a required time period.
8. The plan may also include a comprehensive long-range air quality management plan.

Several of these functions are discussed in greater detail below.

Public participation plays a crucial role in the development of a Strategy Implementation Plan. Public hearings should be held to discuss proposed strategies. Following the process of public input and debate the strategy implementation plan may be revised and finalised. In the United States the public is given a sixty day response period for proposals. Government agencies are given prescribed time limits thereafter to incorporate changes and promulgate the revised plan.

Should new sources be planned or modifications to existing industries be proposed, the strategy implementation plan must be revised. The revision should include a new source review permit program to govern the construction and operation of new and modified major stationary sources. New source review procedures should include prescribed, legally enforceable, times for each step of the process, to ensure that industry is not prejudiced through indefinite delays.

### *ESTABLISHMENT OF AN EMISSION INVENTORY*

An emission inventory is a comprehensive, accurate and current account of air pollutant emissions and associated data from specific sources over a specific time period. An emission inventory is a key element in programs aimed at improving and maintaining air quality for several reasons:

- An inventory helps define problems in terms of which pollutants should be considered, which sources are important, and what control measures might be most effective. Appropriate air pollution reduction strategies may thus be selected.
- In addition to containing information on present emission levels from the various source categories, an emission inventory should ideally indicate future levels of emissions in the absence of any intervention strategies. The effectiveness of various intervention strategies may then be evaluated.
- Emission inventories are prerequisites for either dispersion of receptor modelling.
- An emission inventory provides the basis for the planning of ambient monitoring networks.

Two main sets of factors are needed to establish an emission inventory:

- a set of emission factors (e.g. grams of SO2 per kg of coal combusted) for each source category;
- source extent data.

The most commonly used source of emission factors in the US EPA document AP-42: Compilation of Air Pollutant Emission Factors. Industrial source data consist of stack and exhaust flow parameters, production levels, throughputs, control device efficiencies, as well as information on source location and plant layouts. In addition to industrial source data, transportation, demographic and land use planning data are needed for the establishment of the inventory. Information on the location and intensity of future activity will also need to be collected from planning departments.

Technical guidance documents caution that local emission factors should be used wherever feasible. For example, use of vehicle emission factors from the US or the EU in the estimation of vehicle emissions is inappropriate due to the combined differences in local engine design and fuel formulation, which result in substantially different emission factors. The Department of Minerals and Energy is currently involved in the measurement of emission factors for South African manufactured vehicles using local fuels [AN95].

The preparation of the first disaggregate emission inventory would require two to three person-years of effort and associated support costs. Once established, the inventory would form a key element in the maintenance and control of the air quality plan, and would need to be updated annually to keep it comprehensive, accurate and current. One full time professional officer and one administrative assistant would be required.

Emission inventories should ideally be established and maintained at a local (MAQA) level and coordinated at a regional (provincial) level.

The highest priority is to update and complete the particulate matter source inventory compiled for the Vaal Triangle for the 1992 year [VA95]. This inventory omitted wind-generated fugitive sources (due to resource constraints), and data from certain large industries was not supplied in the requested format and detail. The particulate matter inventory would have to be merged with the national SO2 emission inventory, and then extended to other criteria pollutants (e.g. VOCs).

*DISPERSION MODELLING*

Current and historical air quality may be determined from monitoring data. Planning for future air quality requires predictive tools, to relate anticipated changes in activity indicators to ambient conditions. Air dispersion models, using emission inventories as inputs, provide such tools. EPA guidance for development of State Implementation Plans requires use of dispersion and receptor models, either in combination; use of dispersion models alone; or use of two receptor models, with control strategy developed using a proportional model. The use of receptor and dispersion models in combination is the preferred method.

Dispersion models calculate ambient air concentrations as functions of source configurations, emission strengths, terrain features, and meteorological characteristics. Such models thus provide useful tools to ascertain the spatial and temporal patterns in ambient concentrations arising from the emissions of various sources.

As dispersion models are predictive, they may be used to determine the impact of potential strategies aimed at reducing emissions, on ambient concentrations. The effectiveness of various strategies may be evaluated prior to their implementation, so facilitating the process of cost-benefit analysis. It is also possible for a region to demonstrate attainment of ambient air quality standards subsequent to proposed intervention through dispersion modelling.

There are numerous types of dispersion models, including the Industrial Source Complex model (ISC), RAM, the Fugitive Dust Model (FDM), the Urban Airshed Model, the Hot Spot Model, Climatological Dispersion Model (CDM), Multiple Point Source Model with Terrain Adjustment (MPTER) and Single Source (CRSTER) Model. Extensive use is currently being made in South Africa of the US EPA's FDM and ISC models, which are appropriate to urban scale dispersion. Modeling of photochemical smog requires use of complex multi-dimensional urban grid models, incorporating chemical reactions (Urban Air Shed Model - UAM). The UAM has not yet been applied in South Africa.

Dispersion models are generally more reliable for estimating longer time-averaged concentrations (e.g. annual averages) than for estimating shorter-term concentrations (e.g. 24-hour) at specific locations.

A weakness of dispersion models for computing ambient particulate concentrations is that such models are currently unable to analyze the impact of gaseous precursor emissions on the formation of secondary particles. Receptor models are therefore frequently used to determine the total secondary particulate contribution, which is then apportioned among source categories by a proportion consistent with the inventory of nitrogen oxides and sulphur dioxide emissions.

Dispersion modelling may be done in house by the metropolitan authority or private consultants may be contracted. Various environmental consultants and agencies in South Africa currently have technical knowledge of dispersion modelling methodology and software.

Dispersion modeling would constitute an essential part of the Vaal Triangle air quality management plan.

*RECEPTOR MODELLING*

Receptor models infer the relative impact of various sources on ambient air quality by reconciling particle size, shape and chemical composition data of ambient air samples with particle size, shape and chemical composition data for various emission sources in the vicinity of the ambient air measurement site. Receptor models are essentially historical, giving the source contributions to ambient concentrations which occurred in the atmosphere. In this sense they are complementary to dispersion models, which are essentially predictive.

There are several types of receptor models including, chemical mass balance (CMB), factor analysis (FA), optical microscopy (OM) and automated scanning electron microscopy (ASEM). The selection of a receptor model depends on data availability and source characteristics. The most widely used receptor model is the chemical mass balance (CMB) model. CMB compares the chemical "fingerprints" of emissions from several source categories to the chemical composition of the sample.

Receptor modeling exercises are based on intensive field campaigns. Once completed for a region, however, it is not necessary to repeat them on a regular basis. A repeat study three to five years after major interventions would be appropriate, as part of a SIP update. A comprehensive source apportionment study for the Vaal Triangle region has been completed [EN95].

*MONITORING OF AMBIENT AIR QUALITY*

The aim of air quality monitoring is to obtain information on ambient concentrations of pollutants and on the spatial and temporal changes of such concentrations. Air quality monitoring makes it possible to ascertain whether air pollution concentrations comply with standards, or whether reduction strategies undertaken have been successful in reducing ambient concentrations. On-line, real-time monitoring is often used to provide early warnings during pollution episodes.

The MAQA would be responsible for:

- the planning of an ambient monitoring network in the Vaal Triangle, including particulates, gases, and air toxics
- the coordination of all ambient monitoring
- the collection and collation of data from all areas in the Vaal Triangle
- making regional air quality information available to the public
- annual network reviews
- coordination of monitoring procedures and requirements with any national ambient air quality network.

The following tasks would be undertaken by staff employed in local government environmental health departments:

- maintenance of monitoring sites
- episode monitoring
- special purpose monitoring
- quality assurance
- data compilation and reporting
- public availability of local information.

*PERSONAL MONITORING AND EXPOSURE/RISK ASSESSMENT*

Monitoring the exposure of individuals is important to identify sources which have the most severe impact on human health and welfare.

Use may also be made of an exposure index to measure the relative importance of an emission with respect to its impact on human health. One example of the development of an exposure index involves multiplying the contribution of a source at a specific time to ambient particulate at ground level, with the number of people living or working at that location at that time. The source with the highest index would have the largest impact on the largest number of people and would be a priority in an air pollution control plan [VA95].

Intervention strategies adopted may thus be evaluated on the basis of the ability of such strategies to reduce the exposure levels of individuals.

## DISCUSSION

In this sub-section we discuss a number of issues related to the main theme of the Metropolitan air Quality Authority and its functions. These include the relationships with transportation and land use planning; comments on advantages of metropolitan rather than national air quality management; and comments on public participation.

*AIR QUALITY, TRANSPORT AND LAND USE PLANNING*

Important relationships exist between air quality management, land use planning, and transportation planning. New land use developments can influence both travel patterns and exposure levels. The location of a residential area in close proximity to an industrial area would, for example, result in increased levels of human exposure to the emissions generated by the industry. Extended road transportation networks and increased traffic flows resulting from such new developments would directly influence air quality through enhanced tailpipe emissions and increased re-entrainment of dust on roadways. Unless this relationship is recognised and channels of communication established between local and regional agencies responsible for land use planning, air quality management and transportation planning, air quality management in the Vaal Triangle is unlikely to succeed in the long term.

Santa Barbara's Memorandum of Understanding provides a good example of the nature of the relationship required between transport management and air quality management authorities. The Santa Barbara Association of Governments (SBCAG) is the regional agency responsible for preparing regional transport plans and programs. Most of these programs require the participation of cities, the county, and other affected local agencies. A number of these programs also have implications to regional air quality plans such as the "1994 Clean Air Plan". Since the SBCAG currently works with cities and the county on regional transportation programs, and because of the close interaction between many of these programs and the regional air quality plan, the Air Pollution Control District (APCD) and SBCAG have entered into a Memorandum of Understanding whereby the SBCAG is charged with developing the transportation elements of the plan, particularly the transportation control measures (TCM). TCMs are essentially measures that seek to reduce the use of the single passenger vehicle and to improve the efficiency of the transportation system, and are implemented by a number of local agencies such as local cities and the county. Local emission control measures therefore reflect both APCD rules and the TCMs put forward by the SBCAG [SA94].

## *TRANSPORTATION PLANNING IN THE VAAL TRIANGLE*

In the Vaal Triangle it may be necessary to establish a metropolitan transportation planning organisation in order to ensure the longer term success of air quality management strategies. Such an organisation would be responsible for the development of a long-range transportation plan and a transportation improvement plan (TIP) for the region. Close collaboration between the Transport Planning Organisation and the Metropolitan Air Quality Authority would ensure the coordination of air quality and transport planning activities and facilitate the effective integration of the respective planning processes.

The Transportation Planning Organisation would be expected to provide demographic and transportation data that would form the basis for the emission inventory created and maintained by the Metropolitan Air Quality Authority. The organisation should also assist the Metropolitan Air Quality Authority through its analysis of transportation control measures which may be included in the strategy implementation plan, and its review and comment on draft elements of the plan.

Transportation planning, like air quality and land use planning, is a function that would require, certainly in the Vaal Triangle, governmental cooperation across metropolitan and provincial boundaries.

In the United States one of the main functions of Transport Management Associations is the aggressive promotion of and provision of alternatives to single occupant vehicles [CO95].

## *LOCAL VERSUS NATIONAL CONTROL*

Urban air quality management at a metropolitan rather than a national level or even provincial level is proposed for two main reasons:

- Decentralised management of air quality is essential to ensure that strategies aimed at securing ambient standards are tailored to suit the local context, including physical features, the social and economic priorities of the region.
- Decentralised management would promote and facilitate public and local industry participation. Local involvement in the pollution control process by all role players is better achieved when control is exercised at the lowest level of authority consistent with effective performance.

However, in the case of adjacent metropolitan authorities, such as occurs in the Vaal Triangle, a joint metropolitan authority should be charged with the main executive powers for the implementation of air pollution control rather, than individual metropolitan authorities or substructures, since:

- Zones of impact of strong sources frequently overlap multiple local authority areas. Should standards be exceeded in one area, control of local emissions in adjacent areas may only have a limited effect on reducing ambient concentrations. Airborne pollution is a thus a regional problem, affecting an air basin, a region defined by physical and meteorological boundaries which delineate the primary emission and impact zones of the air pollution cloud.
- Effective air pollution management necessitates the utilization of specialist techniques for monitoring and modeling. The expertise and funds necessary for such management may not be available at local levels, and could certainly be more effectively utilised is shared over local government structures within an air basin.

In terms of these criteria, air quality management for the Vaal Triangle at a cooperative metropolitan level appears to be an attractive option for two reasons:

- The Vaal Triangle region may be considered as a coherent airshed, or air basin, due to its fairly uniform terrain. Highest pollution episodes occur during meteorological stagnation, during which local low and intermediate level emissions dominate.
- The Vaal Triangle region is comparatively isolated from neighbouring urban areas by extensive rural areas. Air pollutants transported from such nearest large urban regions (Witwatersrand, Witbank) give rise to background levels which are low in comparison to local source contributions within the Vaal Triangle.

Air quality management strategies implemented at the metropolitan level to control sources within the region should therefore prove effective.

## *A LOCAL CASE STUDY: DURBAN METROPOLITAN REGION*

Adaptations of imported strategies need to adjust to the realities of local circumstances. Experience from the Durban Environment and Development Project provides a local example of a metropolitan air quality plan, which provides also some insights into public participation.

The city of Durban initiated the State of Environment and Development Project as part of its Local Agenda 21 Programme. The air sector of the programme aimed at investigation of baseline conditions and the provision of recommendations for a plan of action for ambient sulphur dioxide reduction. The assessment of baseline conditions in the city and the development of a comprehensive data base to assist decision making was seen as crucial to the development of realistic environmental and development strategies. The experience of the city of Durban further reveals that Durban's current management system needs to be expanded to cover the entire Metropolitan level so as to facilitate air quality management on a catchment basis [DI95].

Baseline studies included the collection and collation of macro-population and land-use data base data for the Greater Durban Metropolitan Area, the compilation of existing data generated by specialist studies, and the establishment of a bibliography of experts and organisations involved in environmental and development issues in the region. Information on the ambient concentrations of various pollutants facilitated the identification of areas in which ambient levels exceeded recommended guide-lines. Emission reduction strategies could then be focused on problem areas.

Despite a sincere and substantial effort on the part of the Durban authorities to harness public participation in the process, public interest groups still feel a great sense of alienation [PE95]. Problems include an historic suspicion of industry, and doubts on validity of information supplied, based on a perceived or actual lack of technical understanding. These are issues that would have to be given serious consideration and explicitly addressed in any Vaal SIP.

## EXISTING BASELINE STUDIES FOR THE VAAL TRIANGLE

The purpose of this section is to review some of the recent air quality studies conducted in the Vaal Triangle. Further details of the substance of the investigation may be found in a recent review of atmospheric research: "Air pollution and its impacts on the South African Highveld" [HE96].

### *EMISSION INVENTORY*

The Chief Air Pollution Control Officer of the Department of Environment and Tourism currently responsible for the compilation of a national atmospheric emission inventory of scheduled process emissions. The first inventory, which included the Vaal Triangle was established in 1989. Subsequent work in this sphere has included the compilation of a rapid survey source inventory for the Vaal Triangle [MU92], and the establishment of a comprehensive emission inventory of particulate matter for the region for the year 1992 [VA95].

The 1992 Vaal Triangle Emission Inventory was based on US EPA emission factors and inventory techniques. US EPA emission inventory technology is well established and documented and provides a sound methodology for local inventory compilation [VA95]. Despite the existence of such a comprehensive emission inventory for the Vaal Triangle, staff is currently needed to update the inventory in order to keep it complete, accurate and current. The inventory excluded wind blown dust sources (due to resource limitations). Submissions from certain large industries did not contain information in the required format or detail and revisions are required to ensure the overall validity of the inventory. The inventory was compiled using the PC software database "Paradox" for DOS.

### *AMBIENT AIR QUALITY MONITORING AND RECEPTOR MODELLING*

There are currently several agencies active and several sites in the Vaal Triangle at which ambient monitoring is being undertaken. Groups are involved in such monitoring, including DEAT, Eskom TRI, Mintek and AER (Pty) Ltd. Several industries monitor ambient conditions adjacent to their own operations.

A summary of continuous gaseous and particulate monitoring results was conducted as part of the VAPS study, covering the period 1990 to 1993 [BU94]. In 1996, all available monitoring data for the Vaal Triangle (and five other cities) for the period 1985 to 1995 was assembled in a PC-computer database as part of the Vehicle Emissions Study of the Department of Minerals and Energy [TE96]. Results are available in the PC software database "Microsoft Access". The data base includes results of criteria pollutants from ambient stations operated by local Vaal Triangle companies. One of the disappointing findings was that there was little uniformity or intercomparison in the calibration procedures and reference materials used for gaseous pollutant analysers.

During 1994 Mintek conducted a year long receptor model ambient air study campaign in the Vaal Triangle. Samples of particulate matter (PM-10 size range) were collected for week long periods at three sampling stations in the commercial centers of Vereeniging, Vanderbijlpark and Sasolburg [EN95]. Following the physical and chemical analysis of the samples, receptor modeling was undertaken to quantify the contribution of various source types to the ambient particulate concentrations.

An agency is currently needed to coordinate such monitoring efforts, and facilitate the more frequent collection and collation of the data generated. Furthermore attempts should be made to extend ambient monitoring into the coal-burning residential suburbs of the Vaal Triangle.

Calibration procedures and reference materials should be determined by at a national level, and coordinated at local level by a body such as the proposed MAQA.

### *PERSONAL MONITORING AND EXPOSURE ASSESSMENT*

The monitoring of the exposure of individuals to pollutants has been undertaken in various parts of the Vaal Triangle as part of the Vaal Air Pollution Health Study. Results are contained in the reports of that project [TE94].

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