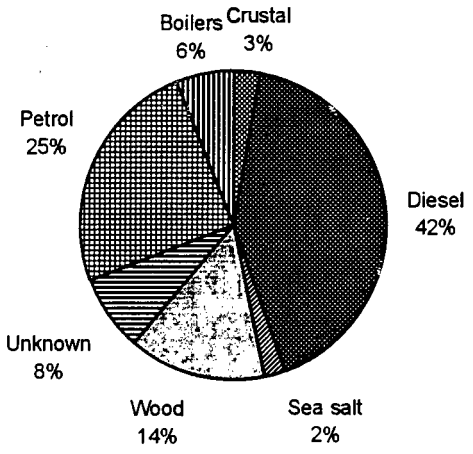
FINE PARTICULATE MATTER SOURCE APPORTIONMENT OF THE BROWN HAZE IN CAPE TOWN

M C WICKING-BAIRD

exceeded on the worst brown haze days. In general it can be said that, due to Cape Town's unique meteorology, Cape Town experiences strong pollution episodes for only a few hours per day on some days of the year. Pollution levels, and visibility, during these occasions are comparable with some of the worst polluted cities in the world, but they are not sustained. For this reason daily and annual air pollution standards are seldom exceeded.

Ambient sampling was carried out on 29 brown haze episodes at each of the monitoring sites. In order to satisfy a number of data quality criteria for modelling, only four to six brown haze episodes were modelled for each monitoring site. Average PM2.5 source apportionment of the brown haze episodes modelled is shown below.

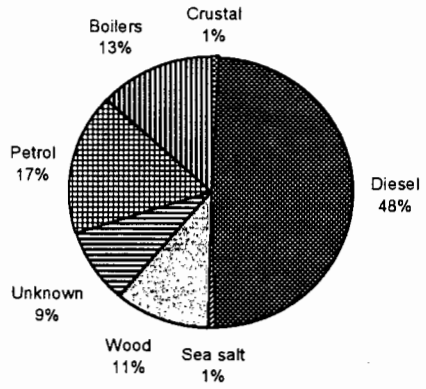
PM2.5 apportionment



The results show that the major source of the brown haze in Cape Town is diesel vehicles, with petrol vehicles, wood burning, and industrial boilers also being significant. A significant unknown source also exists, which comprises mostly organic carbon. It is likely that a significant portion of this organic carbon is derived from industrial process emissions. The Caltex refinery and the Athlone power station are included under boilers, together with other oil-fired and coal-fired boilers. Due to the emissions of the Caltex Refinery and the Athlone power station being above the inversion layer during the worst period of the brown haze, in the early morning, they are not expected to form a significant portion of the boiler contribution. The model indicated tyre burning and Kynoch Fertiliser Factory emissions to be insignificant. It must be emphasised that these results do not reflect on possible localised air pollution problems that may exist.

Since this study was driven by visibility concerns, a qualitative investigation into the effect of visibility was carried out. This involved applying an empirical visibility model, developed for Denver, to the PM2.5 apportionment. The graph below shows how the PM2.5 apportionment is transformed when a visibility model is applied.

Visibility apportionment



Diesel vehicles are high in sulphates and carbon species which are significant variables in the visibility model, therefore the visibility apportionemnt shows a larger contribution of diesel vehicles than the PM2.5 apportionment does. Similarily the crustal component contributes less to the visibility apportionment than the PM2.5 apportioment because it does not contain any important visibility degrading components.

On assessing the modelling results certain improvements were proposed to improve the accuracy of the results these were:

- generating source profiles from various diesel vehicles
- generating source profiles from coal fired boilers in the area. This would include sampling from boilers operating under efficient and inefficient conditions.
- assessing the variability of source profiles for oil fired boilers operating in various states of efficiency.
- asssesing the reproducibility of identical source measurements

Furthermore modelling showed that there was the possibility that there were certain sources missing from the modelling set. Most modelling runs showed that a zinc rich source was missing. It is proposed that a refuse burning or galvanising industry source would solve this problem.

Finally the qualitative visibility assesment of the brown haze showed that the visibility and PM2.5 apportionments could be different. For this reason it is proposed that a visibility model be generated for the Cape Town region. This model can be used with the present PM2.5 data set to provide a more quantitative visibility apportionment for the region.

ACKNOWLEDGEMENTS

A number of persons dedicated considerable personal time and effort to the study, in particular the members of the Technical Committee. The Technical Committee comprised Grant Ravenscroft of the former Scientific Services Branch of the Cape Town Municipality, Hans Linde of the former Air Pollution Branch of the Cape Town City Council, Professor James Willis of Geological Sciences of the University of Cape Town, and Mark Wicking-Baird and Mark de Villiers of the Energy Research Institute. The author would also like to thank Professor Harold Annegarn of the Schönland Research Centre of the University of the Witwatersrand for his valuable assistance throughout the project. We also thank Keith Moir of the Cape Town International Airport Weather Office for providing meteorological data on a daily basis.

We would also like to acknowledge the significant input of the Desert Research Institute of the United States into the Brown Haze Project. Many of the brown haze procedures were based on those developed by the Desert Research Institute who are recognised as being the world leaders in receptor modelling research. The Desert Research Institute also carried out carbon analyses of our filters, and when attempts at X-ray fluorescence spectrometry analysis failed in South Africa, we had to rely once again on the Desert Research Institute to carry out these analyses.

The research team are also grateful to the Brown Haze Steering Committee for their advice and guidance throughout the study. The members of the Steering Committee were:

Prof H.J Annegarn, Sconland Research Centre
Mr Walter Anthony, Bellville Municipality (former)
Mr K.J. Balchin, South African Breweries
Mr Colin Bird, South African Property Owners' Association
Mr G.E. Bleimschein, BP Southern Africa
Mr P. Boxall, SANS Fibres
Mr L.E. Bremer, Cape Metropolitan Council (former)
Mr D.J. Brook, Milnerton Municipality (former)
Mr M.J. Burr, Kynoch Fertilizer
Mr G.C. Coetzee, Coalcor (former)
Mr M.G. de Villiers, Energy Research Institute, University of Cape Town
Mr C.J. du Preez, Department of Environmental Affairs and Tourism
Prof R.K. Dutkiewicz, Energy Research Institute, University of Cape Town
Mr J.F. du Toit, Cape Town City Council (former)
Mr D.A. Gerneke, Electron Microscope Unit, University of Cape Town
Mr B.D. Goodwin, Caltex Oil
Mr B.H. Hesse, City of Tygerberg
Mr M.L. Hawke, AECI
Mr J. Holliday, SOEKOR
Mrs Felicity Jervis, Public Relations Consultant
Mr J. Laskarides, Total South Africa
Mr H.J. Linde, Cape Town City Council (former)

Mrs L. Marais, Kynoch Fertilizer
Mr S.D. Matchett, Shell South Africa
Mr C. McK. McClelland, SAPIA
Mr I.R. McLachlan, SOEKOR
Mr K.J. Moir, Cape Town International Airport Weather Office
Mr E.J. Oswald, Cape Metropolitan Council
Mr T. Plint, Consol Glass
Dr M.E.E. Popkiss, Cape Town City Council (former)
Mr F. Potgieter, Koeberg Nuclear Power Station
Mr G.R. Ravenscroft, Scientific Services, Cape Town City Council
Mr G. Roberts, Kuils River Municipality (former)
Mr F.J. van Zyl, Durbanville Municipality (former)
Mr I. Weston, Pinelands Municipality (former)
Mr M.C. Wicking-Baird, Energy Research Institute, University of Cape Town
Prof J.P. Willis, Geological Sciences, University of Cape Town
Mr B.H.A. Winter, Energy Research Institute, University of Cape Town

The research team are also grateful for the financial support given by the following organisations.

Bellville Municipality
BP Southern Africa
Caltex Oil
Cape Oil Products
Cape Town City Council
Consol Glass
Department of Health
Engen Petroleum
Kynoch Fertilizer
Milnerton Transitional Metropolitan Substructure
National Association for Clean Air, Western Cape Branch
Pinelands Municipality
Pinelands Metropolitan Transitional Metropolitan Substructure
SANS Fibres
Shell South Africa
SOEKOR
South African Property Owners Association

I would also like to thankMark de Villiers for his involvement in the Brown Haze Study and for the help he gave me with editing this thesis.
I would also like to thank Mrs. B. Bailey for help with formatting of this thesis.

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1. INTRODUCTION

1.1 Description of the brown haze in Cape Town

"Brown Haze" is a term used to describe a brown-coloured smog found predominantly in the wintertime in the Cape Town region. It occurs mostly from April to September due to strong temperature inversions and windless conditions that can occur during these months, which lead to the build-up of pollutants emitted into the atmosphere. The haze extends over most of the Cape Metropolitan Area, but does not appear, by visual observation, to be of uniform intensity. It shifts, depending on the direction of any light wind. The haze is normally most intense in the morning and then lifts and disperses as the day continues.

The haze has a strong degrading effect on visibility which is immediately apparent to the general public and to tourists. Capetonians are especially proud of the natural beauty of their city, and the haze is increasingly eroding this pride. Also of concern is the effect on the tourist industry which is projected to be Cape Town's most important economic growth area.

The haze is also cause for concern to residents because of health risks that may accompany the visible air pollution. Small particles, largely responsible for the haze, can also have serious respiratory effects if their concentration is sufficiently high. The same conditions that are conducive to the formation of a haze are also conducive to the accumulation of gases which are invisible, but if sufficiently concentrated can have unpleasant health and odour effects.

1.2 Background to this study

The problems of inadequate air quality are not new to Cape Town. By the late sixties Cape Town was experiencing a thick smog caused by the three power stations in the area, coal-burning locomotives and tugs, industrial incinerators, and heavy fuel burning appliances. In 1968 the City Council initiated a programme of air pollution control and within a decade Cape Town had significantly reduced pollutant levels. This was achieved through measures such as termination of the use of coal-burning locomotives and tugs, the closure of two power stations, and enforcement of standards for fuel burning appliances. However, since then another form of air pollution, termed the brown haze, began to emerge. The haze and to a larger extent, concern over photochemical smog formation, prompted local authorities to begin installing a sophisticated pollution monitoring network in Cape Town from the mid-eighties. The monitoring equipment targeted pollutants mostly associated with motor vehicles as this was thought to be the major cause of the problem. Although significant pollutant levels were measured little was known of the contribution of each potential source to the brown haze.

It has been difficult to determine quantitatively whether the number of incidents of haze are increasing since no measurements have been made of the severity of the haze. However the City Council measure the haze daily by visual observation and they are convinced that the haze problem is intensifying. The problem has also been highlighted by the local press, and was further highlighted by the comments of a number of overseas researchers who claimed that the haze urgently required investigation.

In view of the concern over the brown haze, it was decided that it had become necessary to analyse its constituents and determine its sources. Authorities in Cape Town made a plea to the National Government for assistance, but insufficient funds were available. The Cape Town Branch of the National Association of Clean Air then undertook to raise funds for a pilot study of the haze. A total of R30 000 was raised.

The pilot study was carried out in 1992 by the Energy Research Institute, and its objective was to investigate research requirements to understand the nature and causes of the brown haze. The pilot study concluded that based on comparisons with other cities Cape Town does have a serious air pollution problem, and that air quality is likely to get worse. It was estimated that a major study, costing about R400 000, would be required to identify the causes of the haze. The pilot project concluded that a source apportionment study, focusing on particulates and to a lesser extent gases, was necessary and that such a study was possible with local resources.

The Energy Research Institute then approached all potential funders of the brown haze project including local industry, associations, the Department of National Health, and local municipalities. By the end of 1994 sufficient funds had been raised to begin the study.

1.3 Objectives of thes Brown Haze study

The main objective of the second phase of the brown haze study was to determine the contribution of all major sources to the brown haze, and to obtain a better understanding of the mechanism of haze formation. The focus of the study was therefore on visibility, rather than health, although the two are closely related. Identifying contributions to the haze will indicate the most important areas where authorities should focus their activities, and will enable the effects of possible measures to be assessed. The study also examined where Cape Town is heading in terms of air quality and the options available to improve air quality. The study did not examine any localised air pollution problems that may exist.

1.4 Management structure for the project

At the outset of the project a project management structure, shown in Figure 1.1, was agreed upon by the sponsors and main stakeholders:

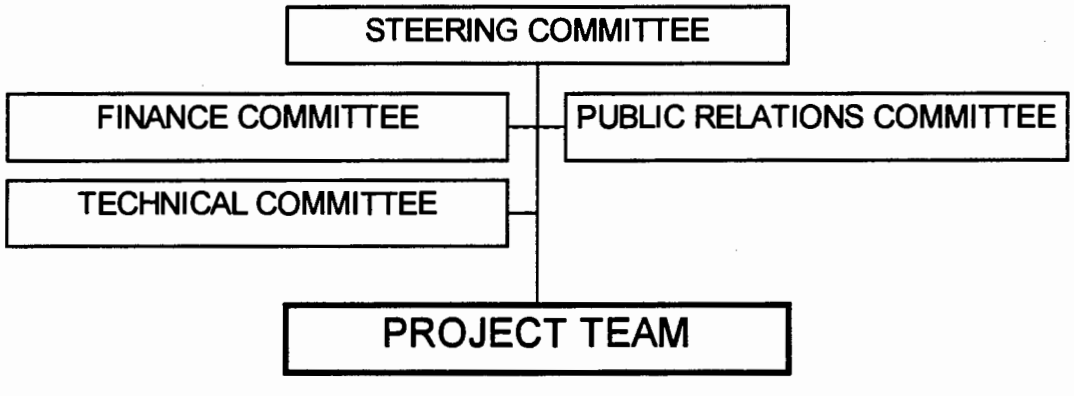


Figure 1.1 Management structure for the brown haze project

The Project Team was responsible for the carrying out of the research. It was provided with technical guidance from the Technical Committee. The Steering Committee, comprising sponsors and persons with specialist knowledge, was responsible for overseeing the entire project. The Finance Committee audited the project balance sheet. The Public Relations Group ensured that the general public was informed about the research both during and after the project.

1.5 Basic methodology

Visibility impairment of the brown haze is caused by the scattering and absorption of light by particles and gases. Generally, in urban areas, particles less than 2.5 microns in size (PM2.5) are the single largest cause of visibility impairment. They are also the most harmful size range of particles to human health. Because of the importance of PM2.5 in the haze the main focus of the study was a source apportionment of PM2.5. The apportionment used a receptor modelling approach that required chemical data about the main sources and the brown haze itself.

The brown haze was sampled over a one year period using an ambient sampling network that consisted of PM2.5 samplers situated at four sites in the Greater Cape Town area. This network was geared for optimum sampling during brown haze episodes. In addition to the PM2.5 sampling there was continuous measurement of PM10, NO_2, NO, SO_2, ozone, non-methane hydrocarbons, and meteorological parameters at the four sites.

2. LITERATURE REVIEW

2.1 Health effects of air pollution

The effects of air pollution on health has attracted the attention of many regulatory bodies[11,13,16,18]. This is because pollutants such as oxides of nitrogen , sulphur dioxide, volatile organic compounds, ozone and particulates have been correlated with changes in mortality, instances of respiratory complaints and cardiovascular illnesses, as well as carcinogenicity. Health effects of pollutants are determined in a number of ways. Laboratory experiments determine the threshold effects of pollutants, while epidemiological studies attempt to link changes in ambient pollutant levels with health effects in communities.

2.1.1 Nitrogen dioxide

Of the oxides of nitrogen (NO_x), nitrogen dioxide (NO_2) is linked with health effects. NO is emitted from high temperature combustion, and later partially converted to NO_2 by photochemical reactions. Sources of NO include motor vehicles and fossil fuel burning power plants. Nitrogen oxides are less soluble in water than sulphur dioxide and are therefore associated with deep lung penetration as scrubbing of the gas in the nasal passages is not efficient[11]. Animal experiments have shown that NO_2 causes alteration in lung metabolism, structure and function, and an increase in the susceptibility to pulmonary infections. Studies on humans have shown that, with asthmatics in particular, NO_2 has a bronco-constricting effect.

In a paper by Özkaynak[8] reviewing epidemiological studies into the health effects of ambient NO_2, no conclusive association was made between ambient NO_2 and respiratory illness although it was suggested that high levels of this pollutant could cause the prolonging of respiratory complaints.

2.1.2 Sulphur dioxide

Sulphur dioxide (SO_2) is a colourless gas that is soluble in water and can be readily oxidised by coming into contact with water droplets in the atmosphere. Therefore the health effects of the gas are often associated with the secondary aerosol pollutants such as ammonium sulphate [$(NH_4)_2SO_4$] which is linked to atmospheric visibility degradation[12]. Atmospheric SO_2 results mainly from the combustion of fossil fuels such as in power stations, motor vehicles and industrial boilers.

Due to its high solubility in water SO_2 is readily absorbed in the mucous membranes of the nose and the upper respiratory tract[13]. High occupational exposures (more than 10000 $\mu g/m^3$) to the gas give rise to severe brochoconstriction, chemical bronchitis and tracheitis. Lower concentrations (500-2700 $\mu g/m^3$) cause bronchospasm in asthmatics. Typical ambient levels are much lower than this (less than 100$\mu g/m^3$). SO_2 also oxidises in the atmosphere to form sulphate particles. These have been correlated with changes in mortality[13] and these effects will be discussed in more detail later in the chapter when particulates are discussed.

2.1.3 Volatile organic compounds

Volatile organic compounds (VOC's) are described by the United Nations Economic Commission for Europe[14] as "all organic compounds of anthropogenic nature other than methane that are capable of producing photochemical oxidants by reactions with oxides of nitrogen in the presence of sunlight". Most VOC's do not occur in appreciable enough concentrations in the atmosphere to constitute a health risk, but the ones that do are: benzene, aldehydes, 1,3-butadiene, n-hexane, and some chlorinated hydrocarbons. The sources of these VOC's are vehicle exhausts, petroleum fuel evaporation from refineries and vehicles, and industries that use solvents such as the paint or plasticizer industry.

Health effects of VOC's differ from compound to compound, but in general they have one of the following effects: carcinogenicity, neurobehavioural or nephrotoxic. Benzene is a well known carcinogen[15] and has been linked to incidences of leukemia[13,14] as has 1,3-butadiene[45]. Aldehydes such as formaldehyde have been linked with irritation of the eyes, nose, throat and upper respiratory tract[13]. n-Hexane effects respiratory and cardiovascular function.

2.1.4 Ozone

Ozone in the urban atmosphere is a photochemical oxidant whose formation is the result of interactions between oxides of nitrogen and hydrocarbons in the presence of sunlight. Motor vehicles are primarily associated with these precursor pollutants, although stationary sources burning fossil fuels also contribute to nitrogen oxide emissions. The atmospheric concentrations of ozone are a strong function of the amount of solar insolation and the precursor loading in the atmosphere[8].

Ozone exposure causes irritation to the airways resulting in inflammation, increased permeability in lung tissue, and destruction of pulmonary macrophages[9]. Large or intermittent chronic exposures can cause thickening of airways and alveoli membranes with eventual loss of function. High ambient ozone concentrations have been associated with restricted activity, asthma symptoms, and respiratory admissions to hospitals[10].

2.1.5 Particulates

Particulate air pollution and its health effects are associated with complaints of the respiratory system[1]. More specifically researchers have shown that particulates are linked to increased mortality and an increase in the hospital admissions for respiratory and cardio-vascular illnesses[1,2,3,5]. Furthermore particulates are associated with mutagenic activity[4,6] which in turn indicates their cancer causing potential. In South Africa the investigations into the health impacts of particulates have centred around domestic fuel burning[72,73,74,75]. These investigations conclude that children from the ages of 8 - 12 years exposed to wood or coal smoke during winter there is an increased risk of 290% for developing upper respiratory illnesses and a increase of 420% in the risk of contracting lower respiratory illnessses[73].

In many countries the primary health standard for particulates is PM10, which refers to particles of aerodynamic diameter less than 10μm. This standard was chosen as representing the particulate size that has the potential to penetrate the upper airways of the respiratory system[7]. PM10 can be subdivided into three categories, based on the methods of formation of particles:[1]

(a) Nucleation Mode Particles (10 - 200 nanometres) which are formed by the condensation of hot gases. The ratio of the number of particles to the total mass of particles in this mode is high. They have a short lifetime in the atmosphere.

(b) Accumulation Mode Particles (0.2 - 2 microns) which are formed by the coagulation and growth of Nucleation Mode Particles. These have a long atmospheric lifetime and make up the bulk of the atmospheric airborne particles. These are also primarily associated with emissions from combustion sources.

(c) Coarse Mode Particles (2-10 microns) which are mechanically generated and have a short atmospheric lifetime due to their high deposition rate. Relative to the Nucleation Mode, the ratio of the number of particles to the total mass of the coarse mode is low.

These three categories are, however, generally simplified to a coarse fraction (2.5 to 10 microns) and a fine fraction (less than 2.5 microns). Coarse particles are associated with particulate deposition in the bronchial region while fine mode particles are deposited further into the respiratory system resulting in their slower clearance from the lung[5].

This had lead to separate research into the health effects of the fine mode and coarse mode of particulates. Researchers have shown that PM2.5 has a much stronger correlation to health effects than PM10[1,2,5]. It is postulated that this is due to the greater penetration into the lung; the fact that fine particles readily infiltrate buildings causing indoor and outdoor levels to be similar and thus exposure times longer; and the larger number of particles in the fine mode may effect the ability of the respiratory system to clear out the particles efficiently.

2.2 Air pollution standards/guidelines

Due to the adverse health effects of the pollutants mentioned in the previous section, certain ambient air quality standards/guidelines have been set to protect the general public against adverse health effects[16]. The difference between standards and guidelines lies in their enforcement. Wheras standards are pollutant levels that by law can only be exceded a set number of times over a given period, guidelines are concentrations of pollutants that an organisation recommends should not be exceded in the intrests of public health. The United States Environmental Protection Agency (EPA) and the World Health Organisation (WHO) are the primary bodies for the publishing of air quality standards/guidelines. Table 2.1 shows the standards/guidelines proposed by these bodies along with the South African recommendations proposed by the Department of Environmental Affairs and Tourism (DEAT).

Table 2.1 Air Pollution Standards ($\mu g/m^3$)

POLLUTANT	AVERAGING TIME	EPA[17] STANDARD	WHO[13] GUIDELINE	DEAT[18] GUIDELINE
Nitrogen Dioxide	1 year 1 hour	100	40-50 200	94 376
Ozone	1 hour 8 hour	235	 120	235
Sulphur Dioxide	1 year 24 hours 10 minutes	80 365	50 125 500	86 286 1716
PM10	1 year 24 hours	50 150		60 180
PM2.5	24 hours 1 year	65 15		

Table 2.1 shows that there are both short term and long term standards/guidelines for some pollutants. This is aimed at protecting the public from the risks associated with both acute and chronic exposure to pollutants[13,18].

Air pollution standards/guidelines are constantly being reassessed and modified due to research into their health effects, and because of improvement in the technologies available for measuring the pollutants. The US EPA is presently involved in the revision of particulate and ozone standards[19,20]. The proposed new ozone standard is $157\mu g/m^3$ averaged over 8 hours as opposed to the previous 1 hour averaging time. It is anticipated that this standard will be implemented by the year 2000[20]. The proposed particulate matter standard involves a new measurement range. The original standard was based on particles less than $10\mu m$ (PM10), and while this is to be kept, a further standard based on particles less than $2.5\mu m$ (PM2.5) was recently introduced. The reason for the emphasis on PM2.5 is that it has a strong relationship with health effects[1]. This size fraction is associated with emissions from combustion sources and therefore the PM2.5 standard will place more emphasis on the impact of these emissions[19].

2.3 Air pollution studies in Cape Town

2.3.1 Pollution problems in the Cape Town Metropolitan Area

Monitoring of pollutants has taken place at some sites in Cape Town since the sixties. The pollutants measured were SO_2 and particulates by the soiling index method. In 1975 a study was commissioned by the Cape Town City Council to carry out an air pollution study of Greater Cape Town[21]. The study found that the levels of the pollutants SO_2, NO_x, particles and ozone were within international air quality standards although concern was expressed over high episodic concentrations of ozone, NO_x and particulates.

As a result of this the report recommended the implementation of an air quality management programme in the area. This would include the measurement of ambient air pollutant concentrations as well as the setting and enforcement of air pollution standards for emitters and for ambient pollutant concentrations.

2.3.2 Brown Haze Pilot Study

Due to the occurrence of a brown haze on calm days in the winter months a pilot study was carried out in Cape Town from June to August 1992 whose objectives were[21]:

- to develop a methodology to sample and analyse the haze
- assess local analysis potential
- determine the constituents of the haze
- attempt to determine the major sources of the haze
- compare the results of the study with other cities and pollution standards
- determine requirements for the next phase of the brown haze study.

From the study it was concluded that during brown haze episodes particulate levels were comparable to those in other heavily polluted international cities, and that there was the possibility of particulate concentrations exceeding international guidelines. Further, the infrastructure existed in South Africa for a more comprehensive source apportionment study to be carried out.

2.3.3 Milnerton Air Quality Study[23]

An air pollution study focusing on exposure assessment followed by health risk assessment was undertaken by the CSIR between October 1994 and October 1995. This was as result of widespread complaints from the communities of Milnerton and surrounding areas. The study included continuous gaseous and particulate sampling as well as passive volatile organic compound monitoring using resin badges, and pollen and fungal monitoring.

The study identified benzene, oxides of nitrogen, fungal spores and pollen as health risks. There were also exceedences of the WHO SO_2 10 minutes-exposure guideline on 17 February 1995 at Table View. It was recommended that monitoring in the area continue with a more detailed benzene study being suggested. The study also recommended that the public be informed of air pollution levels.

2.3.4 Dispersion modelling in the Greater Cape Town Region

A dispersion modelling study for SO_2 was undertaken in 1993/94 by Dracoulides[24]. It was aimed at modelling the dispersion of SO_2 throughout the area and to assess the accuracy of the model by comparing the predicted ambient levels with those measured at Cape Town City council sampling sites. This was important as dispersion models are useful for the evaluation of future air pollution control strategies and their potential controls.

Emissions for the years 1991 and 1992 were modelled, and the model predicted accurately for the Bellville area, but under-predicted concentration by a factor of 2 to 4 at Goodwood and the Cape Town CBD. The study concluded that the model was able to predict adequate air pollution concentrations at locations away from Table Mountain.

2.4 Air pollution models

Air pollution models are mathematical representations of the atmosphere and so can be used by researchers and scientists to attempt to manage air quality. The first step to air quality management is to have knowledge of the contributions of emission sources to the ambient air pollution levels. Dispersion and receptor models are commonly used.

The route by which the two models assess source impacts are different and thus give each model advantages in certain situations. Dispersion models take emission inventories and meteorological data and hence assess the impacts of sources on a chosen receptor. Receptor models require information about ambient and source pollution chemistry to assess source impacts at a receptor.

Air pollution receptor models are based on the following mass conservation expression:

$$C_i = \sum_{j=1}^{p} a_{ij} S_j \quad \text{.....(1)}$$

Where:

- S_j = estimated contribution of source j to the receptor.
- C_i = concentration of chemical species I measured at the receptor
- a_{ij} = the fractional contribution to the receptor of chemical species I from source j
- p = the total number of independent contributing sources

Dispersion models require absolute emission rates while receptor models require relative chemical compositions of sources as inputs. Source data for receptor models is more robust and easier to obtain. In a receptor modelling workshop manual series Watson[29] states that dispersion models are limited in that they are unable to quantify source impacts over short episodes and in complex terrain. This is because emission inventories are unable to reflect hourly and daily emission variations. Receptor models do not need meteorological data inputs and so are more accurate in complex terrain. According to Watson[29] they are far more applicable to the assessment of 24 hour pollution episodes. Receptor models are thus more suited to an episodic sampling study such as the brown haze. Further, particularly in the Cape Town central business district (CBD), dispersion modelling becomes inaccurate[24].

There are a number of receptor modelling techniques. These range from statistical techniques such as factor analysis to chemical mass balance models, to microscopic techniques. Microscopic techniques were not considered for this study as analysis using a Scanning Electron Microscope (SEM) is time consuming and expensive, also the facilities did not exist in South Africa to perform automated particle by particle analysis on filter samples. Analysis by SEM takes place under vacuum and can result in the loss of organic carbon species from the filters, this adds to the fact that SEM analysis is an unreliable method for measuring organic species particularily sorbed and liquid organics[29]. Factor analysis uses a large dataset of samples from receptor sites and attempts to estimate the fraction of a species in the

emmissions from a source, and the fractional contribution of the sources. This method was not suitable for the study as the dataset of ambient samples would be small due to the episodic nature of the brown haze. A chemical mass balance model approved by the US EPA has been chosen for this study[30] . This type of model has been extensively used in studies in the USA[31,32,33,34,35] and there are well documented procedures for performing such a study including extensive quality control procedures[32,35].

2.4.1 The Chemical Mass Balance Model

The specific model to be used is the Chemical Mass Balance Model. The model consists of the following sets of equations:[30]

$$C_i = F_{i1}S_1 + F_{i2}S_2 + ... + F_{ij}S_j + ... + F_{iJ}S_J \quad i = 1..I, j = 1..J \quad (2)$$

where: C_i = Concentration of species i measured at a receptor site
F_{ij} = Fraction of species i in emissions from source j
S_j = Estimate of the contribution of source j
I = Number of chemical species
J = Number of source types

Inputs to the model are C_i and F_{ij} and the outputs are S_j. The accuracy of the outputs depends on the accuracy of the inputs and for this reason values of the inputs are inserted along with estimates of the errors associated with these values.

Before using this model it is recommended in the EPA '*Protocol For Applying and Validating the CMB Model*'[46] that checks be made to see whether the model is appropriate or not for the data to be obtained.

A general summary of the recommended steps for the validation of the model is:

- Determine the general applicability of the CMB model to the application at hand.
- Set up the model by identifying and assembling the source types, source profiles, and receptor concentrations needed for model input. Make a preliminary application of the model to these data.
- Make any model input changes which can be justified to resolve the identified problems. Rerun the model.
- Assess the stability of the model results and their consistency with the preliminary analyses.
- Evaluate the model results by comparing them with other receptor or dispersion model results and reconcile any differences.
- Examine the model's statistics and diagnostics to identify potential deviations from the model assumptions. These are:
  (i) Compositions of source emissions are constant over the period of ambient and source sampling.
  (ii) Chemical species do not react with one another, i.e., they add linearly.

(iii) All sources with a potential for significantly contributing to the receptor have been identified and have had their emissions characterised.
(iv) The number of sources or source categories is less than the number of species.
(v) The source compositions are linearly independent of each other.
(vi) Measurement uncertainties are random, uncorrelated, and normally distributed.

2.4.1.1 Applicability of the CMB Model

In the recommendations for validation of the model mention was made of the determination of whether the model is applicable to the apportionment task at hand. The applicability of this particular model is determined along the following lines:

- A sufficient number of samples have been taken in accordance with the guidelines of the study (eg. every sixth day for 24 hours).
- Minimal concentration analyses on samples are: Al, Si, S, Cl, K, Ca, Ti, V, Mn, Fe, Ni, Cu, Zn, Br and Pb. The inclusion of Cr, As, and Se; elements; cations; anions; and elements and organic carbon are desirable. The analyses must be such that the concentrations of the majority of the species should be greater than the detection limit and the variability of the filter blank. The uncertainties of the measured concentrations should be known or estimated.
- The potential sources can be identified and grouped into categories that are unique with respect to their chemical makeups. These groups should be sufficiently different so as to be discernable by the model.
- The compositions of the source profiles are representative of how the source is perceived at the receptor. This implies that changes in the source composition between source and receptor are accommodated to make the model physically meaningful.
- The number of types of sources must be less than the number of chemical species measured.

2.4.1.2 Model setup

When setting up the model it will be necessary to choose the fitting species and source profiles. The choice of these may vary from sample to sample depending on specific emissions and on meterological conditions. For example a factory could be running a different fuel in their boilers. Meterological conditions could effect the choice of sources for a fit. An example of this would be when the prevailing wind makes it impossible for a certain source to be 'seen' at the receptor site. There are EPA documents that give guidelines on data quality[30,46].

An important aspect of the accuracy of the model is the accuracy of the inputs to the data. Here it is recommended that strict quality assurance methods be applied. The accuracy of data uncertainties in particular will have a large influence on the model as the model is weighted towards those values that have a small uncertainty.

For ambient samples the uncertainty is mainly represented by the uncertainty in the analytical measurements and the uncertainties represented by the sampling flowrate. There are

guidelines on how to input data and their uncertainties in the '*EPA Protocol for Applying and Validating the CMB Model*'[46]. It is important that uncertainties be assigned otherwise the model could give undue weight to a particular measurement.

When running the model the choice of fitting sources must be done carefully. Based on the ambient conditions a source may or may not affect the receptor. An example of this could be if the source is downwind of the receptor. It is also suggested in the validation protocol that sources can be eliminated if it is found that; based on emission rates, stack height, microscopy, distance from receptor etc.; the source contributes <5% say, then it should be left out of the fit. Also to be eliminated are those sources that are not emitting at the time of sampling. Once again it is important that the uncertainties of the source profile measurements be estimated as accurately as possible. A useful guide for these uncertainties is that the lower limit of the uncertainty is the analytical uncertainty while an upper limit can be obtained when it is seen that the sum of all fractions of elements in a source profile can not exceed 1.

2.5 Source apportionment studies around the world

Source apportionment studies have been performed since the late 1970's. These have been carried out as a result of perceived high particulate loadings in the atmosphere. Table 2.2 summarises some studies and gives results of apportionment, where available, as well as the type of model used and the date when the study was performed.

Table 2.2 Source apportionment studies

	Receptor Model	Date Performed	Particle Measure	Sources and Contribution
San Francisco Bay[31]	Chemical Mass Balance	1991-1992	PM10	Geological Dust 18% Vehicles 13-18% Wood/Veg Burning 40% Sulphate 3-4%
Duarte California[36]	Principal Component Analysis	1983 and 1987-1988	PM3.5	Soil 23% Sulphate 16% Vehicles 10% Organic Carbon 12%
San Joaquin California[37]	Chemical Mass Balance	June 1988 - June 1989	PM10	Soil 54% Nitrate 15% Vehicles 10% Construction 8%
Denver Colorado[33]	Chemical Mass Balance	1978	PM2.5	Vehicles 26% Coal Combustion >20% Wood Burning 12%
Shanghai[38]	Chemical Mass Balance	1990	PM10	Area Sources 53% Construction 6.2% Road Soil 8.5% Sulphate 8.3% Open Sources 6.4% Soil 4.9%
Milan[39]	Factor Analysis	1988	PM15	Metal Smelting Crustal Material Potassium Rich Source Vehicles Regional Crustal Material Sulphate
Philadelphia[34]	Chemical Mass Balance / Multiple Linear Regres.	1982	PM10	Sulphate 49-55% Crustal Material 17-24% Vehicles 4-6%
Copenhagen[40]	Chemical Mass Balance	1983	TSP	Crustal Dust 20-34% Traffic 37% Fuel Oil Combustion 20% Combined Source 28-50%
Japan[41]	Chemical Mass Balance	1977-1985	PM10	Soil 17.7-28.9% Marine 1.6-8.0% Refuse Burning 4-7.9% Oil Burning 1.5-4.0% Iron Smelting 0.5-6.8%
Hong Kong[42]	Factor Analysis	1986-1987	PM10	Construction 6.48 $mg.m^{-3}$ Vehicles & incineration 1.93 $mg.m^{-3}$ Wind blown Dust 7.14 $mg.m^{-3}$ Coal-fired Power Plant 4.92 $mg.m^{-3}$ Oil Combustion 8.15 $mg.m^{-3}$
Tuscon[43]	Chemical Mass Balance	1989-1990	PM2.5	Motor Vehicles 50-62% Geological Material 25-31% Ammonium Sulphate 5-11% Volatile Nitrates 8% Ammonium Nitrate 0-1%
Vaal Triangle[47]	Chemical Mass Balance	1994	PM10	Arc Furnaces 11-26% Soil Dust 0-35% Domestic Coal Fires <10-35%

2.6 Visibility apportionment

The Brown Haze Study focused on the visibility degradation effects of the haze. Visibility(V) or visual range of an observer is linked to the transmission of light through the atmosphere by an extinction coefficient (b_{ext}). This relationship is given by the Koschmieder equation as[27]:

$$V = - \ln (C_{min})/b_{ext} \quad \text{..... (3)}$$

where C_{min} is the minimum perceptible contrast between two objects, such as a mountain and the horizon. This is usually taken as 2%[25] making (2):

$$V = 3.912/b_{ext} \quad \text{.....(3a)}$$

Light extinction (represented by b_{ext}) is made up of the following independent components:[35]

- Scattering by gases (Rayleigh Scattering) which is a constant value for a given temperature and pressure. Molecules of gas in the atmosphere divert light from a sight path.

- Gases absorb light and transform it into molecular energy. Nitrogen dioxide concentration is associated with light absorption by gases because absorption by other gas molecules is negligible.

- Absorption of light by particles occurs when black or coloured particles transform light into heat. Absorption is linked to the concentration of elemental carbon in the atmosphere.

- Particles scatter light in a similar way to gases. Scattering is a function of the wavelength of light, particle size and the index of refraction for the particles. Particles of 0.5μm in diameter are the most efficient at scattering light.

Therefore a basic model for the extinction coefficient is as follows:

$$b_{ext} = b_{sg} + b_{ag} + b_{sp} + b_{ap} \quad \text{..... (4)}$$

where s and a refer to scattering and absorption respectively, and g and p indicate contributions of gases or particles. A number of studies[25,26,27] have shown that different chemical species have differing effects on visibility degradation. These visibility effects are split amongst six main groups which are:

- fine ammonium sulphate (S)
- fine ammonium nitrate (N)
- fine organic carbon (C_{ao})
- elemental carbon (C_{ae})
- remainder of fine particles (R)
- gaseous NO_2

Groblicki et al (1981)[27] incorporated the effects of these visibility affecting groups into the basic model for the extinction coefficient (3) using multiple linear regression. This yielded the following equation:

$$b_{ext}(Mm^{-1}) = [6.6S + 2.8N + 4.4 \times 1.2 \times C_{ao} + 3.2C_{aef} + 1.7R - 17] + (1.73S)/(1-\mu) + (1.47N)/(1-\mu) + 12.5C_{aef} + 3.8C_{aec} + 0.33\ NO_2 \quad (5)$$

where: μ= relative humidity(RH) /100
the term in [...] represents b_{sp} in (3)
the subscripts c and f represent the coarse and fine fractions.
S, N, C_{ao}, C_{ae} and R are in units of $\mu g/m^3$
NO_2 has units of ppbv
$Mm^{-1} = 10^{-6}$ m

Equation (4) is used to determine the contributions of the six main visibility affecting species to light extinction. The equations are:

$$f_S = [\ S(0.066 + 0.0173\ (1-\mu)^{-1} - 0.011\ b_{sp}^{-1})\ ] / b_{ext} \quad (6)$$
$$f_N = [\ N(0.028 + 0.0147\ (1-\mu)^{-1} - 5 \times 10^{-3}\ b_{sp}^{-1})\ ] / b_{ext} \quad (7)$$
$$f_{Cao} = [\ 1.2C_{ao}(0.044 - 7 \times 10^{-3}\ b_{sp}^{-1})\ ] / b_{ext} \quad (8)$$
$$f_{Cae} = [\ C_{aef}\ (0.157 - 5 \times 10^{-3} b_{sp}^{-1}) + 0.037\ C_{ae}\ ] / b_{ext} \quad (9)$$
$$f_R = [\ R\ (0.017 - 2.9 \times 10^{-3}\ b_{sp}^{-1})\ ] / b_{ext} \quad (10)$$
$$f_{NO2} = [\ 3.3\ NO_2\ ] / b_{ext} \quad (11)$$

where f is the fractional extinction due to a certain species.

Studies by Watson et al[43] and Richards et al[44] also proposed models for b_{ext} as a function of the six visibility reducing species and relative humidity. They are:

$$b_{ext} = [1.0+[1.0/(1-\mu)]]S + [1.8+[1.3/(1-\mu)]]N + R + [3.4+[0.6/(1-\mu)]]C_{ao} + 13.1C_{ae} + 0.21NO_2 + 13 \quad (12)$$

$$b_{ext} = [0.384+0.792RH]S + [0.32+0.66RH]N + R + 9.1C_{ae} + [0.32+0.66RH]C_{ao} + 0.17NO_2^{*} + 9.9 \quad (13)$$

Note: NO_2^{*} is in units of $\mu g/m^3$

The models mentioned above are Multiple Linear Regression Extinction Models and for the calculation of b_{sp} have the general form:

$$b_{sp} = \sum_{j=1}^{n} E_j C_j \quad (14)$$

where E_j is the scattering efficiency of species j, n is the number of components and C_j is the measured concentration of the jth chemical component. The Ej's are "estimated using multiple linear regression when a time series of corresponding b_{sp} and C_j have been measured, with b_{sp} as the dependent variable and the C_j as independent variables[28]." Equation (4) for

example represents a model derived from measurements of b_{sp} made in Denver. So the applicability of the model is assessed relative to the Denver airshed.
Lowenthal et al[28] stated that this type of model has physical significance under restrictive conditions which are:

- all components contributing to scattering are included as independent variables
- the components are externally mixed
- sufficient samples have been taken to provide stable solutions
- scattering efficiency for each component is constant
- chemical concentrations are uncorrelated in time

He went on to say that few studies have examined the effects of deviations from model assumptions on the calculated E_j's. The paper showed that the results from this model were similar to those obtained from a more complex model called the Elastic Light Scattering Interactive Efficiencies Model which gave results that deviated by 11-26% from measured values. However, the report did show that the E_j's calculated at different sites varied by up to a factor of 4.

2.7 Visibility apportionment studies

Previous visibility apportionment studies[26,43,44] have given results in one of two formats depending on the detail required fro the study. The basic approach would be to apportion light extinction to the six visibility affecting species mentioned above. Studies in Denver (1981[26] and 1987-88[44]) did this and their findings are summarised in Table 2.3.

Table 2.3 Visibility apportionment in Denver

Species	Denver 1981 % contribution to extinction	Denver 1987-88 (electrical utilities burning gas)[a] % contribution to extinction	Denver 1987-88 (electrical utilities burning coal)[a] % contribution to extinction
Ammonium Sulphate	20.2	6	6
Ammonium Nitrate	17.2	16	8
Organic Carbon	12.5	21	21
Elemental Carbon (absorption)	31.2	25	30
Elemental Carbon (scattering)	6.5	3	4
Remaining Particulate Mass	6.6	15	15
Rayleigh Scattering	-	6	6
NO_2	5.7	8	10

[a] During the 1987-88 Denver study the electrical utility in the town was alternating between gas and coal as fuel. An apportionment was carried out under these two conditions.

The values in Table 2.3 show which chemical species contribute most to visibility degradation. The two sets of values for the Denver 1987-88 period showing contributions with gas burning

utilities and coal burning utilities show the effect fuel type has on emissions. Coal burning is associated with "black smoke" or the emissions of elemental carbon resulting in a higher visibility contribution for elemental carbon when coal burning utilities are operating. A comparison between the apportionments of 1981 and 1987-88 in the same shows changes in the contributions of ammonium sulphate, organic carbon and remaining particulate mass. This could reflect a changing set of emitters and/or changes in fuel types.

Another approach to visibility apportionment is to apportion visibility to pollution sources. This requires the combination of a model to apportion extinction to the six visibility affecting species, and a receptor model such as the Chemical Mass Balance Model. This approach was used in the Tuscon Urban Haze Study[43]. Table 2.4 shows the range of values obtained for apportionment of the morning and afternoon hazes. The table also shows apportionment of hazes with b_{ext} ranging from 100-200 Mm^{-1} (haze with 40 to 20 km visual range) and for 200-250 Mm^{-1} (strong haze with 20 to 16 km visual range). This sort of apportionment is useful in that it shows the actual visibility degrading effect of sources rather than for chemical species. Ranges shown in the table show the variability in the contributions of emitters from episode to episode. The report also mentions that California and Colarado have visibility standards. California's is that visibility should be greater than or equal to 16km ($100Mm^{-1}$) and Colarado's is 50km ($76Mm^{-1}$).

Table 2.4 Visibility source apportionment in the Tuscon Urban Haze Study (%)

Source	morning haze	afternoon haze	strong morning haze
Primary Geological Material	10-25	10-50	<10-50
Primary Motor Vehicles	25-50	25- >50	>50
Primary Wood Combustion	<10	<10	<10
Primary Smelter	<10	<10	<10
Primary Limestone	<10	<10	<10
Secondary Sulphate	<10	<10	<10
Secondary Nitrate	<10-50	<10	<10-25
Secondary Organic Carbon	<10	<10	<10
NO_2	<10	<10	<10
Rayleigh Scattering	<10-25	10-25	<10

3. METEOROLOGY OF CAPE TOWN

3.1 Introduction

Ambient pollutant concentrations are strongly dependent on the atmosphere into which they are emitted. Ambient measurements are taken at low levels (3-18m) in this study so it is the characteristics of the first 500m of the atmosphere (called the planetary boundary layer) that are important. The meteorological factors that effect air pollutant concentrations in the lower atmosphere are[48]:

- wind velocity
- vertical temperature profile
- mechanical turbulence

These, with rate and height of emissions, govern the ambient pollutant concentrations.

3.2 Overview of the meteorology of Cape Town

In general Cape Town meteorology can be summarised by four typical synoptic maps[49] for the Southern African subcontinent (Figure 3.1).

The summer months are characterised by a high south-easterly air flow (Figure 3.1a) this is caused by a ridging anticyclone over the south Atlantic. This means high wind velocity and consequently high atmospheric turbulence which dilutes and disperses pollutants efficiently.

During the winter months the wind is generally from the north-west (Figure 3.1b). This is caused by a pre-frontal system that also causes low temperatures and overcast conditions. The high wind velocity again performs a diluting function on pollutants in the area. Figure 3.1c shows conditions that occur mainly in early spring and late winter. These are associated with brown haze episodes in the Cape Town region[50]. Berg winds result when a high pressure system over Kwazulu-Natal is associated with one over the Western Cape under pre-frontal conditions.

Figure 3.1d depicts stagnant conditions over the region caused by an anti-cyclone. This causes light variable winds and an elevated temperature inversion. This situation also has the potential to result in pollution episodes as there is insufficient air flow to dilute pollutants.

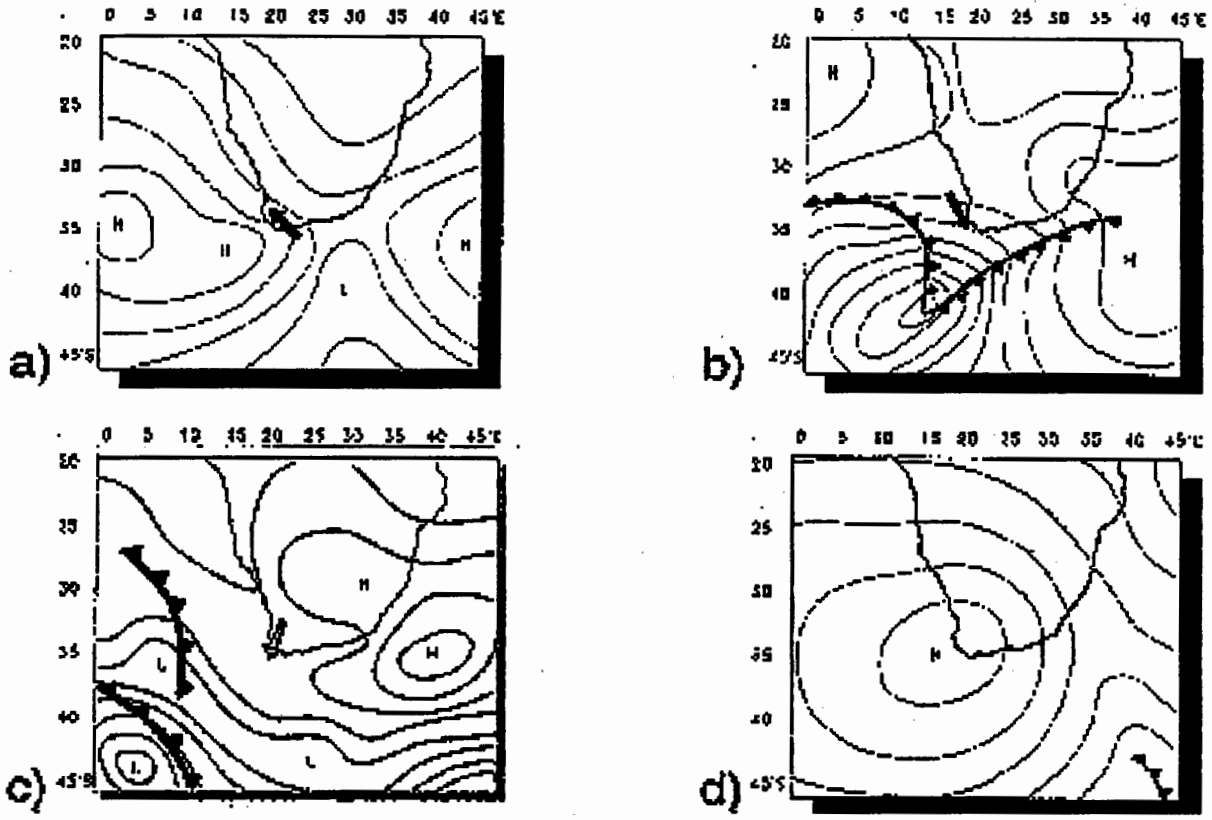


Figure 3.1 Typical synoptic maps for the Southern African subcontinent[49]

3.3 Meteorological zones of Cape Town

Due to the effect of Table Mountain and False and Table Bays the meteorology of Cape Town is complex and has been divided into six zones[51] (Figure 3.2) that show potentially different pollutant loadings.

Zone 1 includes the Central Business District (CBD) of Cape Town. The meteorology here is complex due to the effect of Table Mountain. This causes southerly airflow to have a re-circulating effect rather than a ventilation effect, as in other areas. Temperature inversions are also persistent in the winter months. North-westerly airflow provides the best ventilation for pollution in the area.

Zone 2 runs parallel to the Peninsula mountain chain and includes the Wynberg monitoring site. This zone is the highest rainfall region in the Cape Town Metropolitan Area due to effects of the mountains. Inversions are persistent here too, but tend to break up more quickly than in zone 1 due to the mountain slopes facing the rising sun. This causes increased convective activity. Topography also causes downdrafts so pollution is often dispersed downwards. Ventilation is typically by south-easterly and north-westerly air flow.

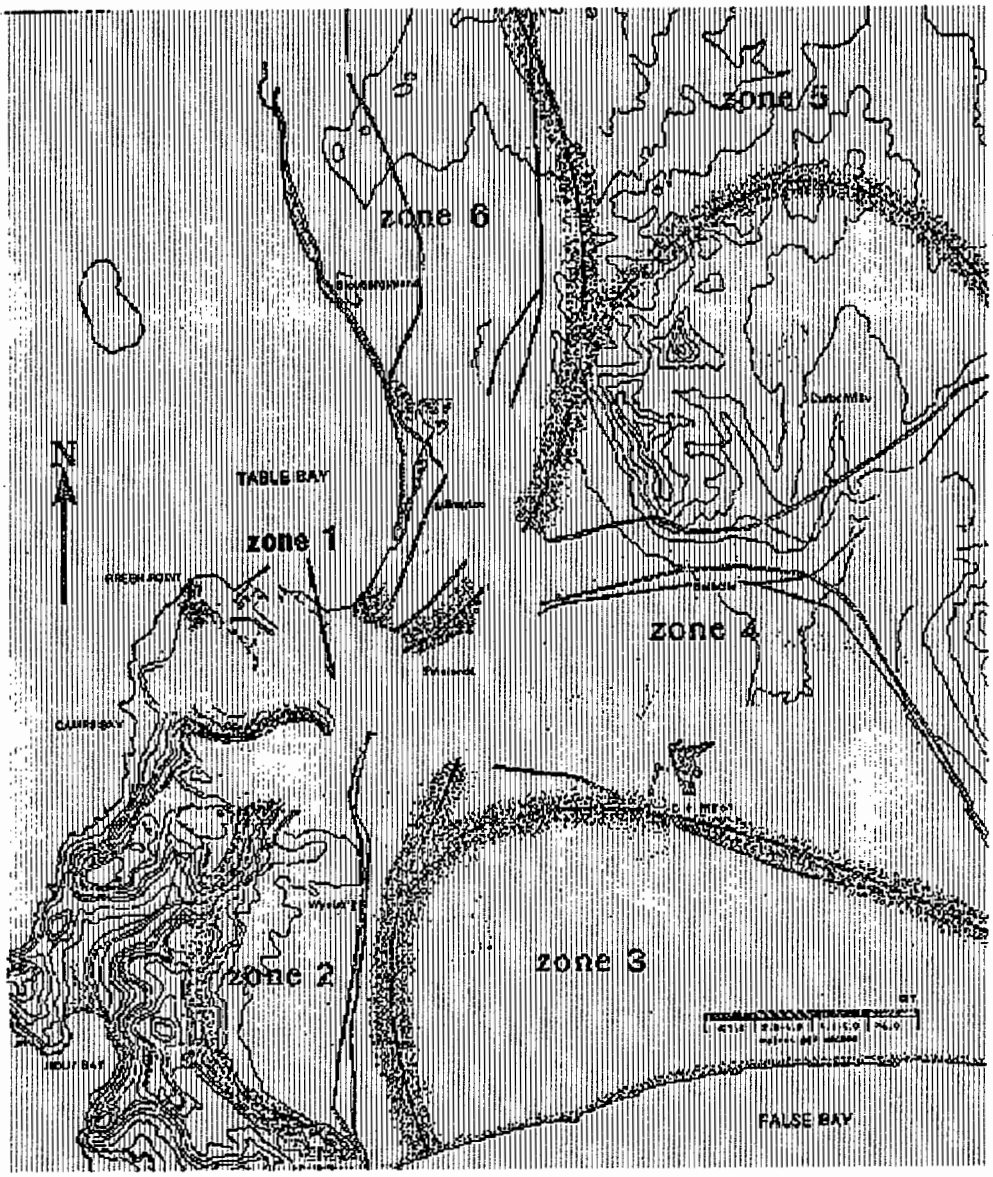


Figure 3.2 Meteorological zones of Cape Town.

Zone 3 represents the Southern Cape Flats area. There is no sampling site in this area. Although inversions do occur here in winter they are generally short lived since from about 10am the zone starts to experience strong air flows either from the south or the north depending on the weather system.

Zone 4 consists of the central Cape Flats area. Most of the industrial areas in the region are found here and the Goodwood sampling site is situated in this zone. In winter, under stable conditions this area experiences low level temperature inversions. These persist well into the morning as this area does not experience the ventilation effects of zone 3. Under unstable conditions, drainage flows are from the north-west or south-east.

Zone 5 is situated north of zone 4 and is considered a beyond the area of study. There is no sampling site in this area. In general the area shows strong daytime winds with a westerly component and weaker night-time winds predominantly from the east.

Zone 6 is the coastal belt from Paardeneiland to Koeberg. There is a sampling site at Table View in this area. As with the other zones southerly and northerly drainage flows dominate in this area. Under stable conditions, however, low level inversions are formed with light sea breezes re-circulating pollutants in the area. The occurrence of the thermal internal boundary layer (a feature of coastal climatology) causes pollutants emitted in this area to be mixed to the ground. This effect can impact on pollutant concentrations some distance inland.

As shown Cape Town can be divided up in to six micro-climatic zones. Of the six zones, ambient pollutant measurements were taken in zones 1, 2 ,4 and 6 during this study.

3.4 Meteorology and brown haze episodes

Most brown haze episodes are associated with weather conditions depicted in Figure 3.1c. According to Jury et al[52] the atmospheric characteristics that are associated with pollution episodes are:

- local berg winds from NNE
- a temperature increase of about 11°C from ground level to 500m above the earth's surface.

The latter represents temperature inversion conditions in the atmosphere. The warm berg winds cause dry night-time conditions in the lower atmosphere. Night-time radiative heat loss and sinking motion from the upper atmosphere combine under these conditions to form a strong ground based inversion. The conditions in the inversion are generally calm and so there is little dilution of emitted pollutants. Emitted pollutants will rise until their "initial buoyancy and vertical momentum are dissipated"[53,54]. Further the layer prevents mixing from the atmosphere above. This effectively means that pollutants are being emitted into a smaller airmass where the air velocity is insufficient for dilution. This results in higher than normal pollutant concentrations.

4. METHODOLOGY

As mentioned previously, this is a source apportionment study using a receptor modelling approach. Source apportionment is the quantification of the relative contribution of each emission source to the pollutants collected at an ambient site (or receptor). To perform a source apportionment it is necessary to collect data about the sources of emissions and about the ambient pollutant levels. The data includes a breakdown of the chemical species making up the particles from the sources and the ambient locations.

The source apportionment is based on PM2.5 due to its importance in terms of visibility degradation and health (see Chapter 2). The basic methodology of the brown haze study was to collect PM2.5 samples on filters from various emission sources (identified by performing an emissions inventory) and ambient sites, have the filters analysed chemically, insert the chemical data into a receptor model to obtain a source apportionment of PM2.5, convert the PM2.5 source apportionment to visibility apportionment, and investigate the mechanisms by which the brown haze is caused.

4.1 Emissions inventory[71]

An emission inventory provides an inventory of primary emissions from the most important sources for a particular area. Emission inventories can be divided into three classes:

(i) **Gross estimation inventory** - Emission estimates are based on summary statistics for fuel consumption, industrial processing, etc. It is not very accurate and mainly used for nation-wide estimates.

(ii) **Rapid survey inventory** - The inventory is compiled for large point sources and through the use of reference documents for area sources. The inventory areas are often divided into zones. The method is reasonably accurate.

(iii) **Detailed source inventory** - The method was developed for use in mathematical atmospheric dispersion modelling. All point sources down to a certain emission level are included. Sources below this emission level are treated as area sources, and mobile sources are treated as a special category of area sources. All emissions are reported on a grid square basis.

The emission inventory used for this study lies somewhere between the first and second class of inventory. The inventory covers the Cape Town Metropolitan Area and is not divided into zones. The emission inventory was compiled for 1995. Emissions investigated were SO_2, NO_x, volatile organic compounds (VOCs), PM10 and PM2.5. SO_2, NO_x, and VOCs are precursors for secondary particulates and were thus included in the inventory. The emission inventory was used to identify the most important emitters. It was these emitters that were used in source apportionment. The inventory is discussed in detail in the "*Cape Town Brown Haze Study*"[71].

4.2 Source sampling

The methodology for source sampling was based on the work done by Mintek[10] and by the Desert Research Institute[11]. Details of the methodology are shown in Appendix A. Essentially sources were sampled using the techniques of either isokinetic sampling, resuspension sampling, or controlled combustion in a chamber. Sources that were characterised were:

- various soils
- road dust
- sea salt
- coal fired boiler
- oil fired boiler
- Caltex oil fired boiler
- Caltex gas fired boiler
- Caltex furnace
- Caltex fluidised catalytic cracker unit
- Kynoch Ammonium Nitrate emissions
- diesel combustion
- petrol combustion
- wood fires
- grass fires
- tyre burning

4.3 Ambient particulate sampling

Procedures used for ambient sampling are outlined in Appendix B and Appendix C.

4.3.1 Description of ambient sampling sites

Ambient particulate sampling took place at four sites. They are Wynberg, Goodwood, Table View and the Central Business District, and their location is shown in Figure 4.1. Detailed maps of the sampling sites are shown in Appendix D. The sites were chosen on the basis of there being existing air monitoring equipment at those sites, as well as all the necessary infrastructure, such as security and electricity. As indicated in Chapter 3, the sites also fall in four of the six meteorological zones identified in the Cape Town Metropolitan Area. A single sample was also taken in Guguletu, which is located near informal settlements.

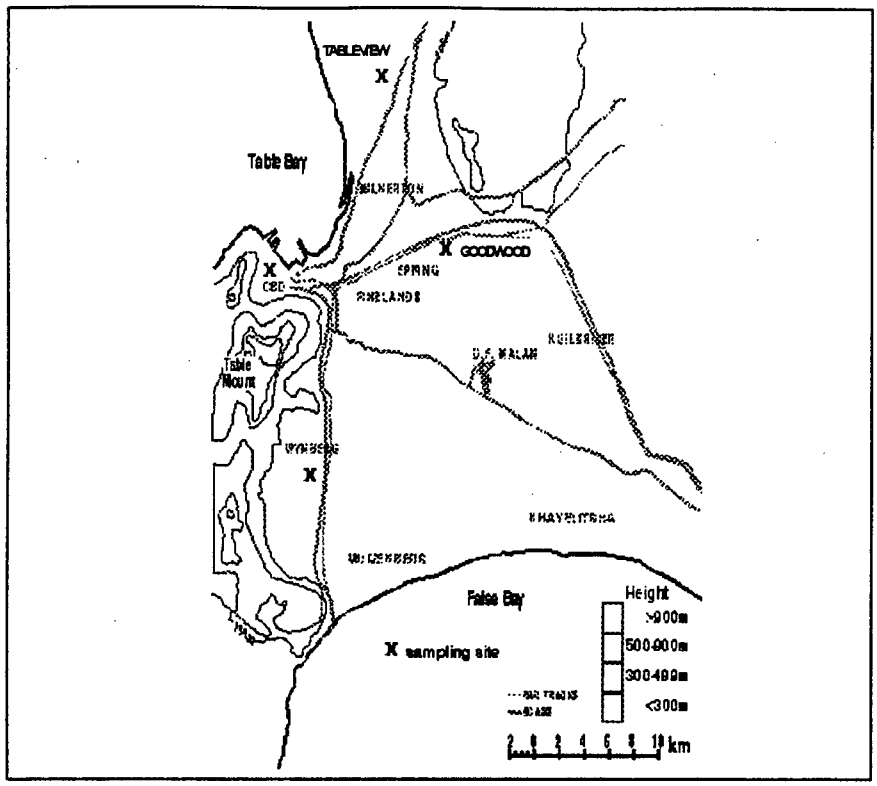


Figure 4.1 Location of the ambient sampling sites

A description of each site is given as follows:

Wynberg

Is located in a residential area a few hundred metres from a main road. Monitoring equipment at the site includes:

- PM10 continuous monitor
- PM2.5 Automated Cartridge Collection Unit (ACCU)
- NO_x monitor
- Ozone monitor

CBD

There are two monitoring sites which are located 100 metres from each other. The sites are at the City Hall and at the Drill Hall. Equipment at these sites include:

- PM10 continuous monitor
- PM2.5 ACCU
- NO_x monitor
- Non-methane hydrocarbon analyser
- Meteorological station

Table View

Is located in a residential area next to an infrequently used road. It is about a kilometre from the sea and is about two kilometres on the prevailing wind side (north-west) of a large refinery (Caltex) and fertiliser factory (Kynoch). Monitoring equipment at this site includes:

- PM10 continuous monitor
- PM2.5 ACCU
- NO_x analyser
- SO_2 analyser
- Meteorological station

Goodwood

It is located in a residential area. The equipment at this site includes:

- PM10 continuous monitor
- PM2.5 ACCU
- NO_x analyser

4.3.2 Sampling frequency and duration

Sampling was carried out for a period of one year from July 1995 to June 1996. Sampling was predominately during brown haze episodes which are characterised by temperature inversions and windless conditions occurring predominantly between April and September. A few samples were collected on clear days for comparison.

Sampling was 12-hourly during haze episodes, but in some instances was extended to 24 hours if there was insufficient filter loading on the filters to be able to perform chemical analysis. Sampling was from midnight to midday and/or midday to midnight. During clear days sampling was allowed to continue until the filters had been loaded enough for analysis. Filter loading was estimated from the continuous PM10 readings.

4.4 Brown haze episode prediction

There are a number of factors that are considered in predicting an episode:

- The Weather Bureau at Cape Town International Airport predicts a temperature versus height profile in the atmosphere a day in advance. This gives a prediction for the temperature inversions which characterise the haze.
- The Weather Bureau also gives six hourly predictions of wind speed and direction from 00h00 for three days at a time. This is important because calm conditions are important for haze formation. Wind tends to blow away pollutants and break up the temperature inversion.
- Synoptic charts also give an indication of the weather patterns. Generally a coastal low pressure system over the peninsula gives an indication of calm conditions in winter months.

It was arranged that the Cape Town Weather Bureau send daily weather prediction reports to brown haze researchers. Taking into account the above factors it was possible to predict brown haze episodes with reasonable success.

4.5 Other ambient data

Each of the sampling sites not only measures particulates but also gives ambient data for a variety of gases, and there is also measurement of wind speed, direction, and temperature. This data was received in hourly average form from the Cape Town City Council. A rigorous calibration process based on EPA procedures is followed at the sampling sites. This consists of a multi-point calibration every three months on all analysers and a level 2 single point calibration every second week. Calibration equipment and gases are audited and accredited by ESKOM.

4.6 Analytical methods

Samples were collected on three types of filters determined by the type of analysis that was required. In all instances sampling was carried out on teflon filters and quartz filters (on 16 occasions polycarbonate filters were used instead of Teflon filters due to a supply delay). In some instances sampling was also carried out on polycarbonate filters. Qualitative Scanning Electron Microscope (SEM) analysis was performed on some polycarbonate filters. Table 4.1 summarises the types of filters used.

Table 4.1 Analytical techniques applied to filter substrates

Filter Type	Analytical technique	Resulting information
Teflon	X-Ray Fluorescence (XRF) Weighing	Concentrations of elements from Mg to Pb in the periodic table
Quartz	Ion Chromatography Thermal Optical Reflectance	Water soluble SO_4^{2-}, Cl^-, NO_3^-, Ca^{2+}, K^+, Mg^{2+}, Na^+, NH_4^+ Organic and elemental Carbon
Polycarbonate	Electron Microscopy X-Ray Fluorescence (XRF)	Particle size distribution, qualitative particle by particle analysis Concentrations of elements from Mg to Pb in the periodic table

These analytical techniques are discussed in Appendix E.

4.7 Apportionment

Apportionment was carried out using the Chemical Mass Balance Model (described in Chapter.2). This Model was originally developed by John G. Watson at the Oregon Graduate Centre[46]. It has since been refined and accepted as a source apportionment tool by the United States Environmental Protection Agency. It has been used extensively in studies in the

United States (Table 2.2). Furthermore, as discussed in Chapter 2, this model is suitable for the episodic sampling carried out in this study.

The output of the model is the contribution of each source to the PM2.5 chemical species sampled over a certain period at a certain ambient site. The source apportionment of PM2.5 for a particular ambient site will vary from day to day due to changes in the meteorology. The apportionment was therefore averaged over the episodes measured.

4.8 Validation

An important aspect of the study was the data validation process. The objective of data validation was to identify deviations from measurement assumptions and procedures during data collection and processing. This applies to the entire study so data validation was carried out at each of the major steps in the source apportionment. These are sample collection, chemical analysis and modelling.

The first assumption of sample collection in this study was that only PM2.5 was collected on to the filters when samples were taken. To make sure this was true the flowrate through the PM2.5 impactor needed to be checked. The TEOM unit had a built in flow controller and it recorded the total volume flow rate through the filters. Samples where this flowrate deviated from 13.7 l/min were flagged as being suspect. PM10 was measured at the same time that filter samples were being taken. Filter samples were flagged as suspect if the calculated PM2.5 concentration was greater than the PM10 concentration.

Chemical data was validated by the different organisations carrying out chemical analysis. This was done mainly by repeat tests. Once all the data from the chemical analysis was received some tests were performed on the data to further check its validity. These were:[47]

- The chemical species masses from chemical analysis were compared against the gravimetric mass of the filter. The check was passed if the gravimetric mass was within acceptable limits.
- The concentration of Sulpur in SO_4^{2-} measured by ion chromatography (IC) should be less than or equal to the Sulphur element measured by XRF. The potassium ion should be less than potassium measured by XRF, the same for the calcium ion and the calcium element. This is because the water soluble concentration measured by IC is less than the total elemental concentration measured by XRF (which includes both soluble and insoluble species).
- A linear relationship should exist between lead and bromine.

Data validation for the modelling apportionment was based on the seven steps proposed by the EPA[46] these are:

(a) Determine the general applicability of the CMB model to the application at hand.
(b) Set up the model by identifying and assembling the source types, source profiles, and receptor concentrations for model input. Make a preliminary application of the model to these data.
(c) Examine the model's statistics and diagnostics to identify potential deviations from the model assumptions.
(d) Evaluate problems that might result from problems with model input data deviations from model assumptions.
(e) Make any model input changes which can be justified to resolve the identified problems.
(f) Assess the stability of the model results and their consistency with the preliminary analyses.
(g) Evaluate the model results by comparing them with other receptor or dispersion model results and reconcile any differences.

5. SOURCE PROFILES

Source profiles were measured for the major air pollution sources in the Cape Town Metropolitan Area (see Figure.5.1), based on the emission inventory. Table 5.1 gives a summary of the emmision inventory carried out during the study[71].

Figure 5.1 Boundaries of the emission inventory

Table 5.1 Summary of primary atmospheric emissions in Cape Town (%)

	EMISSION %				
	SO_2	NO_x	VOCs	PM10	PM2.5
Residential					
Coal	0.6	0.1	0.1	0.3	0.3
Paraffin	1.1	0.2	0.0	0.1	0.1
LPG	0.0	0.1	0.0	0.0	0.0
Wood	0.0	1.9	4.3	16.3	21.8
Transport					
Petrol vehicles	4.9	59.4	60.9	4.9	7.8
Diesel vehicles	8.4	6.3	8.3	16.8	29.4
Brake and tyre wear	0.0	0.0	0.0	0.7	0.0
Paved roads	0.0	0.0	0.0	18.5	3.5
Unpaved roads	0.0	0.0	0.0	12.1	2.3
Aviation fuel	0.1	2.0	0.8	0.3	0.5
Ship diesel	0.2	2.6	0.1	0.4	0.8
Ship bunker oil	3.6	2.1	0.2	0.6	1.0
Industry and commerce					
Coal	14.7	6.6	0.0	8.5	6.5
HFO	23.9	2.5	0.0	4.0	6.7
FFS fuels	0.5	0.5	0.0	0.9	1.5
Diesel	0.3	3.2	0.1	0.5	1.0
Power paraffin	0.1	0.0	0.0	0.0	0.0
Caltex	33.8	5.8	3.0	3.8	5.0
Kynoch	0.0	3.1	0.0	0.2	0.4
Athlone power station	7.0	3.2	0.0	4.0	3.1
Other					
Tyre burning	0.7	0.1	0.2	2.9	2.8
Medical incineration	0.0	0.0	0.0	0.0	0.0
Wildfires	0.1	0.4	1.2	4.0	5.3
Other VOCs	0.0	0.0	28.2	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0

Source sampling was carried out using a number of methods ranging from isokinetic stack sampling to the resuspension of dust samples. Once modelling was carried out, however, it became evident that results of the apportionment could have been improved by producing multiple source samples. This was largely not possible in the study due to budgetary constraints. Multiple samples could have given a better understanding of the variability of sources and therefore a more accurate assessment of the uncertainties of the source profiles.

Total particulate masses were calculated for each source sample by:

- summing organic carbon, elemental carbon, anions not measured by XRF, cations, and all the elements measured by XRF.
- multiplying the organic carbon mass by 1.2 to take into account organic hydrogen and organic oxygen.
- assuming that silicon, aluminium, iron, vanadium, and calcium exist as oxides.

A source can be regarded as acceptable if the ratio of calculated to weighed mass ranges from 75% to 135%. For those sources which do not lie in this range, a larger degree of uncertainty was taken into account in the modelling.

Appendix F contains a graphical representation of the mass fraction of each chemical species in the source profiles. Each of the groups of source profiles are discussed in the sections that follow.

5.1 Oil-fired boilers

Samples were taken from two oil fired boilers in this study. The first was at African Products and was of moderate output. The second sample was from a boiler firing oil at the Caltex Petroleum Refinery. For the African Products boiler the calculated mass was 56% of the weighed mass. This ratio is low and was cause for concern in modelling. For the Caltex boiler the calculated mass was 90% of the weighed mass, which is within acceptable mass validation limits. The composite of these two profiles was also generated for modelling purposes by taking the arithmetic mean of the two profiles.

Heavy Fuel Oil boilers are expected to show significant proportions of aluminium, silicon, nickel, vanadium, sulphur, organic carbon and elemental carbon, with vanadium being a recognised trace element for oil firing. The two profiles show differences in the proportions of these main constituents. These differences are expected as Caltex fires fuel oil that is slightly different in composition to commercially available fuel oil. The firing conditions of the two boilers were also different, with the Caltex boiler firing the fuel oil at a higher temperature. The Caltex boiler has a better combustion as it produces a lower proportion of elemental carbon.

5.2 Crustal material

Crustal samples of Wynberg dust, Table View dust and city road dust were taken in the study and resuspended onto filters. These were taken to represent the crustal material in the vicinity of the sampling sites. For the three crustal material samples the calculated masses were all between 80% and 100% of the weighed masses.

Crustal material shows high proportions of aluminium, silicon, calcium and iron. The three crustal profiles measured, show differences in the proportions of these elements. The aluminium to silicon ratio varies for the three samples. Table View soil has an appearance similar to beach sand which is why it has the highest silicon value of the samples. The Road dust sample has the highest aluminium value and has higher values in other trace metals such as zinc, nickel, iron, copper and lead are high in this profile due to the motor vehicle influence. The Wynberg sample also shows a high iron content which is expected because the soil found here is a reddish colour indicating the presence of iron oxide.

5.3 Caltex Refinery catalyst dust

Besides the crustal material mentioned above, a resuspension sampling method was used to gain a profile of the catalyst dust from the Caltex oil refinery. The calculated mass for this source was 75% of the weighed mass.

This profile was similar to the crustal material in that it had a large proportion of aluminium and silicon. A trace element for catalyst dust is lanthanum which is higher in this profile than in other source profiles.

5.4 Wood burning

Wood burning profiles were generated for Port Jackson and Rooikrantz wood burning. The calculated mass for both samples was between 90% and 100% of the weighed mass.

The wood profiles show a high mass fractions for potassium, chlorine, and organic and elemental carbon. High potassium and chlorine are generally associated with wood burning and the high carbon values are as a result of the fact that wood is an organic fuel.

5.5 Grass and tyre burning

Source profiles were also generated for grass and tyre burning. Grass burning is mainly a summer phenomenon and is not expected to effect the winter ambient samples much while tyres are burnt in the Cape Town Metropolitan Area for warmth and for scrap metal. The calculated tyre mass is over 90% of weighed mass, which is acceptable under the mass validation criteria. The calculated mass for grass burning is 143% of the weighed mass, which may mean that the filter sample was contaminated in some way.

The tyre profile is high in aluminium, silicon, iron, and organic and elemental carbon. Tyre burning does not appear to produce as much chlorine as vegetative burning, but does have a large high-temperature elemental carbon component which is consistent with the black smoke observed from a tyre fire, and the high calorific value of tyres as a fuel.

The grass burning profile is similar to the wood burning profiles discussed above but with a lower potassium value.

5.6 Diesel vehicles

The diesel vehicle profile represents the emissions from the tail pipe of a diesel vehicle driving on an ECE urban driving cycle. The calculated mass of the diesel vehicle sample was 90% of the weighed mass.

The diesel profile is significant in sulphur, organic and elemental carbon. Diesel vehicles are often associated with emitting "black soot" and thus it is expected that there will be elemental carbon in the profile. The diesel vehicle sampled in the study was a well maintained vehicle that did not smoke badly. The Diesel2 profile seen in Appendix F was used in modelling to assess the effect of small changes in the elemental carbon values on modelling. The high sulphur mass fraction is as result of the sulphur found in diesel fuel.

5.7 Leaded petrol vehicles

Petrol vehicle profiles were generated using the same methods as for diesel vehicles. The vehicle profiles analysed in the study had calculated-to-weighed mass percentages of 91% and 78%.

Petrol vehicles show high mass fractions for lead, bromine, organic and elemental carbon. In the study a well maintained and a poorly maintained vehicle profile were used. The main differences between them is the amount of organic and elemental carbon emitted relative to lead and bromine. The poorly maintained vehicle emits more of the carbon species due to poor combustion conditions and the combustion of small amounts of oil. Furthermore oil combustion produces trace metals which, however, are not seen here as they appear to be overshadowed in the profile by the high carbon species. The high values for the carbon species for the poorly maintained vehicle also cause a smaller mass fraction of bromine and lead in the poorly maintained vehicle. A composite profile of the two was made for modelling purposes.

5.8 Miscellaneous profiles

Ammonium nitrate, Portland Cement and marine profiles were used from the EPA source profile database to supplement the profiles measured in the study. These were profiles that were expected to be needed in modelling. A coal flyash sample from the Vaal Triangle study was also used as this was also expected to be necessary.

In addition to these profiles secondary sulphate, nitrate, organic and elemental carbon were used.

5.9 Modelling

The profiles mentioned above were generated for input into the chemical mass balance model. The profiles used can be split into three types, namely: primary, secondary and composite. Primary profiles are profiles that represent the primary emissions from sources discussed above and include the various vehicles, boilers, wood burning and the like. Composite profiles were also generated using the arithmetic means of similar primary profiles and these include composite profiles of petrol vehicles, wood burning, oil boilers and crustal material. These are useful in modelling when it becomes difficult to separate like sources. Very often it is easier to model average (or composite) profiles. Secondary source profiles are the profiles for sulphate, nitrate and organic carbon. These represent profiles for particulates that are not directly emitted but are formed from the reactions of gasses in the atmosphere. Table 5.2. shows the various profiles giving their type and the code used for the profile when modelling.

Table 5.2 Source profile codes for modelling

Modelling Code	Description	Profile Type
APOBL	African Products oil fired boiler	Primary
CALOB	Caltex oil fired boiler	Primary
WBDST	Crustal material from the Wynberg sampling site	Primary
TVDST	Crustal material from the Table View sampling site	Primary
RDUST	Crustal material from paved roads	Primary
CALCT	Catalyst material from Caltex	Primary
RKBRN	Burning of Rooikrantz wood	Primary
PJBRN	Burning of Port Jackson wood	Primary
TYBRN	Burning of Tyres	Primary
GRBRN	Grass Burning	Primary
DIVEH	Diesel vehicles	Primary
SO4	Sulphate	Secondary
NO3	Nitrate	Secondary
MARI1	Sea Salt	Primary
KYLAN	Ammonium Nitrate	Primary
SASFA	Fly Ash from coal burning	Primary
PCEMT	Portland Cement	Primary
CRUST	Crustal Material	Combined
WBURN	Wood Burning	Combined
CRUSTC	Crustal Material and Fly Ash	Combined
OHC	Organic High Temperature Carbon	Secondary
OLC	Organic Low Temperature Carbon	Secondary
EHC	Elemental high temperature carbon	Primary
VEH1	Leaded petrol vehicle (well maintained)	Primary
PETVH	Leaded petrol vehicle (poorly maintained)	Primary
VEH2	Leaded petrol vehicle (average)	Combined
DIES2	Diesel vehicle	Primary
COMPB	Oil fired boiler	Combined

6. AMBIENT CONDITIONS

6.1 General trends

At the four sites used by the Brown Haze Study for sampling particulates, various meteorological and air pollutant levels are continuously monitored and 5-minute average values are recorded. The monitoring, recording, and validation of this data is maintained by the Scientific Services Branch of the Cape Town Municipality. The Municipality provided validated hourly data for each of the sites for the one-year particulate sampling period (July 1995 to July 1996). Table 6.1 summarises the meteorological and air pollutant data collected during the sampling period.

Table 6.1 Monitoring Equipment at Ambient Sampling Sites

	Goodwood	CBD	Table View	Wynberg
NO_2	yes	yes	yes	yes
NO_x	yes	yes	yes	yes
PM10	yes	yes	yes	yes
SO_2	no	no	yes	no
Hydrocarbons	no	yes	no	no
Ozone	no	no	no	yes
Relative Humidity	no	yes	yes	no
Wind speed	no	yes	yes	no
Wind direction	no	yes	yes	no

Table 6.2 indicates average hourly pollution levels for each of the monitoring sites. It is clear that the CBD has the highest average NO_x and NO_2 levels, but Goodwood has the highest PM10 average, although the variation from site to site is not great.

Table 6.2 Average hourly pollutant concentrations (July 1995-July 1996)

	Goodwood	CBD	Table View	Wynberg
NO_2 [µg/m^3]	37	69	21	8
NO_x [µg/m^3]	88	272	31	14
PM 10[µg/m^3]	29	26	23	21
SO_2 [µg/m^3]			13	
Hydrocarbons [µg/m^3]		136		
Ozone [µg/m^3]				26

Table 6.3 indicates the number of exceedences of internationally accepted health guidelines over the one-year period. High NO_2 levels, especialy at the CBD, are once again evident. The high CBD values are due to high vehicle densities in the CBD. It is interesting to note that the PM10 daily standard was never exceeded at the monitoring sites. SO_2 guidelines were only

exceeded on three occasions, excluding an abnormal sulphur fire incident.

Table 6.3 Number of health standard exceedences per pollutant (July 1995-July 1996)

Pollutant	Duration	Guideline	Goodwood	CBD	Table View	Wynberg
NO_2	annual	100 µg/m^3	0	0	0	0
	1-hour	200 µg/m^3	21	87	0	0
SO_2	annual	80 µg/m^3			0	
	24-hour	365 µg/m^3			0	
	10 min.	500 µg/m^3			3	
PM10	annual	50 µg/m^3	0	0	0	0
	24-hour	150 µg/m^3	0	0	0	0

Of particular interest is PM2.5 levels in Cape Town, over the sampling year, compared with the newly introduced US EPA PM2.5 standards. PM2.5 is not measured continuously, but was only measured on particular episodes. However during the episodes measured, the EPA PM2.5 standard of 65 µg/m^3 was never exceeded. Based on the average PM2.5:PM10 ratio during brown haze episodes (60%±17%), and the maximum daily PM10 level in Cape Town (>100 µg/m^3), statistically it is likely that the EPA PM2.5 daily standard has been exceeded in Cape Town. The yearly PM2.5 standard set by the USEPA is 15µg/m^3. Insufficient PM2.5 sampling data on non-haze days was available to be able to draw any clear conclusions on Cape Town's exceedence of the EPA annual PM2.5 standard.

Analysis of the hourly data over the one-year period indicates trends which may help explain the causes of the brown haze:

- In the CBD PM10 often peaks around 11-12 am, about one to two hours later than the NO_x peak. At the other sites PM10 peaks around 8-11 am, at the same time as the NO_x peak (which is considerable lower than the CBD NO_x peak). This indicates that there may be secondary particulate formation in the CBD.
- Smaller PM10 peaks also often occur in the evening at 7-10 pm. This could be due to the afternoon traffic and/or the starting of domestic fires. The Goodwood site peaks can be attributed to late night shopping at the N1 City shopping centre.
- High pollution levels are usually associated with low wind speeds, but on a number of occasions, under strong southerly winds, the Goodwood and Table View sites experience high PM10 levels (but low NO_x levels). This is thought to be wind-blown dust from the Cape Flats.
- There is no observable correlation between humidity levels and pollution or particulate levels.

6.2 Ambient conditions during particulate sampling

During the sampling period of the Brown Haze Study, one of the objectives was to sample as many brown haze episodes as possible. Table 6.4 shows the twenty days during the study with the highest PM10 daily average at the Goodwood site. This site was chosen because it registered the highest PM10 daily average of the three sites over the sampling period. Table 6.4 also indicates that filter samples were taken on six of these days including three of the five days with the highest daily averages.

Table 6.4 Highest twenty PM10 daily averages at Goodwood (July 1995-July 1996)

Date	PM10 Daily Average [$\mu g/m^3$]	PM10 Hourly Maximum [$\mu g/m^3$]	Filter Sample Taken
29-Oct-95	97.50	366	N
30-Apr-96	91.92	304	Y
27-May-96	89.71	224	Y
21-Jun-96	80.17	224	Y
26-Apr-96	77.67	158	N
14-Jul-95	75.13	283	Y
8-May-96	73.58	165	Y
5-Jun-96	69.46	180	N
30-Oct-95	64.13	111	N
28-Oct-95	63.25	145	N
18-Jan-96	60.79	171	N
17-Nov-95	60.17	117	N
19-Jun-96	57.38	206	N
19-Sep-95	56.63	105	N
15-Aug-95	55.25	175	N
17-May-96	52.75	115	Y
16-May-96	52.63	110	N
19-May-96	52.63	173	N
22-Sep-95	52.58	104	N
28-Mar-96	52.00	108	N

Sampling was performed on 29 occasions at Goodwood during the study. Figure 6.1 and Figure 6.2 show plots of daily average and daily maximum PM10 for the sampling period. The symbols indicate days on which filter samples were taken.

The figures also show that the period from April to October is when elevated PM10 values occur. The noticeable peaks in PM10 daily average and maximum shows that pollution in the Cape Town Metropolitan Area is episodic rather than continuous. This supports the assertion made in Chapter 3 that high pollutant levels are caused by favourable meteorological conditions.

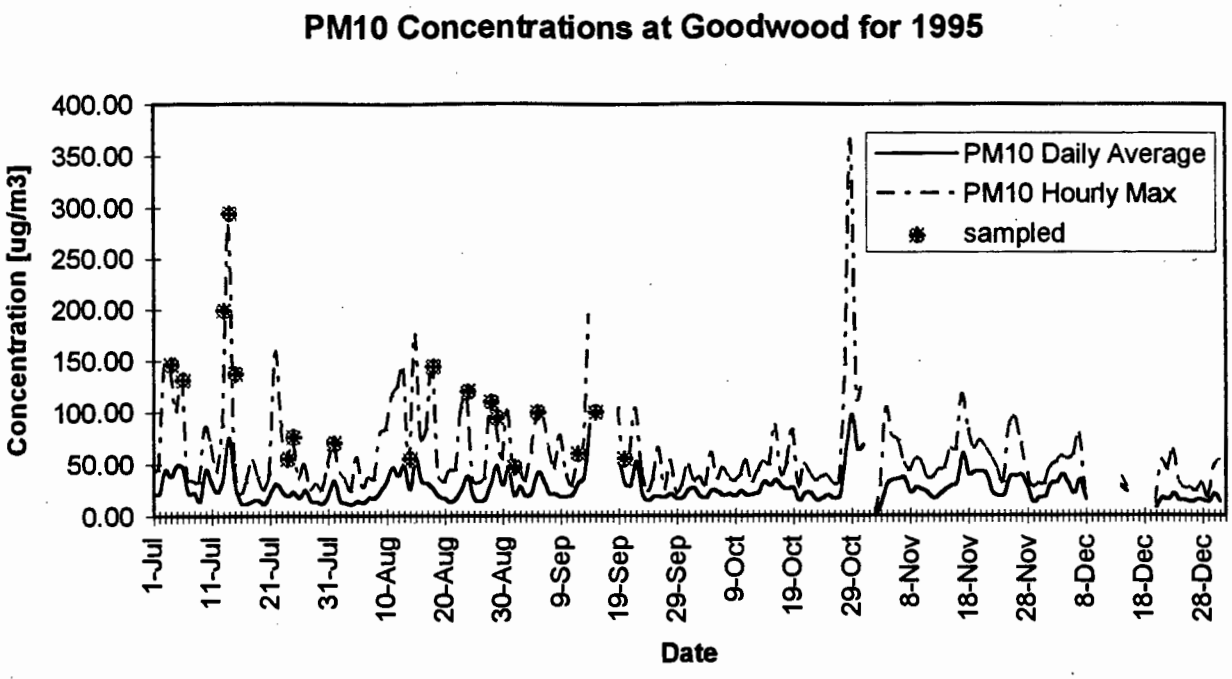


Figure 6.1 Hourly PM10 concentrations at Goodwood for July - December 1995

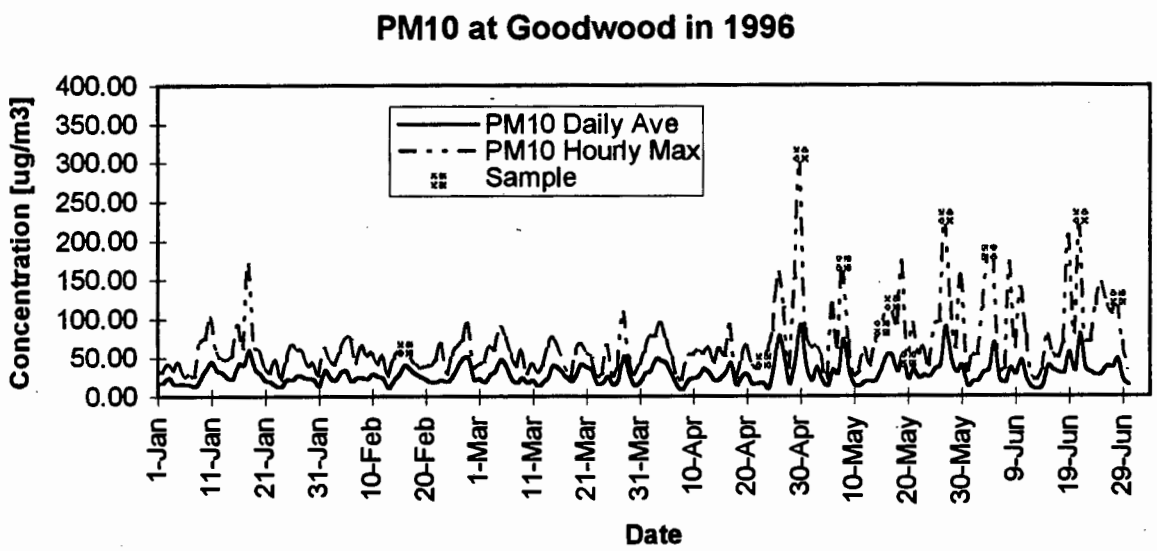


Figure 6.2 Hourly PM10 concentrations for Goodwood for January - June 1996

6.3 PM2.5/PM10 ratio

In Chapter 4 a description was given of the monitoring equipment at each of the four ambient sampling sites. The particulate sampling capabilities at the sites included both continuous PM10 monitoring and the sampling of PM2.5. When brown haze episodes were sampled PM2.5 was collected onto filters which were later weighed. Weight of the filter samples divided by air drawn through the filter gave time-averaged PM2.5. Generally PM2.5 was averaged over 12 or 24 hours. These could be directly compared with continuous PM10 data by averaging PM10 data for the same time as filter samples were taken.

Table 6.5 shows the mean PM2.5 to PM10 ratios for the four sampling sites along with the standard deviations of the data.

Table 6.5 Mean and standard deviations of the PM2.5:PM10 Ratio at the sampling sites (July 1995-July 1996)

Sampling Site	Mean PM2.5:PM10	Standard Deviation
Goodwood	0.60	0.17
CBD	0.57	0.21
Wynberg	0.59	0.22
Table View	0.61	0.14

The PM2.5 to PM10 ratio indicates what proportion of PM10 is made up by PM2.5. As was mentioned in Chapter 2 PM2.5 is associated with emissions from combustion sources so a high PM2.5:PM10 ratio indicates that a large proportion of the ambient PM10 is due to contributions from combustion sources. The large standard deviations of the data indicate that the ratios vary considerably from day to day.

An analysis of this data can give an indication of the mechanisms of different haze episodes. For instance on 30 April 1996 (the day with the highest PM10 daily average on which a filter sample was taken according to Table 6.4) the PM2.5:PM10 ratio was 0.27 at both Goodwood and the CBD, and 0.39 at Wynberg. These ratios are low and indicate that the particulate pollution consisted of mainly coarse particles (indicating geological material). This episode had shown characteristics differing form the norm for a brown haze episode as the PM10 had peaked at midday and the NO_x values had remained low. This further indicated that the high particulate levels were not caused by emissions from combustion sources. The high pollutant values were probably caused by geological dust transported by berg winds.

In contrast to this a sample taken from 00h00 to 12h00 on 25 July 1995 gave the high values for PM2.5:PM10 with all sites except Table View recording above 0.80. This indicates that PM10 concentration was made up mainly of PM2.5 or contributions from combustion sources. Appendix H shows that during the sampling period there was a typical morning PM10 peak

associated with pollutants being trapped under a strong temperature inversion. The high NO_x values at the same time indicate that combustion sources were contributing significantly to pollutant concentrations.

Thus this ratio can be used as a validation tool when assessing the outputs of the Chemical Mass Balance model. From this qualitative analysis one would expect a large proportion of particulates to be apportioned to geological material on 30 April 1996 and a small proportion on 25 July 1995.

7. RESULTS OF THE APPORTIONMENT OF THE BROWN HAZE

7.1 Data validation

Data validation was out carried at each stage of the research process. Validation included:

(a) Independent calculation of the source and ambient profiles to be used for the modelling.
(b) Comparing the calculated and weighed masses on each filter.
(c) Checking known ratios of elements, known tracer elements, and duplicate analysis results.
(d) Checking statistical performance measures of the model.
(e) Matching the output of the modelling with factors such as wind direction and location of major pollution sources.

Following data validation, only those episodes that satisfied all validation criteria were selected for modelling. Table 7.1 shows the PM2.5 concentrations of episodes that were modelled at each of the sites. Six episodes were modelled at Goodwood, and Drill Hall, five at Wynberg and four at Table View. The 16/02/96 was a clear day.

Table 7.1 PM2.5 concentrations of episodes modelled [$\mu g/m^3$]

Date Sampled	Goodwood	Drill Hall	Wynberg	Table View	Guguletu
14/07/95 am			29	19	
14/07/95 pm	51	29	25	27	
25/07/95 am		51	32		
18/08/95				13	
16/02/96	9	12			
30/04/96	23	17	18		
08/05/96	35	34	24		
27/05/96	39	25		17	
04/06/96	22				
22/08/96					76

7.1.1 Comparison of calculated and weighed masses on each filter

Table 7.2 shows calculated mass as a percent of weighed mass on the filters chosen for modelling. The calculated mass is determined in a similar way to that for the source samples. This value is used as a validation tool for the chemical analysis. The criterion is that the calculated mass should be between 75% and 135% of the weighed mass.

Table 7.2 Calculated mass as a percent of weighed mass for episodes modelled

Date Sampled	Goodwood	Drill Hall	Wynberg	Table View	Guguletu
14/07/95 am			133	121	
14/07/95 pm	105	130	134	132	
25/07/95 am		103	127		
18/08/95				104	
16/02/96	98	101			
30/04/96	89	109	80		
08/05/96	99	97	120		
27/05/96	87	102		112	
04/06/96	103				
22/08/96					80

Appendix I gives details of the concentrations of the various elements at the sampling sites. From this data it is evident that approximately 70% of the mass on the ambient filters is made up of carbon. Table 7.3 shows the average percentage contribution of carbon to the filter mass along with the standard deviation of this value over the filter samples.

Table 7.3 Carbon contribution to filter mass

Site	Average Carbon to Total Mass ratio [%]	Standard Deviation [%]
Goodwood	71	7
Drill Hall	73	8
Wynberg	72	9
Table View	68	10

7.1.2 Known element ratios, tracer elements, and duplicate analysis results

The ratio of lead to bromine should be relatively constant as they are mainly produced by vehicles, and vehicles emit these elements in a fixed ratio. Theoretically this ratio should be 1.3

Figure 7.1 shows a plot of lead against bromine for all ambient filters. The slope of the best fit line is 1.7, and together with the small spread of data, give confidence in the data.

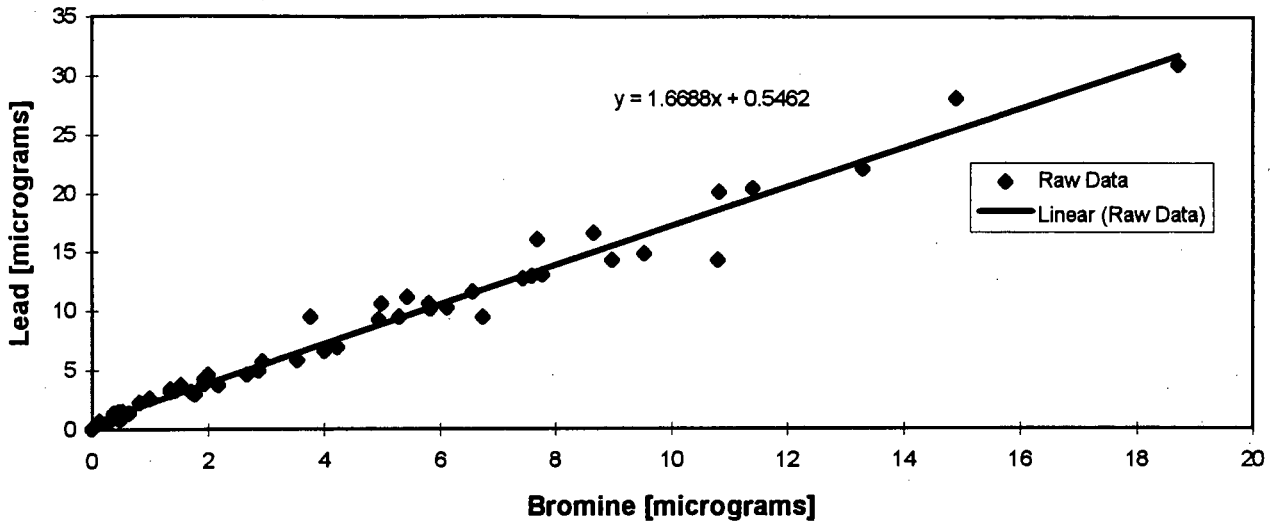


Figure 7.1 Lead vs bromine on ambient filters

The sulphate ion and the potassium ion concentrations showed a good correlation with the values obtained for the sulphur and potassium element by XRF analysis. However, the magnesium and sodium elements did not compare favourably with the sodium and magnesium ion results. This, however, was expected as the XRF analyses for these elements are considered qualitative because they are close in atomic number to the XRF detector window which is made of beryllium. The chlorine element by XRF and the chlorine ion by ion chromatography did not correlate well. No trend was found for their dissimilarity and very often they were not used as fitting species in modelling. Another problem experienced with the ions was that due to supply problems the manufacturers of the quartz filters were changed towards the end of the study. The new filters appeared to have a high background of the calcium ion and the sodium ion, which increased the uncertainties associated with the measurement of the ionic species.

The elemental results were considered very good especially in light of the fact that the Teflon filters were analysed three times for elements by XRF.

7.1.3 Statistical performance measures of the model

The Chemical Mass Balance version 7 receptor model used to apportion ambient particulates to their sources has certain statistical performance measures to assess the accuracy of the apportionment. These performance measures are described in Appendix G. Chi square is one of the most important performance measures, and should be under 4.0 for an adequate model fit. Percent mass is another useful output, which indicates the model calculated PM2.5 concentration as a percent of the measured concentration. Modelled episodes were only accepted if chi-square was less than 4.0 and the calculated mass was within 20% of the

weighed mass. Chi square and percent mass are indicated in the results in Table 7.4, as well as in Appendix J.

7.2 Modelling results

7.2.1 Chemical Mass Balance Model results

Table 7.4 shows PM2.5 source apportionment results for each modelled episode at each site. Air pollution and meteorological data for the episodes modelled is given in Appendix H, detailed PM2.5 data is given in Appendix I, and details of the modelling runs can be seen in Appendix J. The apportionment was split up into the contributions of crustal material, diesel vehicles, petrol vehicles, wood burning, sea salt, boilers, sulphate, nitrate and carbon. The percent mass and chi squared are goodness of fit modelling parameters as discussed above.

The following factors must be considered when interpreting the modelling results:

(a) The crustal group represents the contributions of all geological dust sources including paved road dust.
(b) The petrol vehicle source group is represented by the contribution of well maintained and badly maintained petrol vehicles. Either a composite profile was used in modelling or the sum of the two profiles was used.
(c) The wood burning group represents the contribution of all the wood and grass burning sources.
(d) The boiler source group represents the contributions of both oil and coal fired boilers. This includes emissions from the Caltex refinery and from the Athlone power station. It was not possible to model these sources individually as they did not have unique characteristics.
(e) The contribution of the Kynoch Fertiliser Factory were indicated to be insignificant.
(f) No unique chemical characteristic was given by tyre burning. Tyre burning was indicated by the model to be insignificant, but with a high degree of uncertainty.
(g) The individual sulphate and nitrate groups are secondary sulphate and nitrate.
(h) The carbon source group represents the residual organic and elemental carbon species from modelling. Also significant to the apportionment is the carbon group. Some of the carbon may be secondary in nature, but typical reaction rates of organic carbon indicate that it is unlikely that much of the carbon is secondary carbon. It is likely that a significant portion of the organic carbon derives from industrial process emissions.

Table 7.4 PM2.5 source apportionment results (%, except chi square)

Date	14/07/95	14/07/95	25/07/95	18/08/95	16/02/96	30/04/96	05/08/96	27/05/96	06/04/96
Tableview									
Crustal	6	5		4				6	
Diesel Vehicles	40	40		14				33	
Petrol Vehicles	6	10		3				11	
Woodburning	11	12		16				17	
Sea Salt	3	0		5				9	
Boilers	13	0		16				0	
Sulphate	4	4		32				7	
Nitrate	7	8		4				5	
Carbon	22	34		0				16	
% mass	112	113		94				104	
Chi Square	2.77	2.51		3.81				4.45	
Drill Hall									
Crustal		1	2		7	13	3	1	
Diesel Vehicles		60	43		50	13	60	50	
Petrol Vehicles		36	27		21	17	29	32	
Woodburning		10	11		12	10	16	14	
Sea Salt		0	0		2	0	0	0	
Boilers		0	1		0	0	0	0	
Sulphate		1	13		10	30	5	4	
Nitrate		2	5		2	1	6	3	
Carbon		0	18		17	33	0	0	
% mass		110	120		121	117	119	104	
Chi Square		2.51	0.67		2.76	2.42	1.65	2.29	
Goodwood									
Crustal		1			4	16	4	3	2
Diesel Vehicles		52			16	49	63	43	52
Petrol Vehicles		22			10	29	23	40	39
Woodburning		14			28	19	14	16	7
Sea Salt		0			9	0	3	0	1
Boilers		0			0	0	5	0	0
Sulphate		2			11	21	6	6	5
Nitrate		4			3	3	6	2	3
Carbon		27			0	0	0	0	0
% mass		122			81	137	124	110	109
Chi Square		3.26			3.04	4.77	3.17	3.23	3.43
Wynberg									
Crustal	0	2	3			29	5		
Diesel Vehicles	47	37	41			3	43		
Petrol Vehicles	33	24	35			9	37		
Woodburning	8	19	14			26	26		
Sea Salt	0	0	3			0	0		
Boilers	4	1	0			0	0		
Sulphate	1	1	8			31	4		
Nitrate	2	0	4			1	3		
Carbon	9	5	8			17	0		
% mass	104	89	116			116	118		
Chi Square	2.05	3.12	3.76			5.5	3.89		
Date	22/08/96								
Guguletu									
Crustal	0								
Diesel Vehicles	54								
Petrol Vehicles	10								
Woodburning	28								
Sea Salt	5								
Boilers	0								
Sulphate	2.4								
Nitrate	4.4								
Carbon	0								
% mass	104								
Chi Square	3.24								

8.2.2 Daily trends in the apportionment

14/07/95

Afternoon samples were modelled at all of the sites (second column of Table 8.4) while the morning samples (first column of Table 8.4) were modelled at Table View and Wynberg. There was an inversion and accompanying brown haze in the morning at this site, PM10 levels dropping off by about 12h00 at Goodwood, 14h00 at Drill Hall and 13h00 at Wynberg. The Goodwood site experienced secondary peaks during the afternoon and in particular from 17h00 thus resulting in the a high loading for the afternoon sample. The winds in the morning were from the north-east and were light ranging from 1 to 2 $m.s^{-1}$. In the afternoon the windspeed ranged from 1 to 3 $m.s^{-1}$ with the direction shifting between north-easterly and easterly.

At Table View the morning sample had a high contribution from diesel vehicles with boilers, fires and organic carbon also significant. The Wynberg sample is apportioned mainly to diesel and petrol vehicles. At these sites the afternoon/night-time samples show an increase in the contribution of wood burning, which could result from the lighting of domestic fires for cooking and warmth at night. Carbon concentrations increased from morning to afternoon at Table View and Drill Hall. This could be attributed to a number of factors. Secondary organic carbon particles could have been formed from the morning emissions, or another source of carbon could have entered the airshed during the day. This source of carbon would be associated with some sort of process industry emitting carbon that was not included in the modelling.

25/07/95

Samples were modelled at Wynberg and Drill Hall on this day. These samples were taken from 00h00 to 12h00 to coincide with a morning temperature inversion and high PM10 levels. The wind in the morning was light (1-2 $m.s^{-1}$) and from the north-east. Pollutants were dispersed by the afternoon as the wind speed steadily increased throughout the afternoon with the direction shifting to a more northerly direction.

The Drill Hall and Wynberg sites are dominated by contributions from diesel and petrol vehicles. Both sites experienced the relatively high sulphate contributions (with only the 30/04/96 having a higher sulphate contribution).

18/08/95

There was no strong inversion on this day and wind speeds were significant enough to disperse pollutants. This could then be considered a background sample at the Table View site. The predominant wind direction was between north and north-west.

The major contributor to PM2.5 at Table View was secondary sulphate followed by boilers and diesel vehicles. Sulphate is linked to the production of SO_2 which comes mainly from industry in the Cape Town Metropolitan Area. This, linked to the fact that the boiler contribution on this day is also high, shows that this day is unusual as the major contributor to pollution is industry

rather than vehicles. This could be as a result of the lack of inversion conditions. The lack of inversion conditions is also shown by the fact that the PM2.5 concentration is only 13 $\mu g/m^3$ for the sampling period.

16/02/96

This sample was a summertime sample and was modelled at Drill Hall and Goodwood. There are no inversion conditions in summertime, and this sample was taken to represent a non brown haze sample.

The Drill Hall site showed contributions from emitters (particularly vehicles) that are similar to those on haze days. This is expected since vehicles are considered to be the major emitters in the central city area. The Goodwood site shows a lower contribution from vehicles compared with haze days. There is an increase in sulphates, wood fires and marine aerosol compared with haze days. An increase in sulphates is expected due to the industrial SO_2 emitters in the area. Marine aerosol is associated with sea breezes. The wood burning increase is unusual given the summer months, and may be attributed to some local wood burning during sampling.

30/04/96

This day had the highest PM10 levels of the days sampled. It was not, however, a typical brown haze episode as was discussed in an earlier chapter. It is speculated that the haze was caused by dust transported from the inland regions of the country by northerly winds. This hypothesis is supported by the fact that the PM2.5:PM10 ratio on this day was 0.27 at Goodwood and Drill Hall and 0.39 at Wynberg suggesting that the particulates were mainly crustal. This pollution episode was also characterised by low NO_x levels indicating a possible lower contribution from vehicles. The poor fit of the data relative to other days suggests that sources outside those analysed in this study were the cause of the high pollutant levels. The high crustal material contributions suggests that there is a possibility that the source is crustal. Major contribution also appears to come from sulphates suggesting that the particulates are from a sulphate source.

08/05/96

Samples were taken here from 00h00 to 24h00 during this episode in which high PM10 values persisted throughout the day at Goodwood and Drill Hall. This was as a result of an inversion in the morning and light winds throughout the day (0.5-2.5 $m.s^{-1}$) with variable direction. The Drill Hall site also showed an evening PM10 peak that reached a maximum of 100$\mu g/m^3$ compared to the morning one that reached about 160$\mu g/m^3$.

At the three sites modelled (Drill Hall, Goodwood and Wynberg) the major contributor was diesel vehicles and to a lesser extent petrol vehicles and wood burning.

27/05/96

Samples were modelled at Drill Hall, Goodwood and Table View during this brown haze episode. A temperature inversion saw high PM10 values at Drill Hall and Goodwood while another late night peak occurred at Goodwood probably due to late night shopping in the area. Windspeed ranged from 1 to 4 $m.s^{-1}$ and ranged from a north easterly to a north westerly direction.

The main contributor to the particulates at all the sites was diesel vehicles followed by petrol and wood burning. It is noticeable that the petrol vehicle contribution at the Goodwood site is similar to that of diesel. This could be caused by petrol vehicles dominating the late night peak which is associated with late night shopping at a nearby shopping complex.

06/04/96

A sample was modelled from the Goodwood site on this day. There was a strong morning inversion with an associated peak of PM10 in the morning. Winds were light and north-westerly in the morning picking up from 1 to 3.5 $m.s^{-1}$ in the afternoon as they changed to a more southerly direction.

Vehicle contribution was over 90% with other emitters being insignificant relative to this.

22/08/96

On this day sampling was performed at Guguletu on a once off basis. One of the major problems with obtaining a sample here is security. Before a sample could be taken a secure area needed to be found so as not to lose the sampling equipment. For this reason sampling only started at 12h50 and extended through the night until 10h10. There was an obseved brown haze in the morning along with light and variable winds, however, there was no inversion the next morning as the wind speed had increased during the night. What was noticeable was that there appeared not to be haze conditions at the other sampling sites on this day. This suggests that the conditions here may be unique.

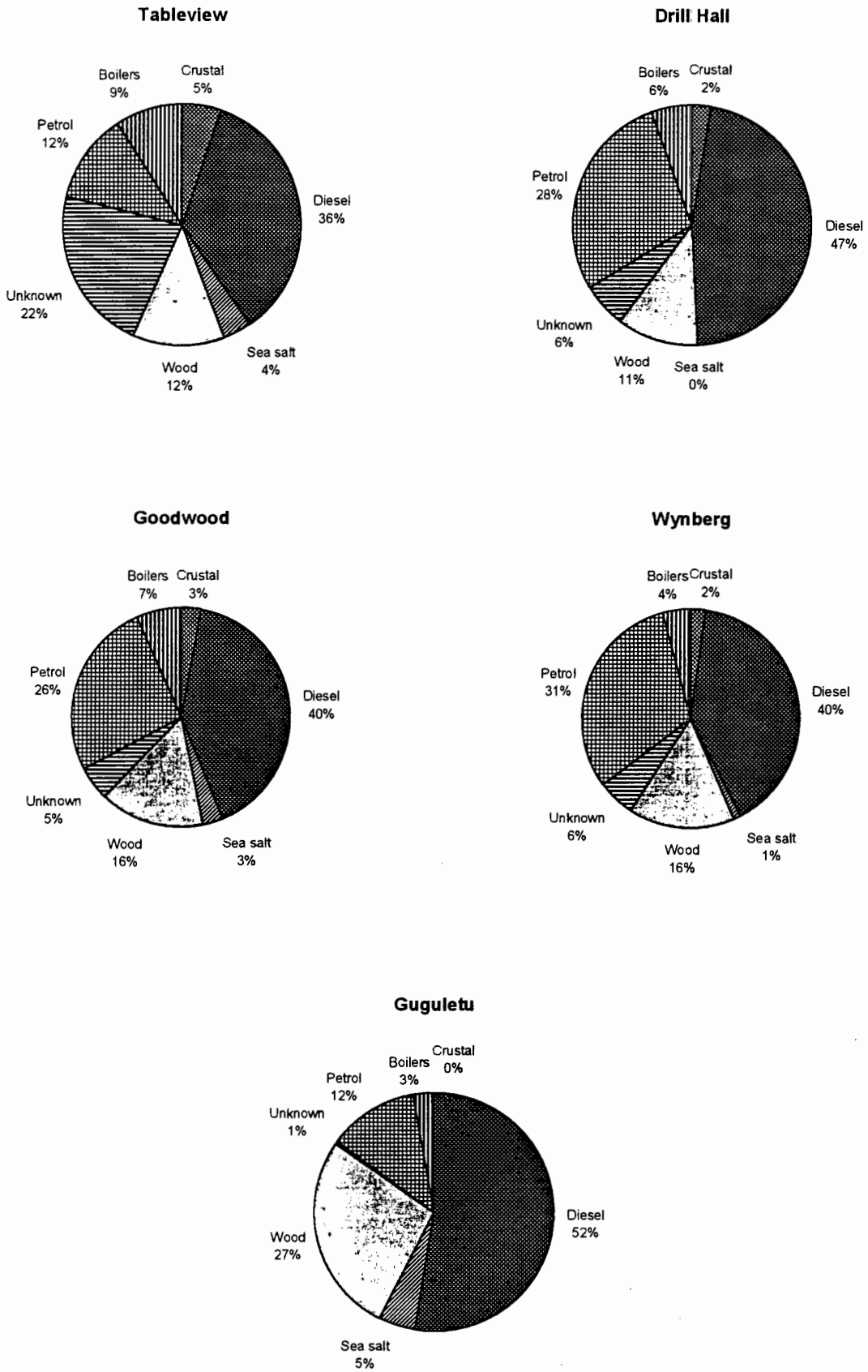
Major contributors to PM2.5 on this day were diesel vehicles and woodburning. The woodburning contibution was higher than at any of the other sites which was expected as the people living in the area rely on wood as a fuel for cooking and heating. If one considers Table.7.1 the concentration for this 10.4 hour period is 76 $\mu g/m^3$. This value was obtained from a sample that did not include the morning haze on this day. Visual observation suggested that the concentration of particulates was highest before the sample was taken. This suggests that high concentrations of particulates can be expected in this area.

7.2.3 PM2.5 source apportionment to primary sources

Secondary sulphate and nitrate will have originated from SO_2 and NO_x respectively. Secondary sulphate and nitrate can therefore be apportioned to primary sources by estimating their contribution to SO_2 and NO_x This has been done using the source inventory. This technique is not accurate as contribution to SO_2 and NO_x will vary depending on the height and time of emissions, as well as geographical location. Nevertheless, secondary sulphate and nitrate are not major contributors to the haze, and therefore inaccuracies in this technique will not significantly affect the source apportionment.

Figure 7.2 shows the final PM2.5 source apportionment results. It is evident that diesel vehicles are the largest single source of PM2.5. Petrol vehicles and wood burning are also significant contributors. The PM2.5 apportionment of each modelled episode is given in Appendix K.

Figure 7.2 Average PM2.5 apportionment for each site (%)



7.2.4 Visibility apportionment

PM2.5 was apportioned in this study so as to assess the visibility affect of the haze. The scope of this project did not include developing a visibility model as described in Chapter 2.6. Rather visibility was asessed on a more qualitative basis using equation (5) in Chapter 2.6. As was discussed in the Chapter 2.6 visibility models place a larger weight on the effects of, sulphates, nitrates, and organic and elemental carbon than on the rest of the material making up the particulates. For this reason applying equation (5) to the PM2.5 apportionment will show how the contribution of sources with high concentrations of these pollutants will change if visibility is considered instead of PM2.5.

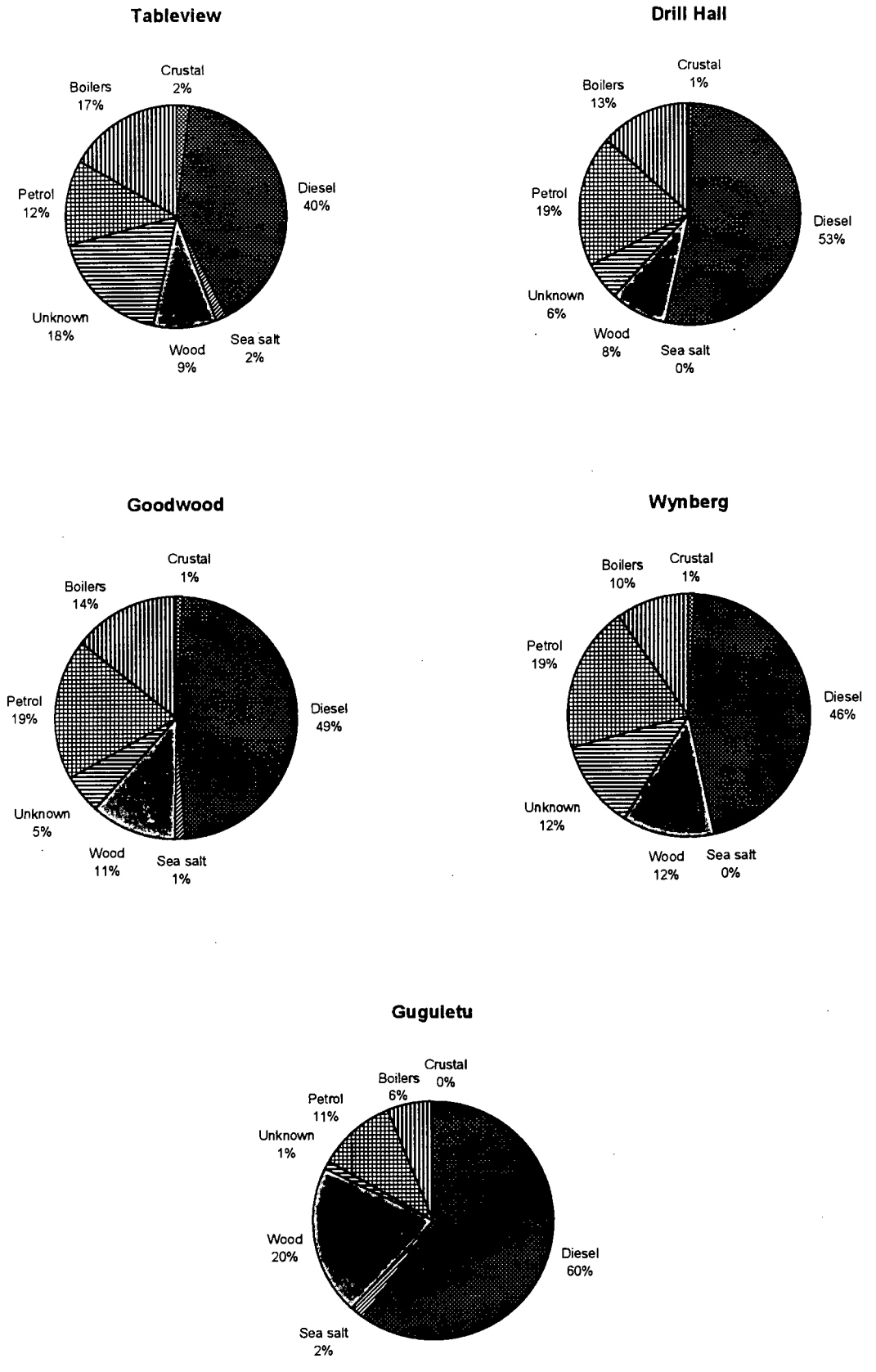
Figure 7.3 shows average visibility apportionment (contribution to the brown haze) at each site. Sulphates and nitrates were apportioned to sources using the same procedure as the final PM2.5 apportionment. The PM2.5 apportionment of each modelled episode is given in Appendix K.

Important factors to be considered when interpreting the results are re-iterated below:

(a) The crustal group represents the contributions of all geological dust sources including paved road dust.
(b) The petrol vehicle source group is represented by the contribution of well maintained and badly maintained petrol vehicles. Either a composite profile was used in modelling or the sum of the two profiles was used.
(c) The wood burning group represents the contribution of all the wood and grass burning sources.
(d) No unique chemical characteristic was given by tyre burning. Tyre burning was indicated by the model to be insignificant, but with a high degree of uncertainty.
(e) The contribution from the Kynoch Fertiliser Factory was indicated to be insignificant.
(f) The boiler source group represents the contributions of both oil and coal fired boilers. This includes emissions from the Caltex refinery and from the Athlone power station. It was not possible to model these source individually as they did not have unique characteristics.
(g) The carbon source group represents the residual organic and elemental carbon species from modelling. Also significant to the apportionment is the carbon group. Some of the carbon may be secondary in nature, but typical reaction rates of organic carbon indicate that it is unlikely that much of the carbon is secondary carbon. It is likely that a significant portion of the organic carbon derives from industrial process emissions.

Note also that due to problems with equipment at the sampling sites often NO_2 concentrations and relative humidity values had to be estimated when using equation (5).

Figure 7.3 Average visibility apportionment for each site (%)



Comparing figures 7.2 and 7.3 it can be seen that applying a visibility model to the PM2.5 apportionment increases the contibution of diesel vehicles. This is because the diesel source profile has high concetrations of sulphates, and organic and elemental carbon. The boiler contribution also increases due to the high sulphate concentration in the boiler profile. The contribution of crustal material to visibility is reduced mainly because crustal material does not have high concentrations of the species that have a high weighting in the visibility model.

7.3 Comparison with other cities

Table 7.4 shows a comparison of the Cape Town PM2.5 apportionment data results with studies in which fine particulates were apportioned. The Cape Town data was disaggregated in the same way that the other studies presented their results. Few PM2.5 apportionment studies are available at present, and so only three cities are included in the comparison. Coarse particle apportionment would skew results to crustal samples.

Table 7.4 Average apportionment

City	Cape Town	Duarte	Denver	Tuscon
Particle Size	PM2.5	PM3.5	PM2.5	PM2.5
Crustal Material %	4	23	-	25-31
Vehicles %	60	10	26	50-62
Wood burning %	14	-	12	-
Sea Salt %	2	-	-	-
Boilers %	2	-	>20	-
Sulphate %	6	16	-	5-11
Nitrate %	4	-	-	9
Carbon %	9	12	-	-

Table 7.4 shows that the contribution of crustal material is low in Cape Town relative to the other studies. This could be attributed to the large contribution from vehicles in Cape Town. The Tuscon study shows a high vehicle contribution as well as a high contribution from crustal material. Sulphate in Cape Town is lower than at Duarte and Tuscon suggesting that there is less of a contribution from industry in Cape Town than in these cities. This is supported by the higher contribution at Duarte. Cape Town's source apportionment appears to be more similar to those in UK cities where it has been found that vehicles contribute over 80% of PM2.5[70].

8 DISCUSSION AND CONCLUSIONS

8.1 Accuracy of the results

A number of potential sources of error exist. These include:

(a) Filter handling errors. Filters can be contaminated, damaged, and chemical species can volatilise. Necessary precautions were taken to minimise these to acceptable limits. Some filters had to be discarded due to damage during transport.
(b) Chemical analysis errors. The analytical techniques used for chemical analysis were all carried out according to international standards. However some chemical species were close to detection limits, resulting in significant degrees of uncertainty. This uncertainty is entered in the chemical mass balance model, and included with the statistical performance measures.
(c) Data management errors. The chances of data management errors was reduced by duplicating a large amount of the work, starting from conversion of the raw data.
(d) Non-representative source profiles being used in the modelling. This source of error is likely to be the largest source of error. With limited resources it was impossible to fully characterise average source profiles for Cape Town. This is particularly true of carbon emissions from combustion which can vary by an order of magnitude depending on the efficiency of combustion. To accurately characterise each source, a statistically chosen set of about 5 to 10 emissions sources should be sampled, whereas in this study usually only two samples were taken for each source.
(e) Omission of significant source profiles. This error can be detected in the statistical performance measures of the chemical mass balance model. In most cases these measures were satisfactory, except on the 30/04/96 when there was a north-easterly wind that could have brought other unaccounted sources into the Metropolitan area.
(f) Error associated with apportioning sulphates and nitrates. The use of the emission inventory to apportion sulphates and nitrates is not accurate because it does not take into account height, time and location of emissions. This error will not have a significant effect on the final results because the contribution of sulphates and nitrates is not major.
(g) Error associated with the empirical relationships between PM2.5 species and visibility reduction. This error could be significant, especially under humid conditions.

Modelling difficulties

Some difficulties experienced were:

(a) During the brown haze study the issue of tyre burning was raised in Cape Town. This was mainly due to the fact that the burning of tyres results in a large amount of "black smoke". An estimate was made in Chapter 5 of the contribution of tyre burning to PM10. The value obtained was not accurate as it was based on a large number of assumptions. As a result of this issue a tyre burning source profile was generated for use in modelling. During modelling of the data, however, it was found that it was difficult to use tyre burning in the apportionment. Often the model was insensitive to the source profile and the standard error of the source contribution estimate was high. Also it appeared that

because of its high silicon and aluminium components, this profile could not be distinguished from crustal matter by the model. Other problems encountered were collinearity between the tyre profile and the wood burning profile. Measures to prevent these problems were unsuccessful and for this reason the tyre burning source profile was not used in the source apportionment.

(b) Vanadium, associated with fuel oil, was close to detection limits therefore giving a high degree of uncertainty for the contribution of fuel oil.

(c) Modelling showed that on some days there was a significant amount of unaccounted carbon. This excess could be because the source profiles used in modelling for combustion sources tended towards the efficient side of combustion. Another possibility is that some of the carbon contribution is due to the formation of secondary organic carbon in the atmosphere. These secondary particles would be formed from the reactions of organic carbon vapour emitted from industry. Another likely possibility is that the carbon contribution is as a result of some source that has not been included in modelling. This could be as a result of organic carbon emitted by process industries. It is possible that these process industries represent small emissions on their own but when added together are significant.

(d) The coal boiler profile used was from the Vaal Air Triangle Study which may be based on more efficient boilers than the average for Cape Town. At times boilers observed in Cape Town produce black smoke and thus could be a source of elemental carbon. There was a consistent shortage of elemental carbon contribution to the ambient levels from the sources indicating a missing source which could be coal fired boilers. The value of this concentration would be no more than 5% based on the "missing elemental carbon on the ambient filters.

(e) The source sampling showed that poorly maintained motor vehicles show high levels of organic carbon. In some cases modelling was carried out with a good and bad vehicle profile, and in other cases it was necessary to use an average vehicle profile. The assumption when using an average vehicle profile is that the contribution of good and bad vehicles to air pollution is similar. This was confirmed in London where 50-60% of the pollution is causes by 10% of vehicles[65].

(f) Zinc was poorly accounted for in the modelling. This suggested a missing zinc source. This was particularly evident at the Goodwood site. An investigation of galvanising businesses in the Cape Town Metropolitan Area show that a large number of them are situated in industrial areas within 10 km of the Goodwood sampling site. Thus galvanising plants could account for the missing Zinc source. Another potential source of zinc is the burning of refuse.

(g) Improvement to the modelling process could be the diesel profile, which was based on only one measurement. If more samples from a range of diesel vehicles had been taken then diesel profile might better represent the diesel fleet in the area. The diesel profile showed a high proportion of low temperature elemental carbon but a low proportion of high temperature elemental carbon. A sensitivity analysis was performed on the diesel high and low temperature elemental carbon, which indicated that moderate changes to these values had little effect on the apportionment results.

8.2 Discussion of significant findings

Average PM2.5 apportionment of the brown haze episodes modelled is shown in Figure 7.4.

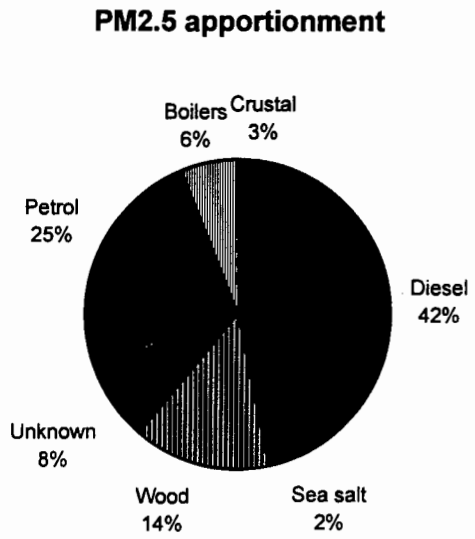


Figure 7.4 Average PM2.5 apportionment for the Cape Town Metropolitan Area

The previous sections discussed errors and modelling difficulties in obtaining the results in figure 7.4 these lead to the following conclusions:

- Errors associated with filter handling and chemical analysis were minimised due to the quality assurance meeasures practiced in the study. Where these errors did exist they were documented and incorporated into the uncertainty parameters entered into the receptor model. So the errors were reflected in the performance statistics calculated by the model.
- The statistical performance measures given for the modelling runs were of such a nature as to indicate that the results obtained in this study for the source apportionment of the brown haze were acceptable. The only possible exception could be the apportionment on the 30/04/96 which was discussed in chapter 8.1.
- The results of the study showed that the major contributor to PM2.5 during brown haze episodes was diesel vehicles with petrol vehicles, wood burning and industrial boilers also being significant.
- There was also an average unknown contribution of 8%. This comprises mostly of organic carbon. The source apportionment could be made more accurate if this unknown source could be defined.
- The source apportionment could be made more accurate by making the source profile data more accurate. This would mean that from 5 to 10 readings from each source be taken rather than the two that were obtained in this study.

8.3 Recommendations

In 8.1 non-representative source profiles were identified as the largest potential source of error in the apportionment. Recommendations to improve modelling results would then focus on a more extensive assessment of the variability of sources. This would include:

- generating source profiles from various diesel vehicles
- generating source profiles from coal fired boilers in the area. This would include sampling from boilers operating under efficient and inefficient conditions.
- assessing the variability of source profiles for oil fired boilers operating in various states of efficiency.
- asssesing the reproducibility of identical source measurements

Modelling also indicated that there was the posssibility of there being certain sources that were not accounted for in modelling. This was particularily shown by unaccounted carbon and zinc on certain days. The problem of unaccounted carbon could be solved by the recommendations above, but if not it may be necessary to investigate process industries in the area to assess their impact on carbon emmisions. The unaccounted zinc indicates that a source of zinc, such as galvanising or refuse burning, was missing in modelling.

A qualitative visibility assessment was carried out in this study using a visibility model derived from another study in the United States. The accuracy of the results could not be calculated and so it is recommended that an attempt be made to confirm the acuracy of this visibility apportionment possibly by conducting visibility measurements with a nepholometer. This would be useful as qualitatively it is apparent that certain sources, that have high concentrations of sulphates and carbon, have an increased contribution to visibility than to PM2.5. This fact is of interest bearing in mind the implications for tourism that the brown haze holds.

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APPENDICES

APPENDIX A: SOURCE SAMPLING

EQUIPMENT

Mintek sampler unit

The Mintek unit samples on to four filters simultaneously and provides the option of either using a PM10 or PM2.5 sampling head. The sampler is of stainless steel giving it resistance against corrosion and heat. The sampler can be used in two configurations depending on the source to be sampled.

Configuration 1

This configuration is used for sampling from industrial stacks and fires. A diagram of this configuration is shown in Figure 1. The probe is placed in the emission stream and bolted on with a flange. From the probe the sample passes through a flow orifice tube and a heating element. The orifice pressure drop indicates whether sampling is done iso-kinetically. The heating element keeps the sample above its dew point, before dilution with ambient air, so as to prevent condensation of water in the system. After the heating element, the sample is diluted and cooled by filtered ambient air from the intake blower. Thorough mixing of the diluted sample is carried out in the mixing tube that is trombone shaped and contains baffles this simulates atmospheric ageing of stack emissions. The sample then enters a resuspension chamber where it is sampled through either PM2.5 or PM10 heads onto four filters. Flow control in the entire unit is facilitated by the outlet blower.

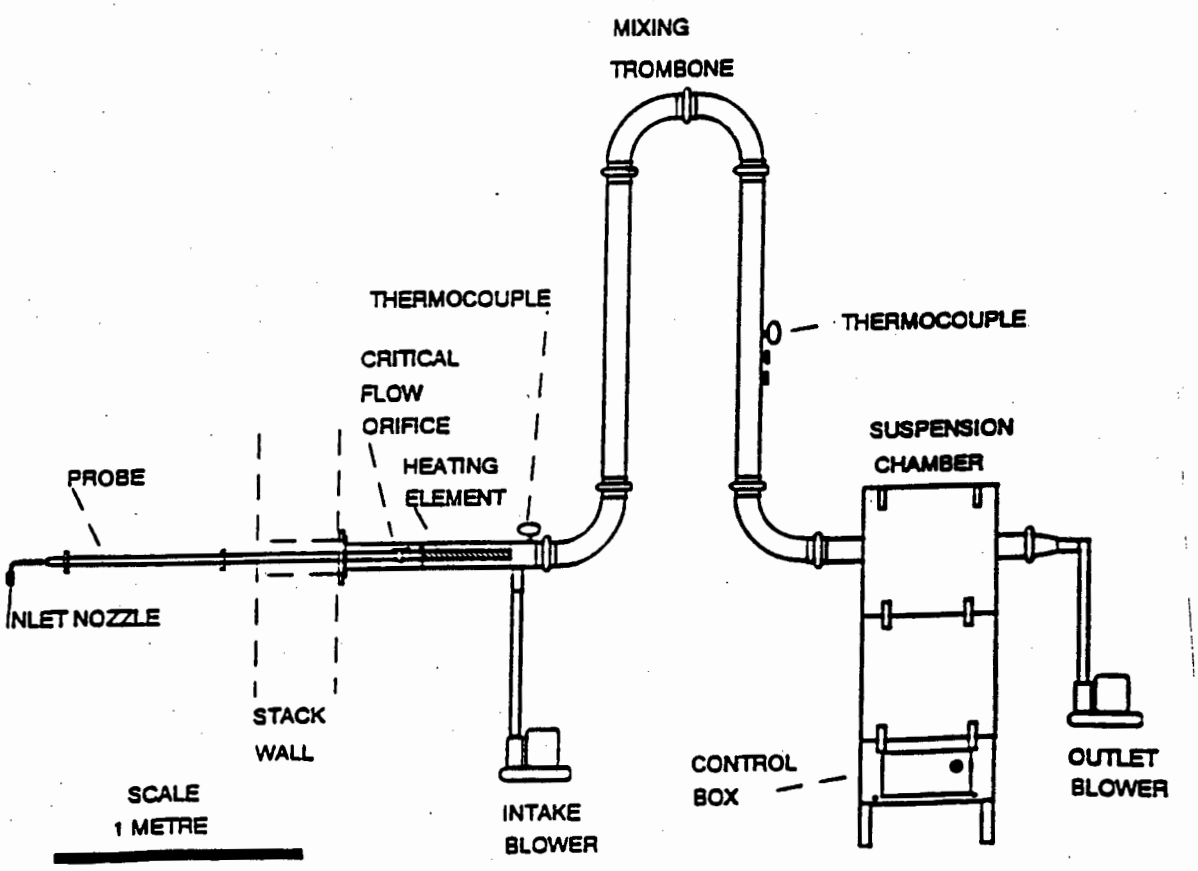


Figure 1. Mintek Sampler Unit in Configuration 1.

Configuration 2

The second configuration (Figure 2.) is used for resuspending grab samples. Here only the sampler and the resuspension chamber are used from the first configuration. In this mode the one opening of the resuspension chamber is connected to a Buchner flask which has compressed air blown through it. The other opening of the chamber is fitted with a filter to let in makeup air. A smooth rubber tube connected the flask to the sampler.

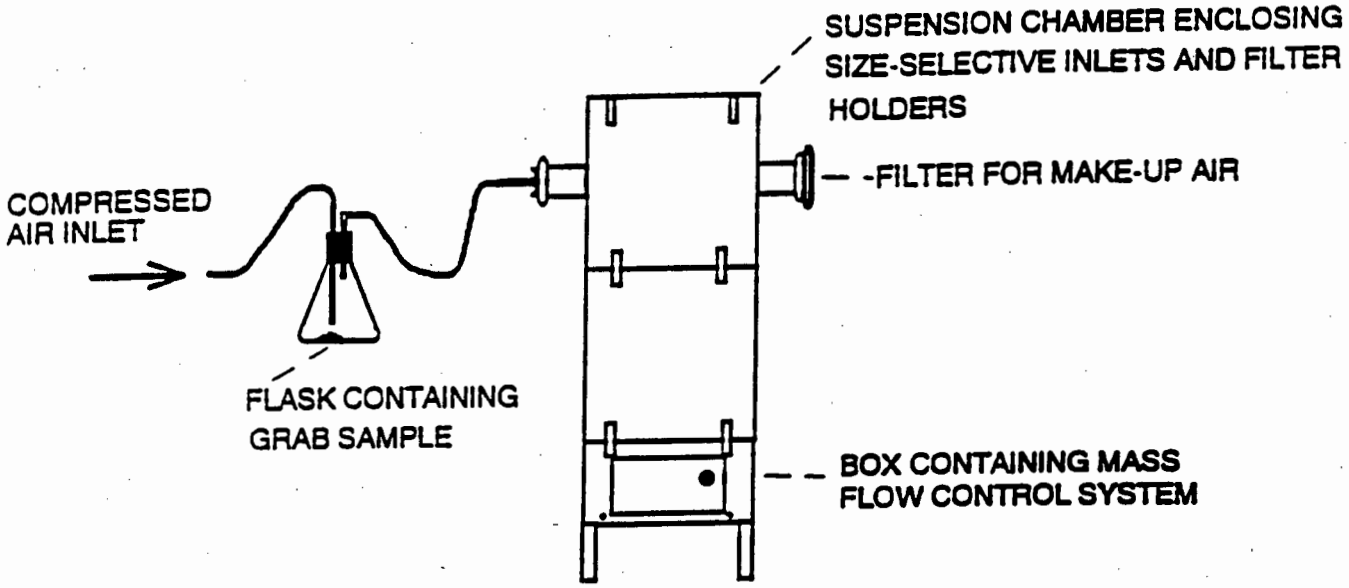
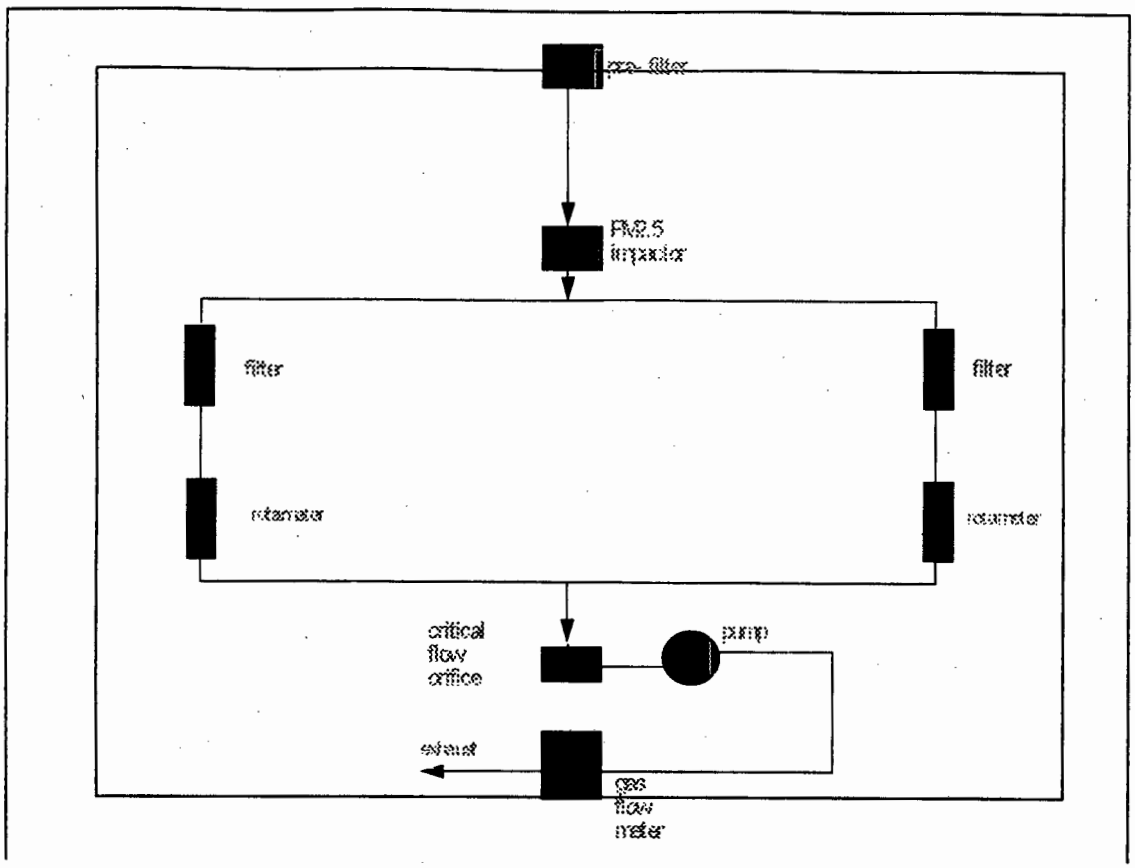


Figure 2. Mintek Sampler Unit in Configuration 2.

Energy Research Institute sampler unit

A second sampler, designed at the Energy Research Institute, is also used to carry out source sampling. It is predominately used for the sampling of resuspended soil, fires and motor vehicles. The sampler collects onto two filters at a time. It has a PM2.5 impactor before the filters to classify the particulates. As with the Mintek sampler it has different configurations for geological sources and combustion sources.



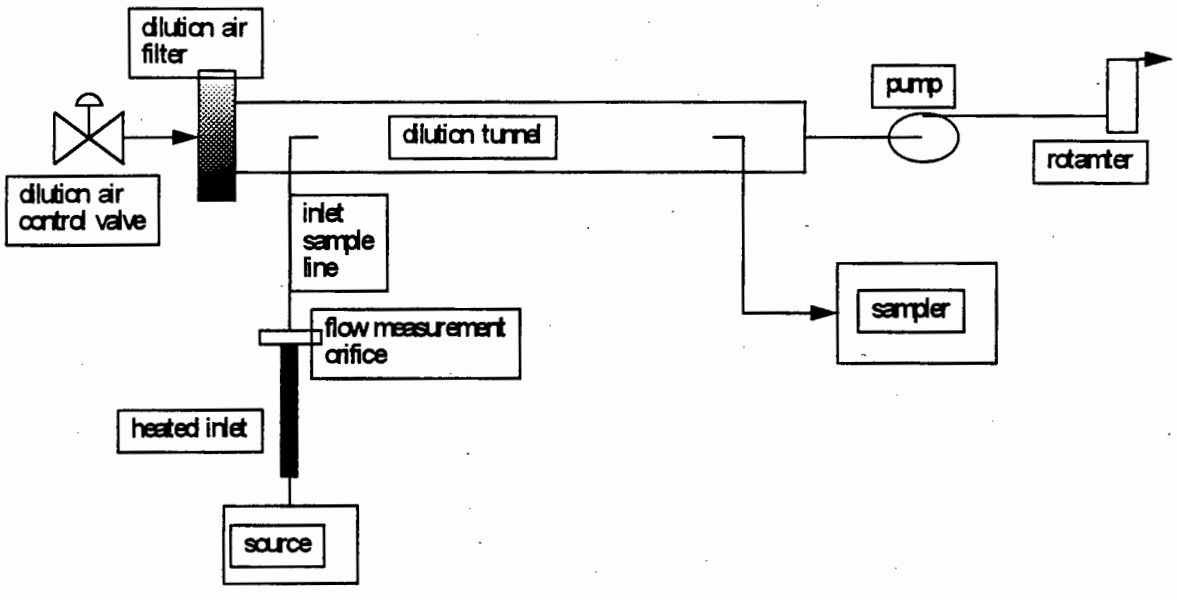
Schematic of Energy Research Institute Sampler Unit.

Configuration 1

This configuration is used for the resuspension of geological material. It is similar to configuration 2 for the Mintek sampler. Here a cellulose chamber is placed over the sampler. The chamber has two openings. The one is covered with a filter so as to provide makeup air to the chamber. The other is connected to a Buchner flask. The Buchner flask holds the geological sample which is 'puffed' into the chamber from a dry compressed air source. The dust is resuspended in the chamber and from there the PM2.5 size fraction is sampled onto filters.

Configuration 2

This configuration is used for combustion sources such as fires and motor vehicle sampling. Due to the fact that there is a considerable amount of moisture associated with these sources a dilution chamber conditions the source stream before filter samples are taken. The dilution chamber is shown in Figure .. It has a heated sample line to the source to be sampled. This line is kept above 1000C to prevent any moisture form condensing out of the sample. Make up air is sucked through a filter and mixed with the sample to dilute it. Mixing of the dilution air and the sample then takes place in a dilution chamber. A side stream to the PM2.5 sampler unit allows for filter samples to be taken.



Energy Research Institute Sampler Unit in Configuration 2.

METHODOLOGY FOR CHARACTERISING SOURCES

Resuspended soil

This source category includes the following specific sources: road dust, beach sand, wind blown raw materials (coal and cement), and wind blown soil. All of the sampling sites may be affected by wind blown soil and samples are taken at each of these sites. A beach sand sample will be taken near Tableview. A road dust sample will be taken from the CBD and from a suburban site.

Sampling will be as follows for wind blown soil:

- Three kilograms of soil will be collected from different points around the ambient sampling site.
- Samples are then sieved to 38 microns using a shaker unit.
- Sample is dried to 40/C in a low moisture environment
- Sample is then aspirated in a resuspension chamber.
- Resuspension chamber is then sampled with a PM10 and PM2.5 sampler onto filters.

Motor vehicles

Characterisation of the emissions of motor vehicles is difficult due to the number of variables involved. Emissions are largely dependent on the following:

- driving conditions
- vehicle age and maintenance level
- vehicle engine capacity
- fuel type

Vehicles on the road experience different driving conditions such as acceleration, deceleration, idle and different loads. These conditions will be represented by running vehicles on a rolling road dynamometer and taking them through the ECE type 1 test driving cycle[12]. This driving cycle involves the vehicle running at different driving conditions. It represents an average of the conditions that a vehicle will experience in driving in an urban area.

Vehicle age and maintenance also play a part in the amount and type of emissions. The combustion state at which the engine is running will effect such things as the elemental to organic carbon ratio in a sample. For this reason cars with good maintenance records and ones with poor records will be tested. This will give a range of profiles to input into modelling.

Vehicles also run on either diesel or gasoline. Both types of vehicles will be tested in the study. Further vehicles have a range of engine capacities. For the purposes of the study these will be split between heavy and light vehicles. Petrol vehicles are typically in the light category.

Thus a number of source profiles for the characterisation of motor vehicle sources will be generated. Two petrol and two diesel vehicles will be tested based on the combination of the variables, heavy or light, and well or poorly maintained. Each of these are driven over an ECE driving cycle during which time filter samples are collected.

The procedure for collecting filter samples from a vehicle are as follows:

- Place vehicle on the rolling road dynomometer at ERI.
- Connect up ERI sampler unit in configuration 2 to the tailpipe of the vehicle.
- Adjust flow through the dilution tunnel so that sampling from the tailpipe is isokinetic, by measuring flow in the tailpipe and in the sample inlet with the use of orifice plates.
- Simultaneously start the ECE driving cycle and sampling onto filters.
- Run through ECE driving cycle.

Residential fuel burning

This category involves the emissions from the burning of wood, coal, and household gas. Profiles for the burning of coal and household gas are available from other studies[10,13]. Emissions from wood, which is the main source of domestic heating in the Greater Cape Town area, are sampled in the study. This is done by connecting up the ERI sampler unit in configuration 2 to a hood arrangement. The hood arrangement consists of a brazier (to burn the wood in), a hood (to direct the smoke up a flue), a connection to a flue, and a sampling port that can be connected to the ERI sampler unit in configuration 2.

There are two main types of wood burnt in the Greater Cape Town area. These are Port Jackson and Rooikrantz wood. The procedure for sampling the emissions from a wood fire is:

- Place some wood in the brazier.
- Ingnite wood .
- Place brazier under the hood which is connected to the dilution tunnel.
- Start blower for dilution tunnel with dilution ratio set at approximately 1:10.
- Start sampler for collecting onto filter media.
- After approximately 1000μg of sample has been collected on each filter, turn off the sampling system.
- Remove filters from filter holders.

Grass fires

Grass fires are mainly a summertime occurrence but are studied because frequently haze episodes start occurring from the month of March which is still dry and fires are frequently observed. Freshly cut grass was collected for burning. The ERI sampler was set up in configuration 2 and connected to the sampling hood mentioned in section 4.3.3. Instead of a brazier a flat tray is used to burn the grass in. This provides better combustion conditions for the grass. The procedure for sampling from grass fires is similar to that wood burning.

Information about the occurrence of fires will be obtained from the Cape Town Fire and Rescue Service.

Tyre burning

An estimate of the overall yearly emissions for tyre burning shows that it is not a significant source of emissions (section 3.4). It has, however, significant and very visible localised impact. Tyres are burnt for the wire that is found in the rubber, the burning of a tyre is characterised by billowing black smoke. The emissions from tyres is studied here using a setup similar to that for the burning of wood.

Industrial emissions

Industrial emissions include emissions from boilers which are usually oil, coal or gas fired. Commercial boilers, such as for hospitals, are also included in this category. Further industrial emissions also include specific factory emissions. In the Cape Town area the following industrial emissions will be characterised:

- Coal fired boiler
- Oil fired boiler
- Caltex oil fired boiler
- Caltex gas fired boiler
- Caltex furnace
- Caltex fluidised catalytic cracker unit (FCCU)
- Kynoch Ammonium Nitrate emissions

The coal fired boiler profile will be obtained from MINTEK source profiles determined for the Vaal Traingle[10]. The coal used in Cape Town is derived from the same region as that used in the Vaal Triangle. The source profile for a chain grate stoker fired boiler with multiple cyclones will be used. This source profile will also cover the Athlone Power Station which uses the same technology. An combustion expert confirmed that the characteristics of particulates from the power station should be no different from those of industrial boilers[17].

Industrial emissions present problems for sampling. These are primarily due the fact that most of these emissions come from reasonably tall chimney stacks. Emissions react to some extent up the length of the stack and therefore sampling should be carried out near the top of the stack. This causes logistical problems in so far as it is difficult to get sampling equipment to the source and in most instances no sampling ports are located near the top of the stack. For this study sampling will be carried out near the base of stacks.

Stack sampling must be done isokinetically. MINTEK have developed an isokinetic sampler for this sort of application [MINTEK sampler in configuration 1]. This sampler will allow for both PM10 and PM2.5 samples to be collected.

Kynoch emissions are mainly of ammonium nitrate. The source profile for Kynoch will be based on a bulk chemical analysis of the product. It will be assumed that the chemical constituents are homogeneous through all size fractions.

The procedure for sampling from stacks is as follows:

- Open port in the side of the stack.
- Manoeuvre an S- type pitot tube in to the middle of the stack. Make sure that the opening is perpendicular to the flow.
- Record the pressure difference for use in calculation of the sampling rate.
- Calculate the sampling rate. This is done using the following steps outlined by MINTEK:

- Calculate the flue gas density by $Y_s=Y_o.(T_o.P_o)/(T_s.P_s)$ ..... (1)
  Y_s=density of stack gas (kg/m^3)
  Y_o=gas density at STP (kg/m^3)
  T_o=273K
  T_s=stack temperature (K)
  P_o=101.325 kPa

- Calculate the stack flue gas velocity by $v_s=k.(.-P/Y_s)$ ..... (2)
  v_s=point velocity of flue-gas at pitot tube inlet position (m/s)
  k=pitot tube characteristic constant
  -P=pressure drop measured across pitot tube

- Calculate the volumetric flow rate at which to sample by
  $Q_o=v_s.A_n$ ..... (3)
  Q_o=volumetric sampling rate (m^3/s)
  A_n=sample nozzle opening (m^2)
- Calculate the required pressure drop across the orifice on the sample inlet line by

$LH=K[Q_o.P_i/T_i]^2$ ..... (4)

LH=orifice differential pressure (Pa)

K=orifice constant = $1.4412x10^9$

- By adjusting the air flow of the two blowers set the differential pressure across the orifice [calculated above] for isokinetic sampling.
- Sample onto cellulose nitrate filters for approximately 30 min. These are then weighed to determine the sampling time necessary to obtain filter samples that have an approximate loading in the range 500 to 2000 Tg.
- Sample onto quartz, nuclepore and teflon filters for the time calculated.

Sea salt

Source characterisation for sea salt will be carried out at Cape Point which is located 50 kilometres south of the CBD on the tip of the Cape Peninsular. The ERI sampler unit in configuration 1 with the cellulose hood removed was used to obtain these samples. The sampler was set up at the CSIR Atmospheric Trace Gas Research Station. Sampling was carried out on days when there was an onshore air flow predicted by the Weather Bureau. Three sets of samples were taken on suitable days and the sampling times were approximately 30 hours long.

Background checks

Although background sources can be significant, it is unlikely that there is any contribution from background sources in Cape Town as there is not much heavy industry within a few hundred kilometres of the study area. Nevertheless the contribution of background sources will be checked. This will be done using a mobile sampler. The samples be taken at areas outside the study area on the prevailing wind side.

APPENDIX B: AMBIENT SAMPLING

EQUIPMENT

The system used for sampling was the TEOM series 1400a Ambient Particulate (PM10) Monitor connected to the Ruprecht and Patashnick Automatic Cartridge Collection Unit (ACCU). A diagram of this is shown in Figure .. A further modification to this system was the addition of a PM2.5 impactor, which is rated at 13.7 l/min and is supplied by Ruprecht and Patashnic, in the line to the ACCU. The ACCU system has eight channels for collecting filter samples and one bypass channel. Flow passes through one of these channels at a time and the TEOM can be programmed to do such tasks as episodic sampling, multiplexing and sampling at specific times.

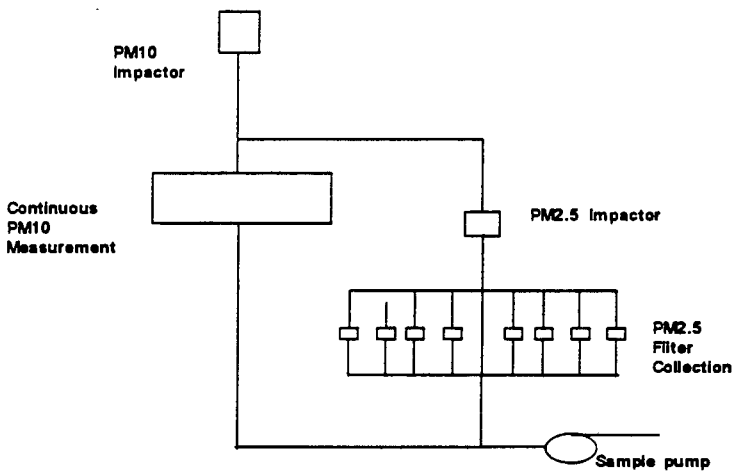


Diagram of the ambient particulate sampling equipment.

Four of these units were used in the study. Once-off ambient PM2.5 samples were also collected at two further sites; Cape Point and Guguletu . These sites are too inaccessible for ongoing sampling, but samples from these sites was important for a better understanding of the brown haze. A sampler built at the Energy Research Institute was used.

The results from the four samplers was be total PM10 concentration through the TEOM oscillating mass balance, and total PM2.5 concentration from the weighing of the filters loaded in the ACCU. PM10 concentrations were continuously measured whilst PM2.5 concentrations were measured on selected days and data represented average values for the sampling period (12 or 24 hours). Chemical analysis of the PM2.5 filters provided detailed chemical information.

Filter holders

The ACCU is loaded with filter packs. The filter packs consist of a filter holder (Gelman 47mm inline filter holder Cat. no. 1119) loaded with a filter. The details of the components of the filter holders are shown in Figure .. The filter holders

are made up of a support disk for the filter, an o-ring for sealing and a casing in which the above are housed and to which piping can be connected.

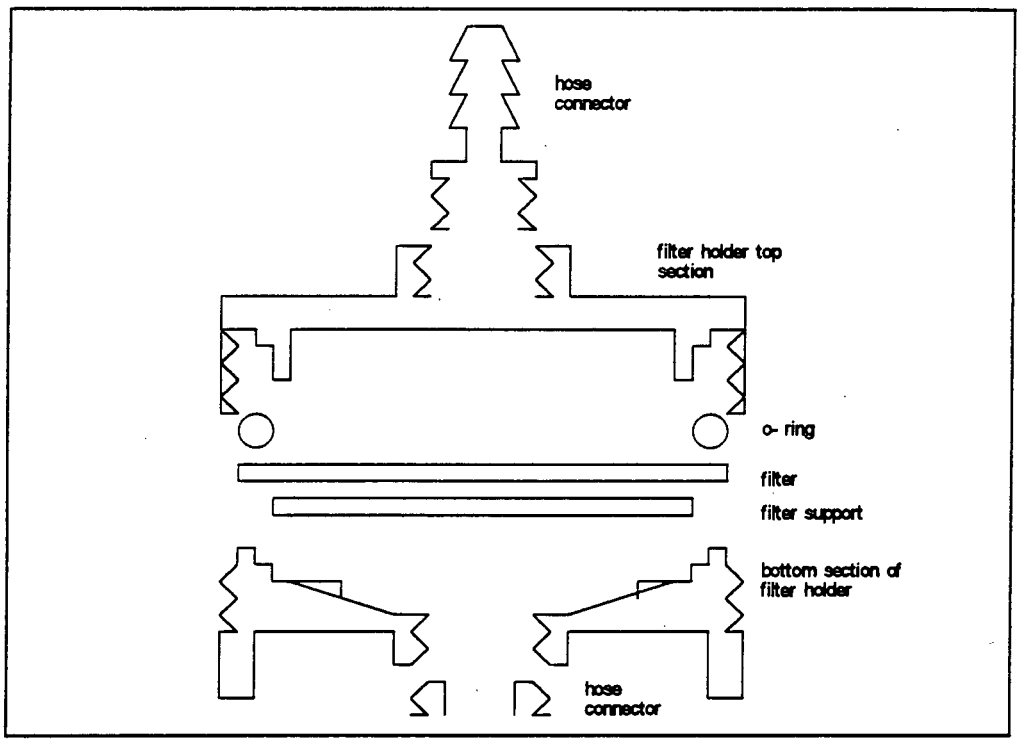


Diagram of filter holder

These filter holders are connected to 6mm piping and when sampling takes place the sample air is expanded from 6mm to 47mm onto the filter. This is over a short distance and there was some concern that this would cause uneven deposition on the filters. This could result in an uneven particle size distribution on the filter and could skew analysis results. In order to check this, filter samples were obtained simultaneously using a normal filter holder and a filter holder with a diffusion tube. No statistical difference could be found in the number, size and shape of particles at six points along the radius of the filters.

SAMPLING PROCEDURE

Once it was decided that there would be meterological conditions conducive to haze formation a sampling procedure was initiated at the four sites. A communications programme designed to communicate with the TEOM analysers was developed by the Cape Town City Council Scientific Services Branch. This programme enables sampling to be triggered remotely at all sites using a modem.

The following procedures were carried out when it was decided that there would be an episode the following day:

- Run Ericom3 [communications programme].
- Dial one of the sampling sites by way of modem.
- Download the ACCU timetable. This gives the TEOM system data on what time to start sampling, what channel to sample on, and the time of finishing sampling.
- Edit the ACCU timetable so that the sampling times are correct for the following day.
- Send the edited ACCU timetable to the site.
- Activate the ACCU timetable.
- Repeat procedure fore nect site.
- On completion, recheck that all sites have been activated.

APPENDIX C: FILTER HANDLING

Filters are used in this study as the surfaces onto which particulates are collected. Due to the analysis that is needed in the study various filter media are used. They are Teflon, Quartz Fibre and Polycarbonate media. Filter handling procedures are based on those of the Desert Research Institute (Chow et al, 1990)[14].

All filters are handled using stainless steel tweezers.

Pre-weighing operations

Teflon Filters:
After Teflon filters are received they are stored in the filter handling area for one to two weeks until they are to be weighed. This is because it is suggested[1] that Teflon filters are unstable just after manufacture and that they need a period of a few weeks to stabilise in mass.

Quartz Fibre Filters:
Quartz Fibre filters absorb organic gases from both the ambient air, and during manufacture. Therefore a process of pre-firing is necessary to reduce artifacts to negligible levels. The filters are fired at 900°C. Since filters are analysed over a temperature range from 25°C to 800°C. The pre-firing removes all possible interferences to analysis.

Filters are fired in batches of 25 or 50 in a 5kW electric kiln at 900°C for approximately 5 hours. The kiln then takes approximately 24 hours to cool down to 100°C so that the filters can be removed. The filters are then placed back into the plastic box in which they arrived. From there they are placed in a desiccator in a fridge until they are to be used.

Polycarbonate Filters:
Polycarbonate filters are kept in the manufacturer's packaging until ready to be used.

Filter labelling

Teflon filters:

XXXXTZZZZ

X= Date of weighing of blank filter

T= Denotes a Teflon filter

Z= Number from 1 onwards which is unique to the filter.

Teflon Filters are labelled in the following fashion:

The labels used are Chevron self adhesive labels. They are of paper and are stuck onto the petri-slides. The filter number can then be written onto this area.

Quartz fibre filters:
Quartz Fibre filters have labels that are in the following configuration:

XQY

Where X is the date on which the filter was pre-fired. Q indicates that the filter is a Quartz filter, and Y is the number of filter that has been used. Values of Y start at 1, which is the first filter that is used.

Polycarbonate filters :
The form of label on these filters are different depending on whether the filter is used for source or ambient sampling. For source sample the label is of the form:

XY#Z

Where X is a set of letters describing the source. Y is a number that is equal to either 10 or 2.5. This number represents wether the sample is PM10 or PM2.5. Z is a number starting from 1. Sources sampled have the following values for X:

OB	-	HFO fired boiler.
CALOL	-	HFO fired boiler at Caltex.
CALF	-	Caltex HFO and gas fired furnace.
WSOL	-	Geological dust from near the Wynberg ambient sampling site.
TSOL	-	Geological dust from near the Tableview ambient sampling site.
RW	-	Woodburning of Rooikrantz wood.

Ambient samples are labelled in the following manner:

XY#ZN

Where X are letters that distinguish the site at which the filter was sampled. From Y one can tell if the sample is PM10 or PM2.5 as it will have either a value of 10 or 2.5. Z is the date on which the filter was sampled, and N denotes a nuclepore polycarbonate filter.

Values for X here are:

DH	-	Samples taken at the CBD site.
TV	-	Samples taken at the Tableview site.
WB	-	Samples taken at the Wynberg site.
GW	-	Samples taken at the Goodwood site.
KH	-	Samples taken at the Khayelitsha site.

Weighing operations for teflon filters

Teflon filters are used for gravimetric analysis and therefore need to be weighed before and after loading. The weighing takes place at the National Accelerator Centre at Faure. The apparatus used is a Mettler M3 balance that is accurate to 1μg. Batches of 25 to 50 filters are weighed at time.

Minimisation of Measurement Interferences:
Humidity and temperature can affect the weight of the filter, so it is important to monitor these. Chow et al[1] suggest that the filters be stored in the weighing environment before weighing. Due to the distance of the balance (about 50 kilometres from the filter storage area) this is not possible. The filters weighing is therefore treated more carefully. On arriving at the balance the filters are immediately placed out on a bench to equilibrate as much as possible to the environment, which is temperature and humidity controlled. The first filters are allowed to equilibrate on the balance. Weights are taken when the filter does not change in mass for about 5 minutes. This method means that the first few filters take a large amount of time to weigh while those that were equilibrating on the bench take far less time as they are in equilibrium with the surroundings by the time they are to be weighed.

Microbalances are also sensitive to static electricity. Static buildup is particularly evident on filters that have been exposed. A radioactive source is located inside the balance chamber to dissipate any potential static charge.

Weighing Procedure:

(i) Filters are transported to the weighing room in the original manufacturers containers.
(ii) The container is placed open on a bench next to the balance.
(iii) About ten filters at a time are placed in labelled petri-slides and lined up next to the balance.
(iv) Each filter is removed from its petri-slide and held up to a fluorescent light. If no pinholes or discoloration are observed the filter is placed on the weighing pan.
(v) The filter is then left on the pan until it has reached a stable weight as defined above.
(vi) The filter is removed from the pan and placed in a labelled petri-slide.
(vii) Weight, label and date of weighing are recorded.
(viii) Weighed Teflon filters are stored under ambient conditions in a dust-free room.

Filter Weight Reproducibility:
Every second filter is reweighed by the procedure used above. The criterion for the acceptance of the weight of the filter is if the weights are within 10 μg of each other. If this is not achieved then the filter is weighed again until this criterion is achieved.

Some batches of filters that have already been weighed are also reweighed by a different operator and the same criterion as above is implemented. This is to guard against operator error.

Weighing operations for polycarbonate filters

These filters are used for Scanning Electron Microscope analysis. They are weighed primarily to assess whether the loading of the filter is sufficient for analysis. The filters need to be loaded to between 200μg and 500μg and so accuracy is not required. The filters are weighed in a temperature controlled environment at the Energy Research Institute on a Mettler AE200 balance that is accurate to 100μg.

Weighing Procedure:

(i) Place filter in labelled petri-slide.
(ii) Allow filter to stand in the weighing environment overnight to acclimatize to the weighing environment.
(iii) Check calibration of the balance by following the calibration procedure in the manual for the balance.
(iv) Place o-ring on the pan and zero the balance.
(v) Check filter for pinholes or discoloration by holding it up to a light source.
(vi) Place filter on the o-ring and record mass.
(vii) Remove filter from the balance.
(viii) Re-zero if necessary.
(ix) Re-weigh the filter. If the weights are the same, replace the filter in the petri-slide for use in sampling.
(x) Weighed Polycarbonate filters are stored under ambient conditions in a dust free room.

Filter holder loading operations

The filter holders are Gelman Polycarbonate Inline Filter Holders. They are designed to be installed in the ACCU.

Teflon filters:
Due to the nature of the filter holders and the thinness of the Teflon filters it was found that the particulates deposit on the filter in a grid formation that is the same as the backing grid for the filter holder. To overcome this drain disks are placed in the filter holder before the Teflon filters. This results in a more uniform deposit on the filter.

The procedure for loading teflon filters is:

(i) Unscrew filter holder.
(ii) Label filter holder with the same label as on the petri-slide of the filter to be used.
(iii) Place drain disk in the filter holder.
(iv) Place filter on the drain disk.
(v) Place o-ring on the filter.
(vi) Screw filter holder back together.
(vii) Place filter holder into container.
(viii) Place container and filter holder into waterproof bag for transportation.

Quartz fibre filters:
Due to the thickness of these filters there is no need for a drain disk. The procedure for loading quartz filters is:

(i) Remove filter box from desiccator.
(ii) Label filter holder with number consecutive to last Quartz filter used. Record this number.
(iii) Unscrew filter holder.
(iv) Place filter in the filter holder.
(v) Place o-ring on the filter.
(vi) Screw filter holder back together.
(vii) Place filter holder into container.
(viii) Place container and filter holder into waterproof bag for transportation.
(ix) Put filter box back into the desiccator.

Polycarbonate filters:

These filters are also of the membrane type as with Teflon filters and so their loading procedure is the same.

ACCU loading/unloading operations

The ACCU system is loaded with the Quartz and Teflon filters. There is no distinction between the two types of filters as far as loading/unloading operations are concerned. These operations occur when six of the eight current channels have been sampled on at a particular site.

Some checks are done during these operations. These consist of recording the total sampling time and volume flowrate through each of the 8 channels of the ACCU. This is done to check whether there were any power failures during the sampling period that were not logged. Before loading filter holders it is checked that the ACCU is not sampling through any of the 8 channels.

Unloading filters

The following procedures are followed for unloading of filters:

(i) Remove used filter holder from channel.
(ii) Record filter label and date of filter removal.
(iii) Replace used filter holder with unused one in the channel.
(iv) Record label and date of installing the filter holder.
(v) Record time and volume flowrate for the channel from the TEOM output display.
(vi) Transport used filter holders to the filter handling area for unloading of filters.

Loading filters

Loaded filters are transported from the sampling sites in their filter holders. It is important that the loaded filters are kept in a dry, cold environment before weighing. The filters are placed in a desiccator in a fridge before weighing. The temperature in the fridge is 0°C.

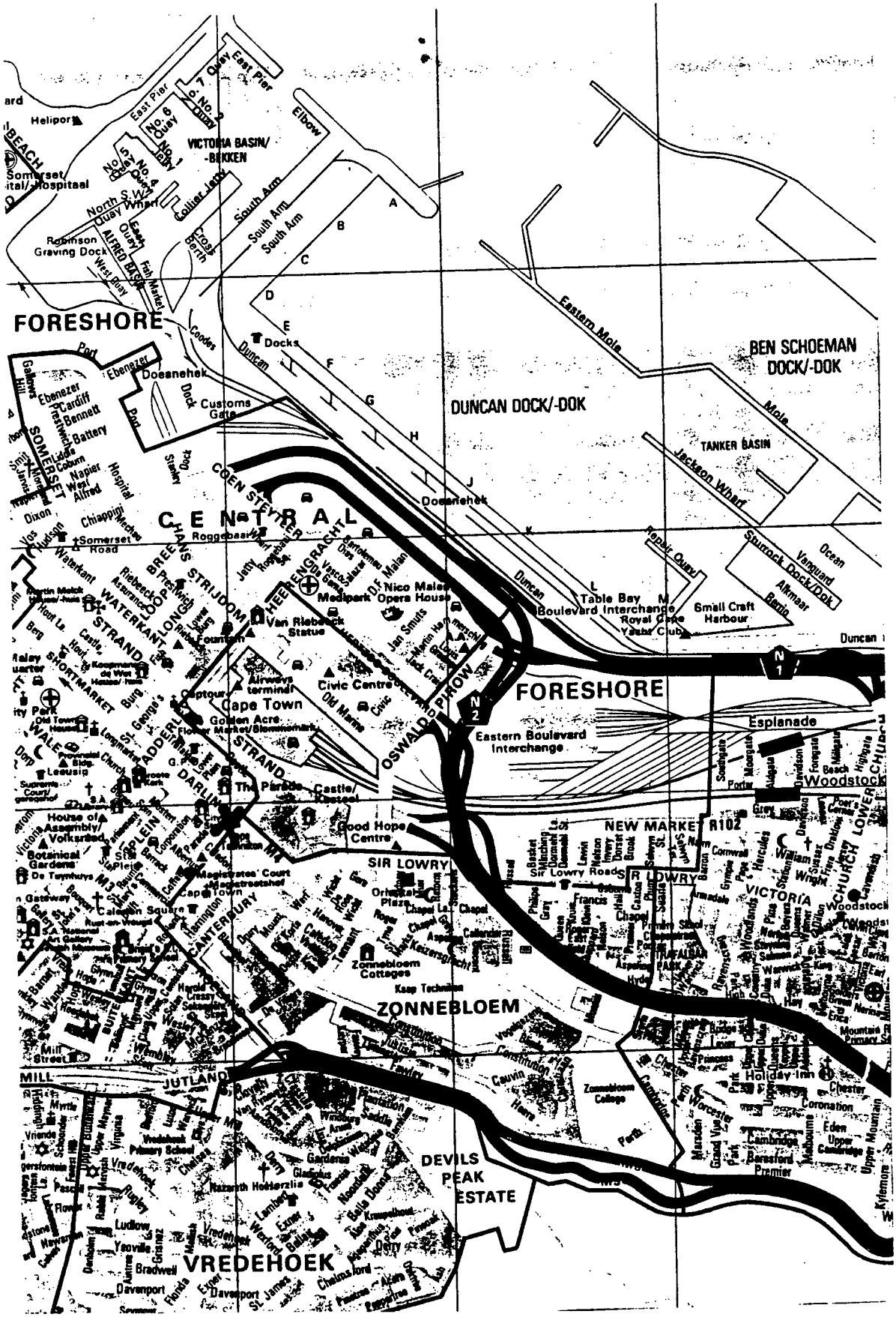
The filter holders, once they have been unloaded, need to be cleaned so that they can be loaded with new filters for sampling. Cleaning is done with warm water and lint free towels.

Loading of the ACCU is carried out as follows:

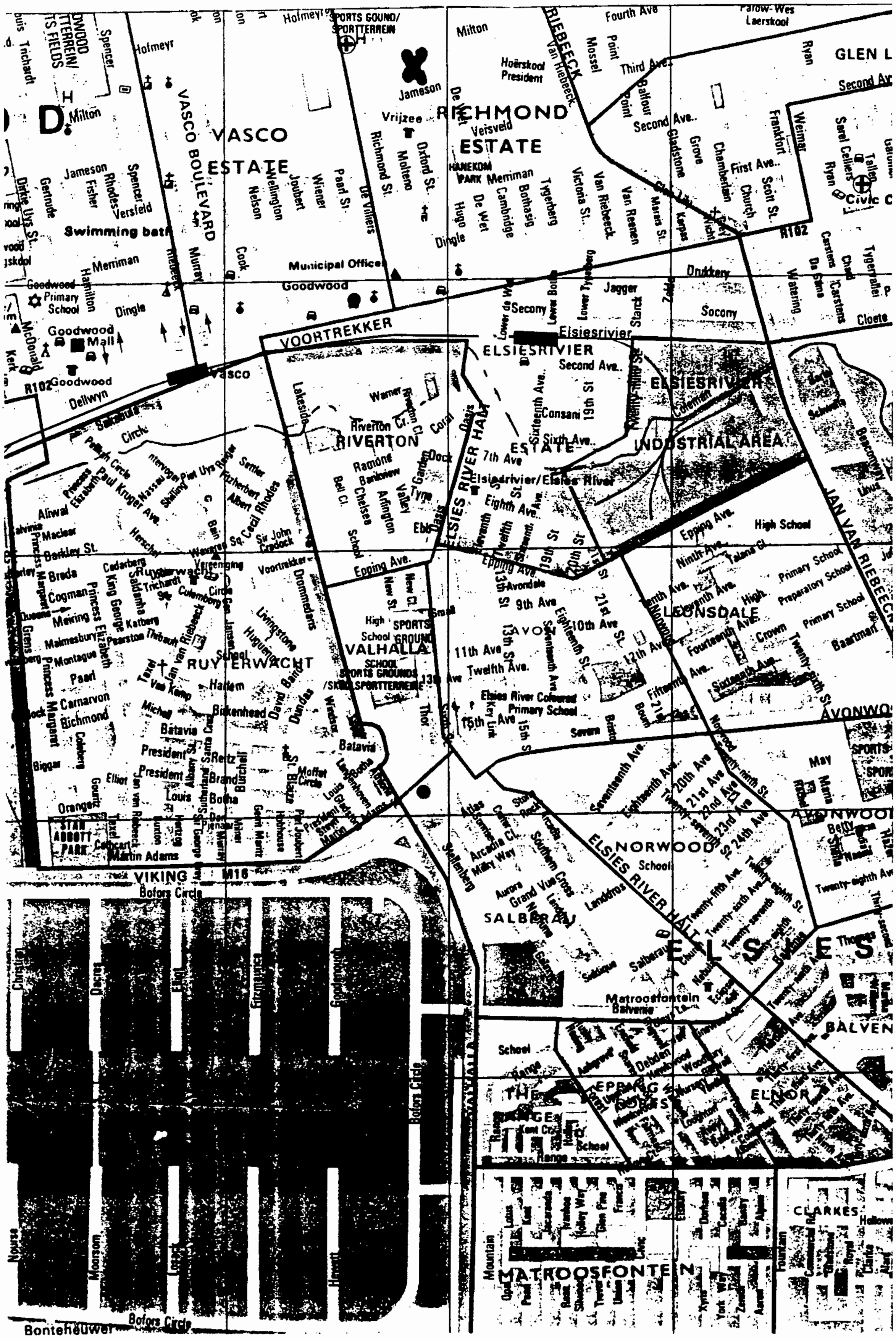
(i) Place filter holders on bench in the filter handling area.
(ii) Retrieve empty petri-slide whose label matches that on the filter holder.
(iii) Unscrew filter holder.
(iv) Remove the o-ring.
(v) Remove the filter from the filter holder.
(vi) Place the filter into the petri-slide.
(vii) Place the petri-slide in the desiccator.

APPENDIX D: DETAILED MAPS OF EACH SAMPLING SITE

Central City



Goodwood


VASCO ESTATE
RICHMOND ESTATE
VASCO BOULEVARD
VOORTREKKER
ELSIESRIVIER
RIVERTON
RUYTERWACHT
VALHALLA
INDUSTRIAL AREA
LEONSDALE
NORWOOD
SALBERAU
ELSIES RIVER HALT
JAN VAN RIEBEECK
MATROOSFONTEIN
CLARKES
GLEN L
Goodwood Mall
Municipal Office
Swimming bath
Elsiesrivier
Vasco
Goodwood
VIKING
M18
Bofors Circle
Bonteheuwel
R102
Epping Ave.
High School
Primary School
Preparatory School

Tableview

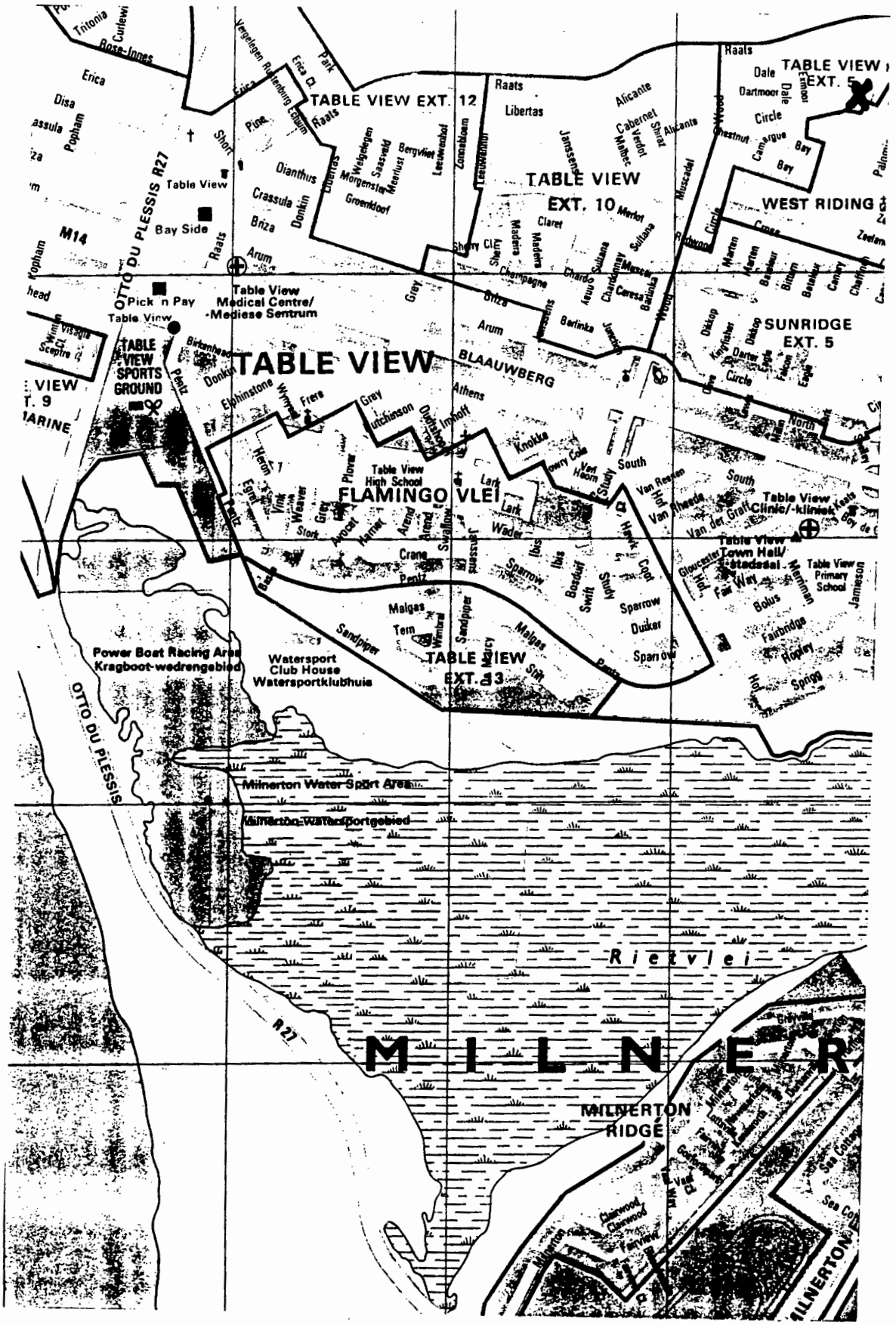
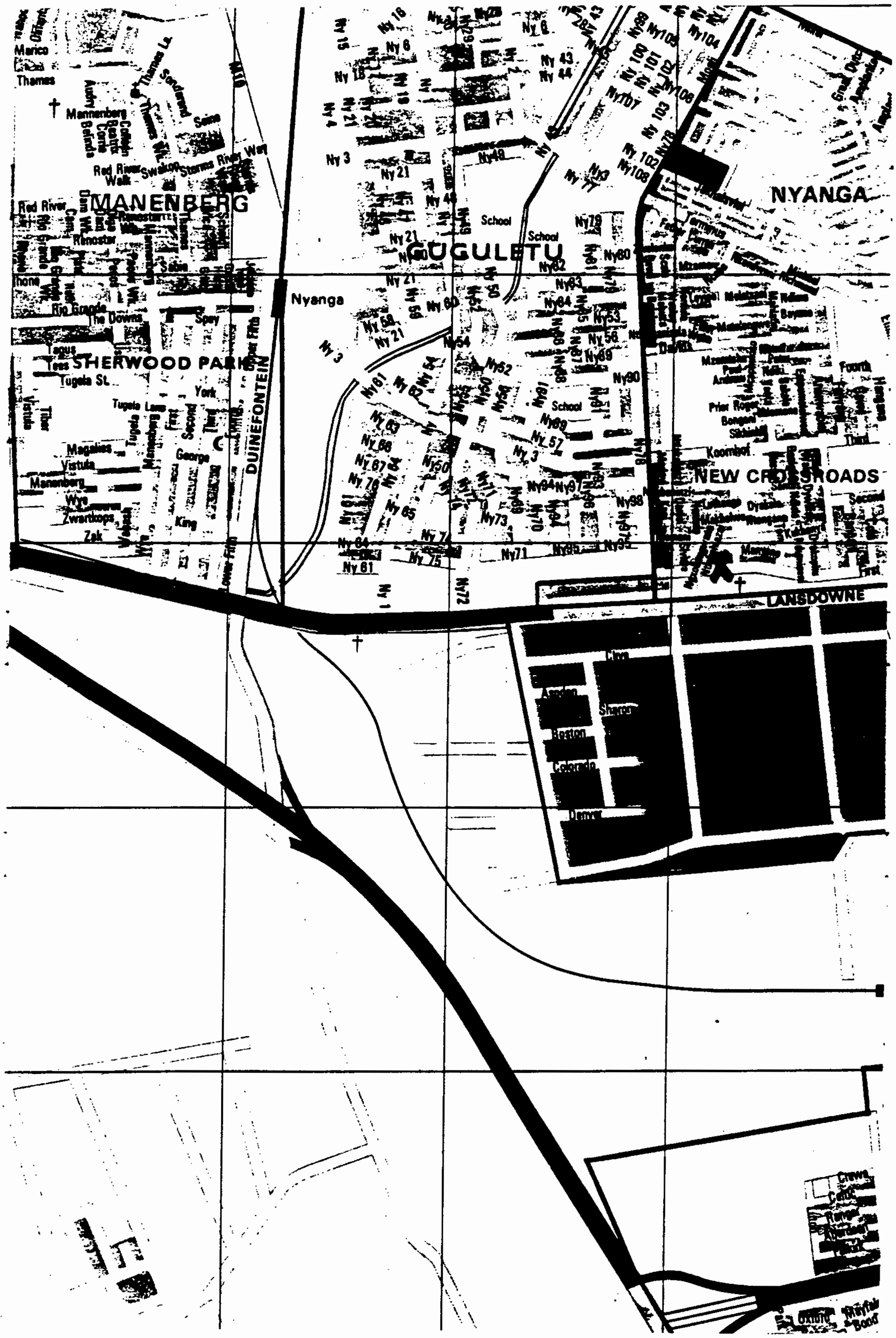


TABLE VIEW
TABLE VIEW EXT. 12
TABLE VIEW EXT. 10
TABLE VIEW EXT. 5
WEST RIDING
SUNRIDGE EXT. 5
BLAAUWBERG
FLAMINGO VLEI
TABLE VIEW EXT. 13
TABLE VIEW SPORTS GROUND
Table View Medical Centre/ -Mediese Sentrum
Table View High School
Table View Clinic/-kliniek
Table View Town Hall/ -stadsaal
Table View Primary School
Pick 'n Pay
Table View
Bay Side
OTTO DU PLESSIS R27
M14
Power Boat Racing Area Kragboot-wedrengebied
Watersport Club House Watersportklubhuis
Milnerton Water Sport Area
Milnerton Watersportgebied
Rietvlei
M I L N E R
MILNERTON RIDGE
R27

Wynberg


KENILWORTH
WYNBERG
PLUMSTEAD
Kenilworth
Wynberg
Harfield Road
Victoria Hospital
Military Hospital/
Militêre Hospitaal
WYNBERG PARK
TENNANT
HERSCHEL RD
NEWLANDS
ROSMEAD
PRINCE GEORGE
MAIN RD
ALPHEN HILL
BOWER
WATERLOO RD
GABRIEL RD
CONSTANTIA
MAYNARD
VICTORIA
WILLIAM HERBERT SPORTS GROUND
Maynardville Open Air Theatre/
Opelugteater
Kenilworth Rd.
Highwick Ave.
Highwick Dr.
Claremont Civic Centre/ burgersentrum
CLAREMONT PUBLIC GARDENS
SPORTSFIELD/ SPORTTERREIN
Wynberg Boys High School
Wynberg Girls High School
CEMETERY
Station
Plumstead
Alphen

Guguletu


MANENBERG
GUGULETU
NYANGA
SHERWOOD PARK
NEW CROSSROADS
DUINEFONTEIN
LANSDOWNE
Nyanga
School
Marico
Thames
Red River
Rio Grande
The Downs
Tugela St.
Vistula
Wye
Zwartkops
Zak
York
George
King
Clive
Aspden
Sharon
Boston
Colorado
Denver
Koombof
Ny 3
Ny 21
Ny 49

APPENDIX E: ANALYTICAL METHODS

Analysis of filter samples is important link in the source apportionment study as the data from analysis allows for modelling of Brown Haze episodes to take place. Important in analysis is to ensure the quality of data obtained and so it is important that rigorous procedures be followed to make sure that all filter samples are treated in a standard way thus minimising errors due to measurement effects. The procedures for analysis in this study are based primarily on those proposed by Chow and Richards (1990)[14]. These are very detailed and comply with EPA requirements.

Weighing

For weighing operations the following guidelines are proposed by Chow and Richards:

- Important that the balance room is dust free.
- Accuracy of the balance must reflect detection limits of analytical apparatus.
- Temperature control. For gravimetric analysis EPA requirement is 20 ± 5°C.
- Humidity control. EPA requirement is 30 ± 5%.
- Balance is sensitive to static electricity so care must be taken to ground them before weighing on anti-static mats.
- Calibration of balances should be done regularly.
- All filters should be documented along with the tests done on them.
- A standard operating procedure should be drawn up incorporating the above points to increase accuracy of analysis.

Weighing is carried out at the National Accelerator Centre. The balance that is used is a Mettler M3 which reads to 1μg. The balance room fits in with all the requirements above. Documentation is described in section 7 and the standard operating procedure is shown in section 4.1.2.

XRF

This analysis was performed at the Desert Research Institute in the United States. Procedures conformed to EPA standards.

Ion Chromatography

Ion Chromatography is the analytical method used to measure the concentration of ions on the filter samples. The analysis is performed at the Geological Sciences Department at the University of Cape Town following the procedures outline by Chow and Richards (1990). Ionic species to be measured are chloride, nitrite, nitrate, sulphate and ammonium. Before the samples can be analysed the ionic species need to be extracted from the filters into solution. Methodology for extraction of the ions from the filters prior to analysis is as follows:

- Remove filters from the petri-slides and place them into polystyrene extraction tubes. For analysis half of a Quartz fibre filter is used. The extraction tubes are housed in an extraction rack.
- Add 15.0 ml of deionised-distilled water (DDW) to the extraction tube containing the filter.
- Add 15.0 ml DDW to one empty extraction tube and mark it as a blank.
- Cap the tubes making sure that the exposed area on the filter is completely and continually submerged.
- Place the extraction rack in an ultrasonic bath that has been filled to approximately 80% with distilled water. Make sure that the water level in the ultrasonic bath is higher than the extraction solution level. Also measure the temperature in the bath and make sure that it is approximately 25°C.
- Sonicate for 60min checking the temperature of the bath at 30 min intervals. If the temperature exceeds 27°C, add ice to the bath to bring the temperature down.
- Remove the extraction rack and place it on the test tube shaker. Shake for 60 min at 60 cycles per minute.
- Store the extracted samples in a refrigerator prior to chemical analyses.

The next step is the analysis itself. This is undertaken on a Dionex ion chromatograph.

Thermal optical reflectance

The analysis for organic and elemental carbon cannot be performed in this country. This analysis will be done at the Desert Research Institute in Nevada USA and so quartz filters will be sent to this institute for analysis. The procedure for this analysis can be found in detail San Joaquim Air Quality Study standard operating procedure report by Chow and Richards. An outline of this analysis method will follow.

Thermal optical reflectance is based on the principle that organic and elemental carbon can be oxidised at different temperatures. More specifically organic carbon can be volatised from the sample at low temperatures in a helium atmosphere while elemental carbon is not removed. The analyser operates by:

- Exposing the sample to different temperature and oxidation conditions thereby liberating different carbon compounds. This involves staged heating to 550°C and then further heating to 700 and 800°C respectively.
- Oxidising these compounds to carbon dioxide by passing them through heated manganese dioxide.
- Reducing the carbon dioxide to methane by passing it over a hydrogen enriched nickel catalyst.
- Measuring the methane formed in a flame ionisation detector.

A further feature of the analyser is its optical (laser reflectance) component which is used to correct for the pyrolysis of organic carbon compounds to elemental carbon. This prevents the organic fraction of the carbon being underestimated. The pyrolysis correction is made by continuously noting the filter reflectance throughout the analysis. Reflectance is measured by a helium-neon laser and a photodetector.

Microscopic analysis

Microscope analysis is a technique that is often used in source apportionment studies. It has the advantages of enabling the detailed study of size, shape and chemical composition of individual particles. To do this an automated procedure for the analysis of individual particles on a filter sample needs to be developed. For this extensive software development is needed and large analysis times are required. Furthermore, for the microscope to be able to discern one particle from another the particles need to be at least a diameter apart on the filter paper. To achieve this filter samples must be taken for short time periods, typically for one hour. Thus if a full episode of 12 hours were to be sampled 12 filter samples would be needed as opposed to the one that is required by this study.

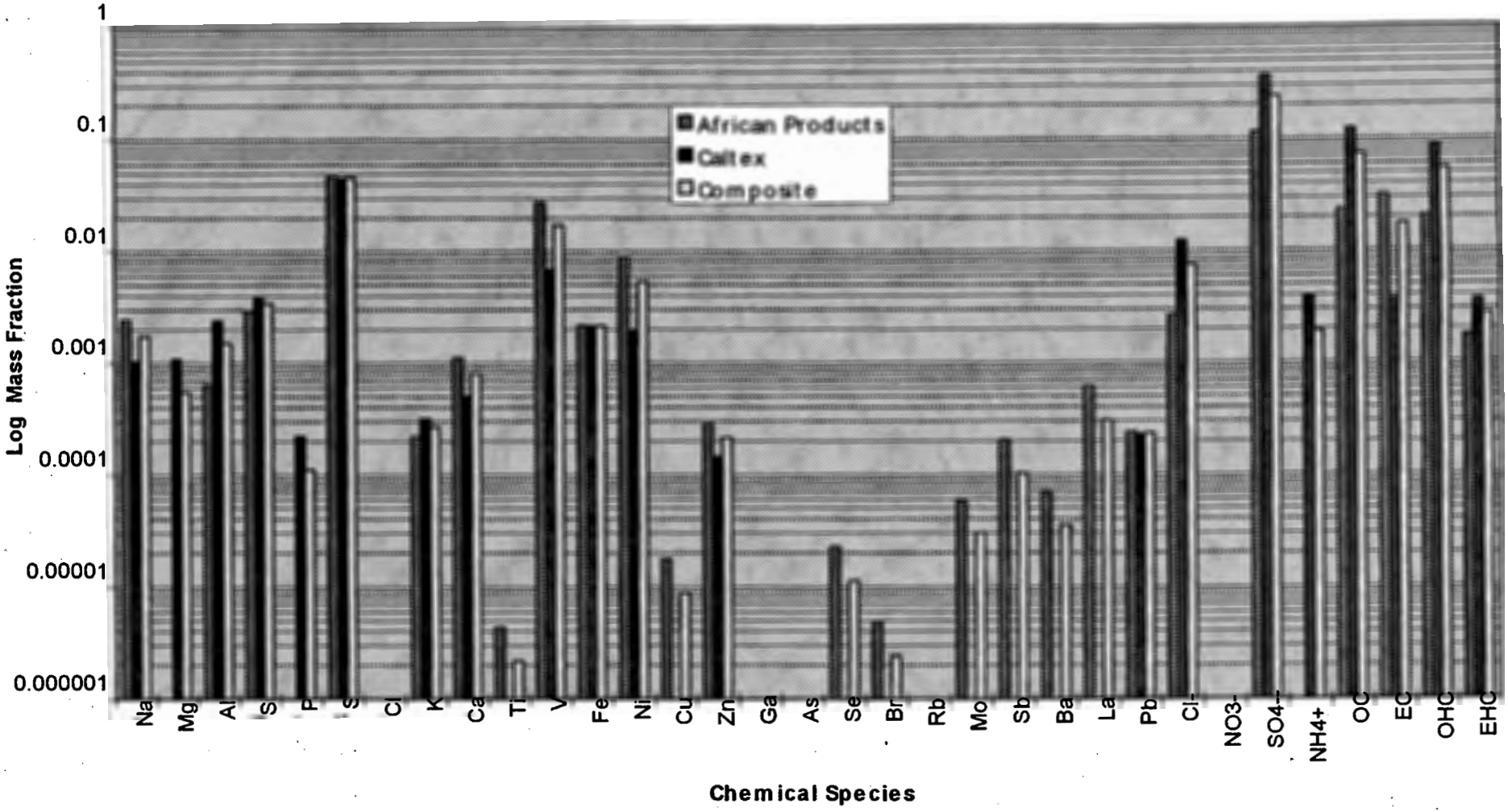
Thus SEM analysis has large costs both in analysis times and in filter papers required. Furthermore the Leica s440 Sigma digital microscope that is available to this study through the Electron Microscope Unit at UCT does not allow for automated particle by particle analysis. So a quantitative study would not be possible here. Instead a semi-quantitative technique will be used. This will mainly act as a check on receptor modelling results and give an indication of any sampling contamination. Imaging will be used to analyse particle shapes and sizes and X-ray mapping will give an indication of what elements are in each particle. From these three types of data and from comparing source and ambient filters qualitative source apportionment can be undertaken by matching particles 'seen on source and ambient filters.

APPENDIX F: SOURCE PROFILES

Source profile codes for modelling

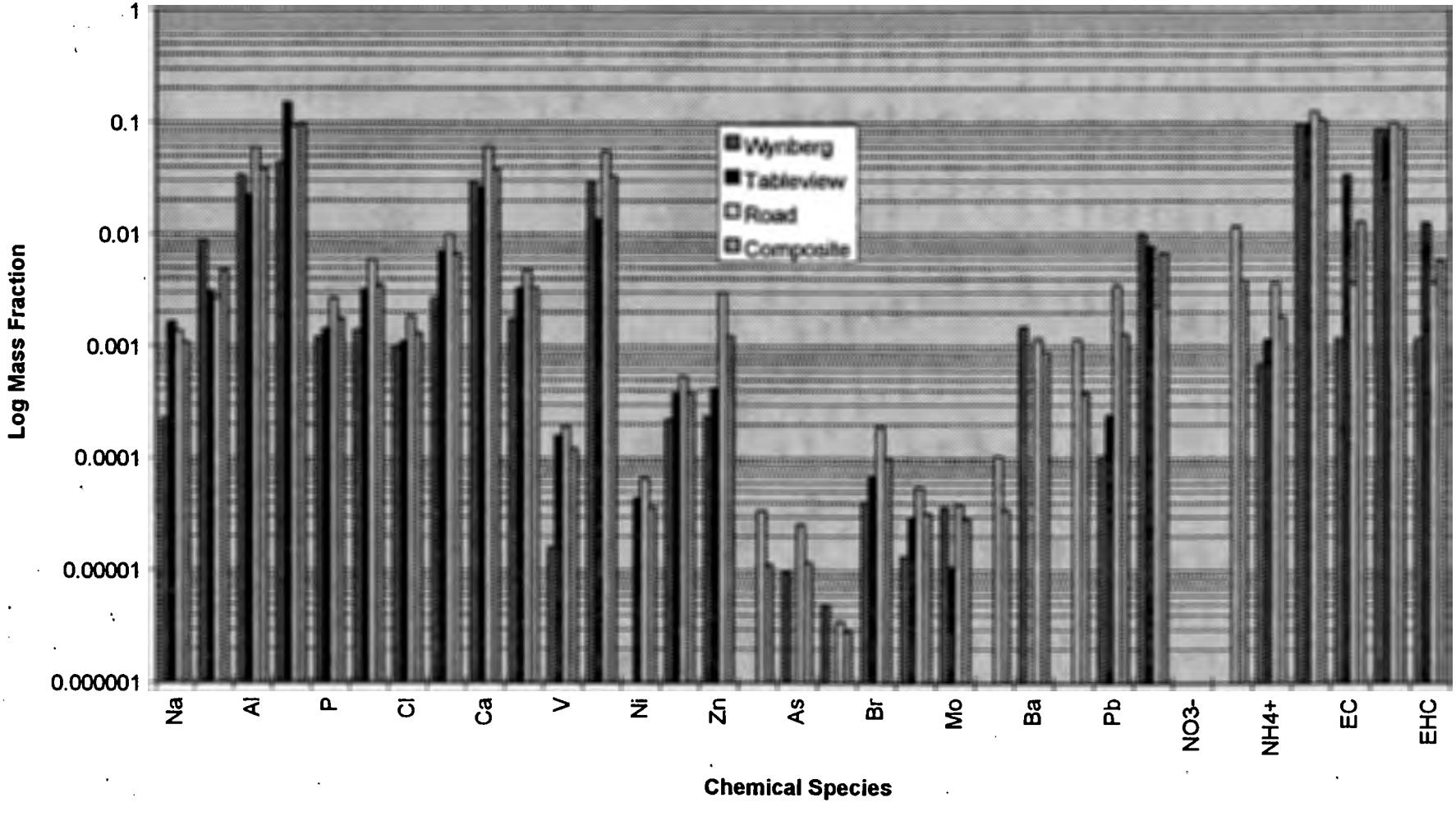
Modelling Code	Description	Profile Type
APOBL	African Products oil fired boiler	Primary
CALOB	Caltex oil fired boiler	Primary
WBDST	Crustal material from the Wynberg sampling site	Primary
TVDST	Crustal material from the Table View sampling site	Primary
RDUST	Crustal material from paved roads	Primary
CALCT	Catalyst material from Caltex	Primary
RKBRN	Burning of Rooikrantz wood	Primary
PJBRN	Burning of Port Jackson wood	Primary
TYBRN	Burning of Tyres	Primary
GRBRN	Grass Burning	Primary
DIVEH	Diesel vehicles	Primary
SO4	Sulphate	Secondary
NO3	Nitrate	Secondary
MARI1	Sea Salt	Primary
KYLAN	Ammonium Nitrate	Primary
SASFA	Fly Ash from coal burning	Primary
PCEMT	Portland Cement	Primary
CRUST	Crustal Material	Combined
WBURN	Wood Burning	Combined
CRUSTC	Crustal Material and Fly Ash	Combined
OHC	Organic High Temperature Carbon	Secondary
OLC	Organic Low Temperature Carbon	Secondary
EHC	Elemental high temperature carbon	Primary
VEH1	Leaded petrol vehicle (well maintained)	Primary
PETVH	Leaded petrol vehicle (poorly maintained)	Primary
VEH2	Leaded petrol vehicle (average)	Combined
DIES2	Diesel vehicle	Primary
COMPB	Oil fired boiler	Combined

Graph Source Profiles for African Products Oil Fired Boiler, Caltex Oil Fired Boiler and Composite Oil Fired Boiler Profile



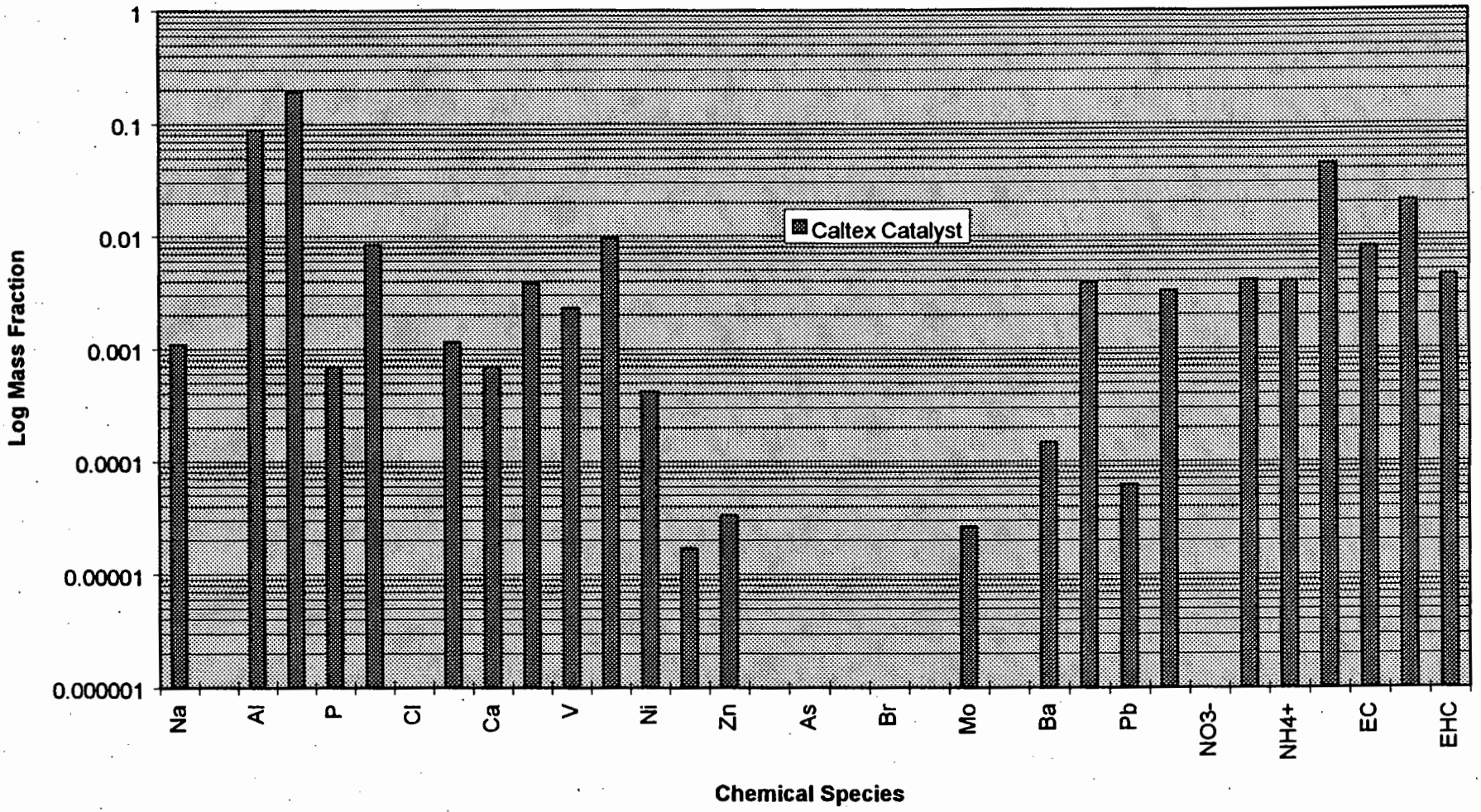
NAME	APOBL [%]	uncertainty [%]	CALOB [%]	uncertainty [%]	COMPB [%]	uncertainty [%]
Na	0.002425902	0.000515602	0.001031293	0.004235374	0.001728597	0.002133321
Mg	0	0.00059887	0.001079365	0.001702041	0.000539683	0.000902162
Al	0.000636419	0.000132464	0.002380499	0.000359184	0.001508459	0.000191416
Si	0.002919687	0.000112212	0.003858503	0.000304308	0.003389095	0.000162169
S	0.046532551	0.000159322	0.045350113	0.000377778	0.045941332	0.000205
Cl	0	0.000757584	0	0.000856236	0	0.000571636
K	0.000217036	2.77271E-05	0.00031746	0.000386395	0.000267248	0.000193694
Ca	0.00111256	4.19817E-05	0.000504762	0.00050839	0.000808661	0.00025506
V	0.027492568	0.000129335	0.006888435	0.000275283	0.017190502	0.000152076
Fe	0.002145763	2.42503E-05	0.002128798	6.48526E-05	0.00213728	3.46191E-05
Ni	0.008727771	3.71143E-05	0.001951474	4.94331E-05	0.005339622	3.09075E-05
Cu	1.75576E-05	4.39809E-05	0	9.20635E-05	8.77879E-06	5.10147E-05
Zn	0.000281356	8.17036E-06	0.000142857	3.35601E-05	0.000212107	1.72702E-05
Br	4.86745E-06	1.94698E-05	0	8.43537E-05	2.43372E-06	4.32858E-05
Pb	0.000238157	1.79922E-05	0.00022449	0.000268934	0.000231324	0.000134768
Cl^-	0.002659713	0.000265971	0.012244898	0.00122449	0.007452306	0.000626521
NO_3^-	0	0	0	0	0	0
SO_4^{2-}	0.114576271	0.011457627	0.364897959	0.036489796	0.239737115	0.019123169
Low Temp. Organic Carbon	0.002868318	0.002043977	0.035827664	0.012551794	0.019347991	0.006358564
Low Temp. Elemental Carbon	0.029378531	0.005514375	0	0.003393794	0.014689266	0.003237521
High Temp. Organic Carbon	0.020338983	0.003215993	0.08707483	0.015419501	0.053706906	0.007875653
High Temp. Elemental Carbon	0.001738375	0.000434594	0.003628118	0.001814059	0.002683246	0.000932695

Graph of Crustal Material Source Profiles



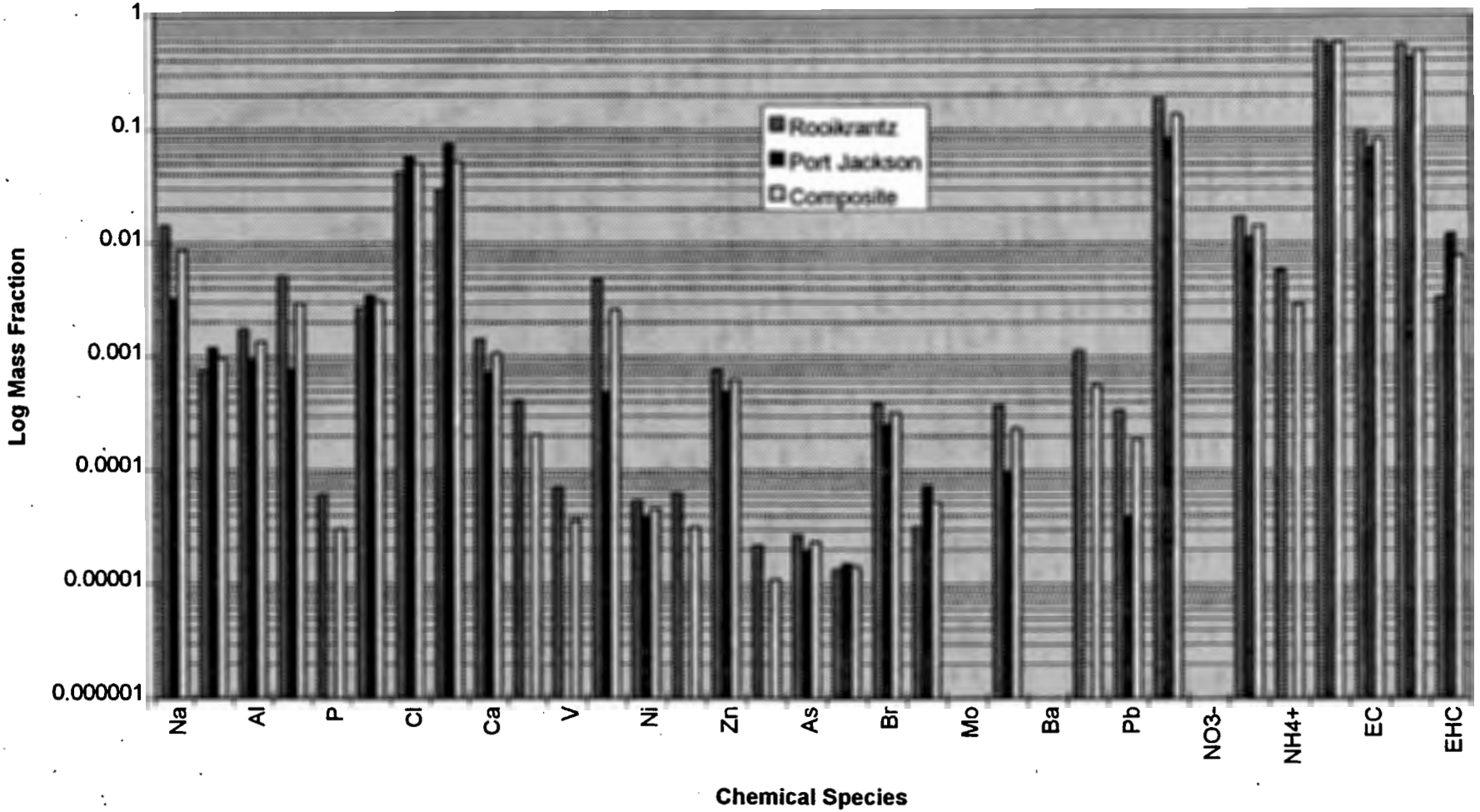
NAME	WBDST [%]	uncertainty [%]	TVDST [%]	uncertainty [%]	RDUST [%]	uncertainty [%]	CRUST [%]	uncertainty [%]
Na	0.000223324	0.00303207	0.001625552	0.003852366	0.001355626	0.002652592	0.001068167	0.001858028
Mg	0.008717201	0.000727697	0.003060568	0.000676972	0.002676865	0.000481669	0.004818211	0.000368154
Al	0.033594169	0.000630612	0.022159306	0.000633438	0.059743489	0.000539697	0.038498988	0.00034804
Si	0.043538192	0.000444606	0.148925237	0.000824921	0.092811252	0.000426549	0.09509156	0.000343206
S	0.001374344	8.86297E-05	0.003162461	0.000121136	0.005932238	0.000138432	0.003489681	6.80625E-05
Cl	0.000958601	0.00013586	0.001085489	0.000150158	0.001832364	0.000145133	0.001292151	8.30454E-05
K	0.00265277	0.000143149	0.007013249	0.000188013	0.01009823	0.000182174	0.006588083	9.94584E-05
Ca	0.029927988	0.000278134	0.026473502	0.000279495	0.060213906	0.000251327	0.038871799	0.000155864
V	1.6035E-05	0.000468513	0.000157729	0.000516088	0.000190265	0.000388116	0.000121343	0.000265934
Fe	0.029436443	0.000154227	0.013426183	0.000110095	0.055383186	0.000137927	0.032748604	7.81243E-05
Ni	0	5.59767E-05	4.35331E-05	6.11987E-05	6.61188E-05	1.09987E-05	3.65507E-05	2.7888E-05
Cu	0.000219242	2.12828E-05	0.000376025	2.42902E-05	0.000531479	1.30215E-05	0.000375582	1.16071E-05
Zn	0.000233528	2.21574E-05	0.000415457	2.52366E-05	0.002998609	2.40202E-05	0.001215865	1.37631E-05
Br	4.05248E-05	5.36443E-05	6.62461E-05	2.01893E-05	0.000191656	1.45386E-05	9.94757E-05	1.97109E-05
Pb	0.00010379	0.000162391	0.000239432	6.15142E-05	0.003490139	4.94311E-05	0.001277787	6.01832E-05
Cl^-	0.010145773	0.001014577	0.007949527	0.000794953	0.002275601	0.00022756	0.0067903	0.000436285
NO_3^-	0	0	0	0	0	0	0	0
SO_4^{2-}	0	0	0	0	0.011795196	0.00117952	0.003931732	0.000393173
Low Temp. Organic Carbon	0.011953353	0.005288151	0.013880126	0.006676975	0.024652339	0.003031499	0.016828606	0.002653228
Low Temp. Elemental Carbon	0	0.002181724	0.021451104	0.006197755	0	0.00099545	0.007150368	0.002215175
High Temp. Organic Carbon	0.085714286	0.012536443	0.083911672	0.012618297	0.100126422	0.012010114	0.08991746	0.007154071
High Temp. Elemental Carbon	0.001166181	0.001166181	0.012618297	0.002523659	0.003666245	0.000758534	0.005816908	0.000960567

Graph of Caltex Catalyst Dust Source Profile



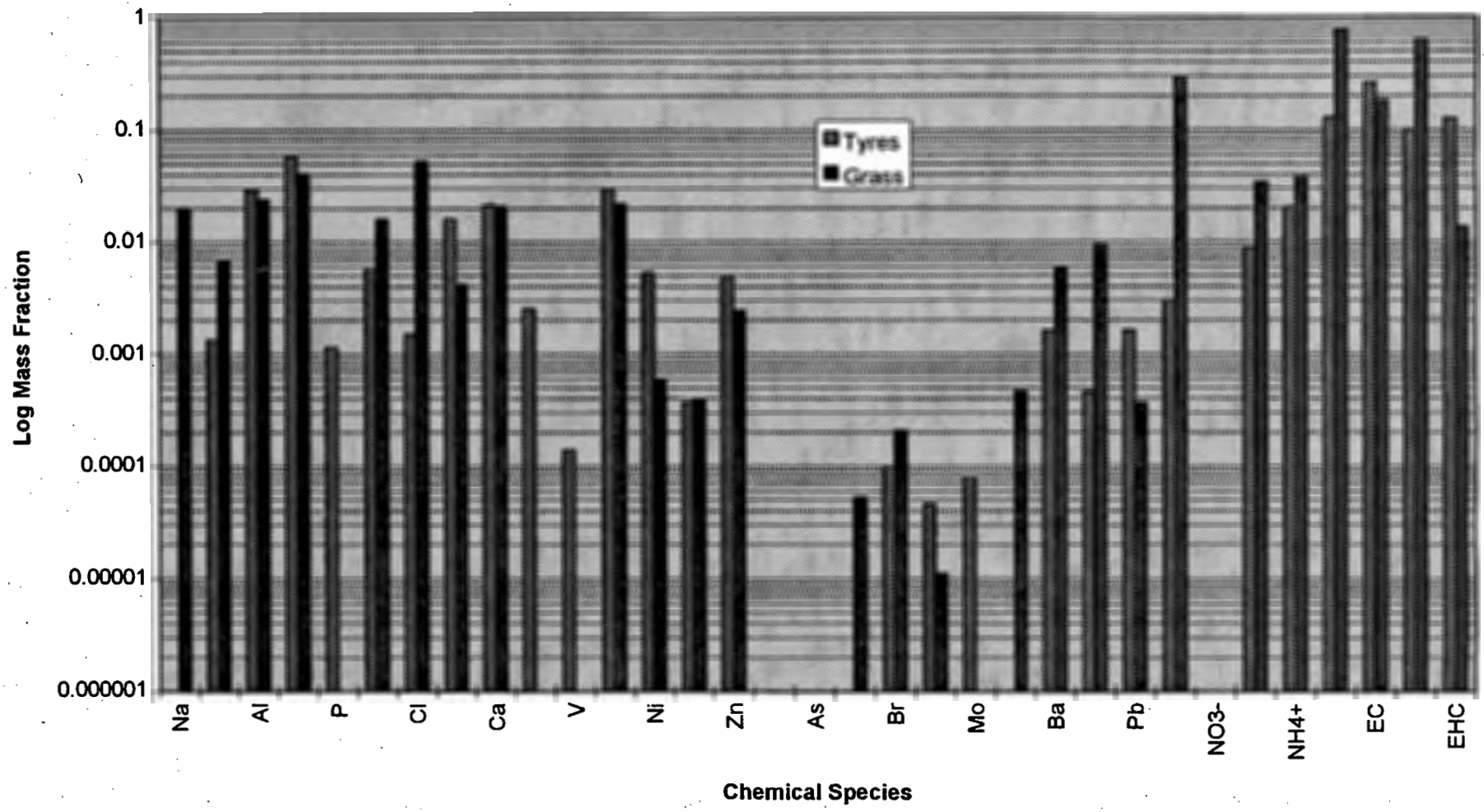
NAME	CALCT [%]	uncertainty [%]
Na	0.001088967	0.001733315
Mg	0	0.000959383
Al	0.087414278	0.000427961
Si	0.19046874	0.000383991
S	0.008367496	5.86263E-05
Cl	0	0.000160195
K	0.001148675	3.0503E-05
Ca	0.000689129	2.86101E-05
V	0.002301839	9.31855E-05
Fe	0.009508437	3.7642E-05
Ni	0.000412006	7.35533E-06
Cu	1.69281E-05	4.00216E-06
Zn	3.32071E-05	4.16441E-06
Br	5.40833E-07	1.1033E-05
Pb	6.19794E-05	1.18442E-05
Cl^-	0.003228772	0.000322877
NO_3^-	0	0
SO_4^{2-}	0.004023797	0.00040238
Low Temp. Organic Carbon	0.023309897	0.00327684
Low Temp. Elemental Carbon	0.003515414	0.001296872
High Temp. Organic Carbon	0.02055165	0.002758248
High Temp. Elemental Carbon	0.004488913	0.000811249

Graph of Wood Burning Source Profiles



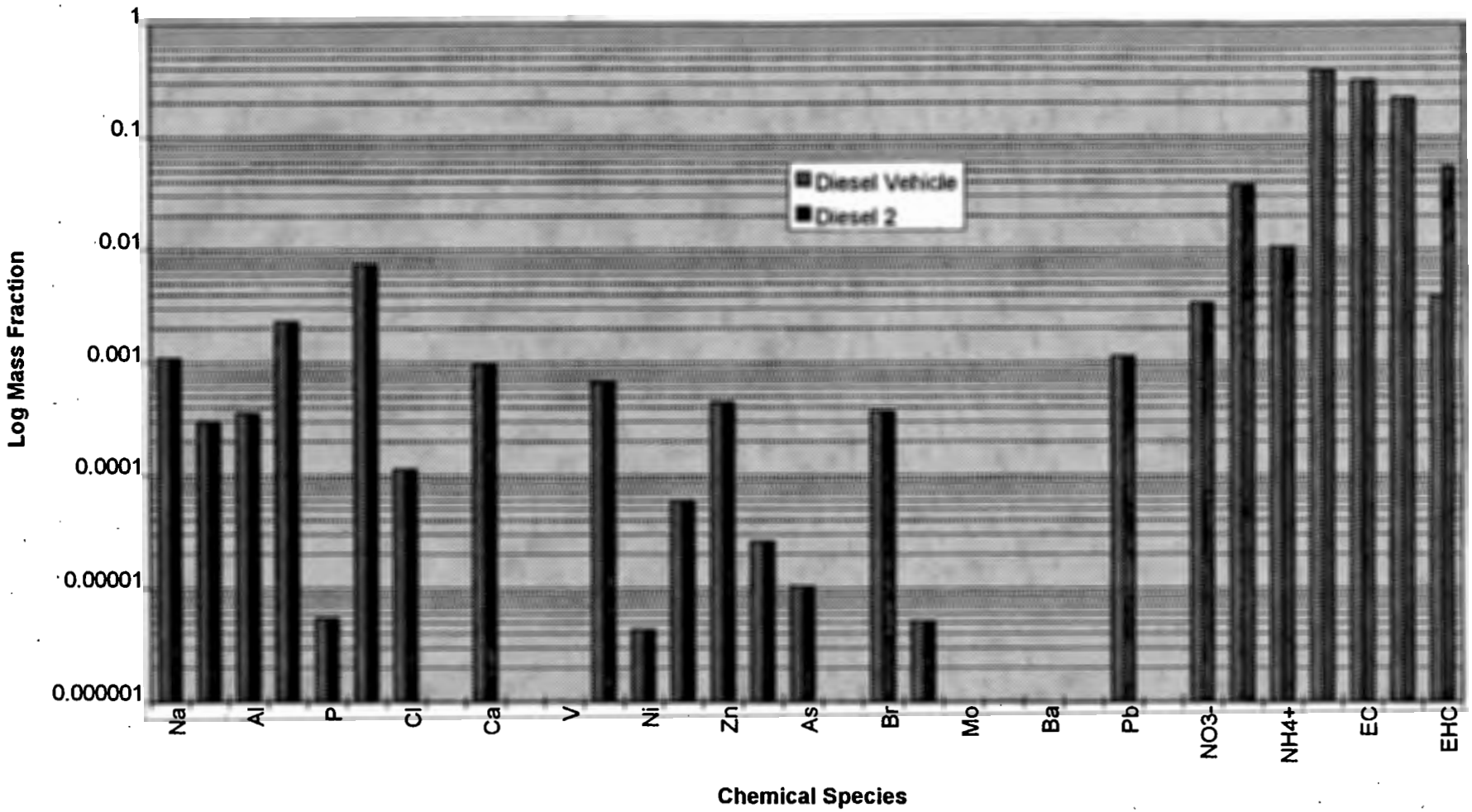
NAME	RKBRN [%]	uncertainty [%]	PJBRN [%]	uncertainty [%]	WBURN [%]	uncertainty [%]
Na	0.014286269	0.001351343	0.003234522	0.004239024	0.008760395	0.002224604
Mg	0.000728657	0.00131791	0.001190619	0.00162364	0.000959638	0.001045597
Al	0.001738209	0.000268358	0.000939212	0.000301313	0.00133871	0.000201746
Si	0.005109851	0.000214328	0.000757598	0.000215385	0.002933725	0.000151927
S	0.002662687	0.000153731	0.00346454	0.000193246	0.003063613	0.000123468
Cl	0.041805373	0.000507164	0.058426642	0.000701689	0.050116007	0.000432892
K	0.02992597	0.000312537	0.075604503	0.000547467	0.052765236	0.000315198
Ca	0.001414627	0.0002	0.0007197	0.001239775	0.001067163	0.000627902
V	7.13433E-05	0.000453134	0	0.000570356	3.56716E-05	0.000364224
Fe	0.004727463	6.65672E-05	0.000474672	3.60225E-05	0.002601067	3.78444E-05
Ni	5.34328E-05	5.61194E-05	3.78987E-05	6.5666E-05	4.56658E-05	4.31897E-05
Cu	6.20896E-05	1.9403E-05	0	6.60413E-05	3.10448E-05	3.44163E-05
Zn	0.000753134	2.62687E-05	0.000488931	2.81426E-05	0.000621032	1.92487E-05
Br	0.000381194	2.1791E-05	0.000253659	2.47655E-05	0.000317426	1.64938E-05
Pb	0.000335224	5.64179E-05	3.93996E-05	0.0002	0.000187312	0.000103903
Cl^-	0.18680597	0.018680597	0.083076923	0.008307692	0.134941447	0.01022231
NO_3^-	0	0	0	0	0	0
SO_4^{2-}	0.016835821	0.001683582	0.011257036	0.001125704	0.014046428	0.001012627
Low Temp. Organic Carbon	0.056119403	0.035469671	0.120450281	0.010351305	0.088284842	0.018474625
Low Temp. Elemental Carbon	0.091641791	0.016843864	0.057410882	0.01246208	0.074526336	0.010476392
High Temp. Organic Carbon	0.545373134	0.06358209	0.424765478	0.049906191	0.485069306	0.040414447
High Temp. Elemental Carbon	0.003283582	0.00119403	0.012007505	0.002626642	0.007645543	0.00144265

Graph of Tyre and Grass Burning Profiles



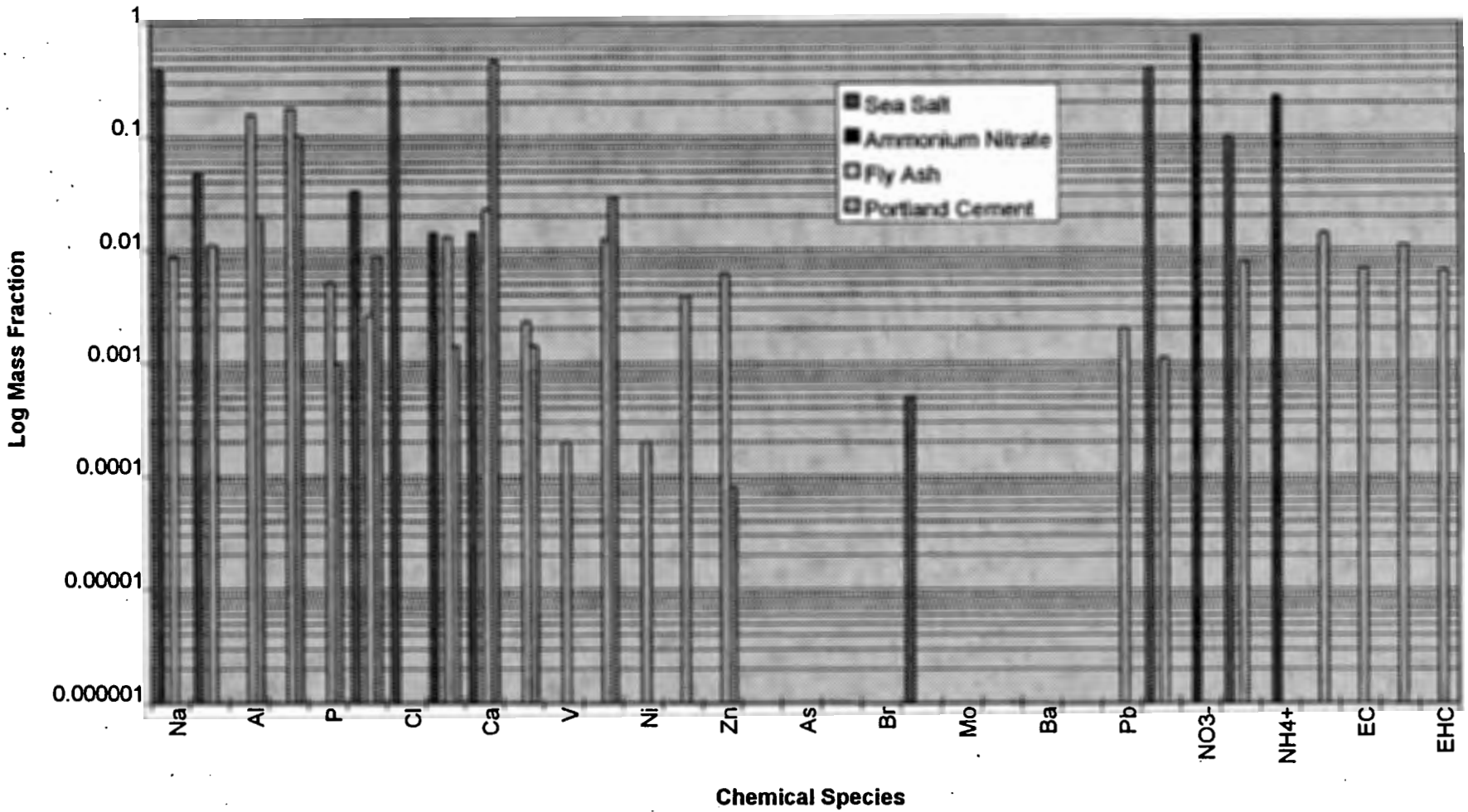
NAME	TYBRN [%]	uncertainty [%]	GRBRN [%]	uncertainty [%]
Na	0	0.002243899	0.019890678	0.003567797
Mg	0.001327188	0.000351592	0.006826271	0.001394915
Al	0.028718568	0.000394695	0.023782203	0.001024576
Si	0.056408886	0.000338329	0.040363559	0.000825424
S	0.005609682	0.000101724	0.01584322	0.000437288
Cl	0.001498806	0.000111008	0.05269661	0.000973729
K	0.015917241	0.00016008	0.004116102	0.000320339
Ca	0.021211008	0.000175597	0.020577119	0.000483051
V	0.000137931	0.000240716	0	0.00234322
Fe	0.029108488	0.000102785	0.021723729	0.000233898
Ni	0.005289655	3.64721E-05	0.000595763	6.10169E-05
Cu	0.000372016	1.49867E-05	0.000389831	5.9322E-05
Zn	0.004896419	3.06366E-05	0.002414407	7.79661E-05
Br	9.7878E-05	1.00796E-05	0.00020678	5.67797E-05
Pb	0.001630371	3.88594E-05	0.000363559	0.000507627
Cl^-	0.002984085	0.000298408	0.294152542	0.029415254
NO_3^-	0	0	0	0
SO_4^{2-}	0.008912467	0.000891247	0.033813559	0.003381356
Low Temp. Organic Carbon	0.028912467	0.001251191	0.156779661	0.012935879
Low Temp. Elemental Carbon	0.134880637	0.040758927	0.168644068	0.033289016
High Temp. Organic Carbon	0.099602122	0.012068966	0.621186441	0.075423729
High Temp. Elemental Carbon	0.126127321	0.022413793	0.013559322	0.004237288

Graph of Diesel Vehicle Source Profile



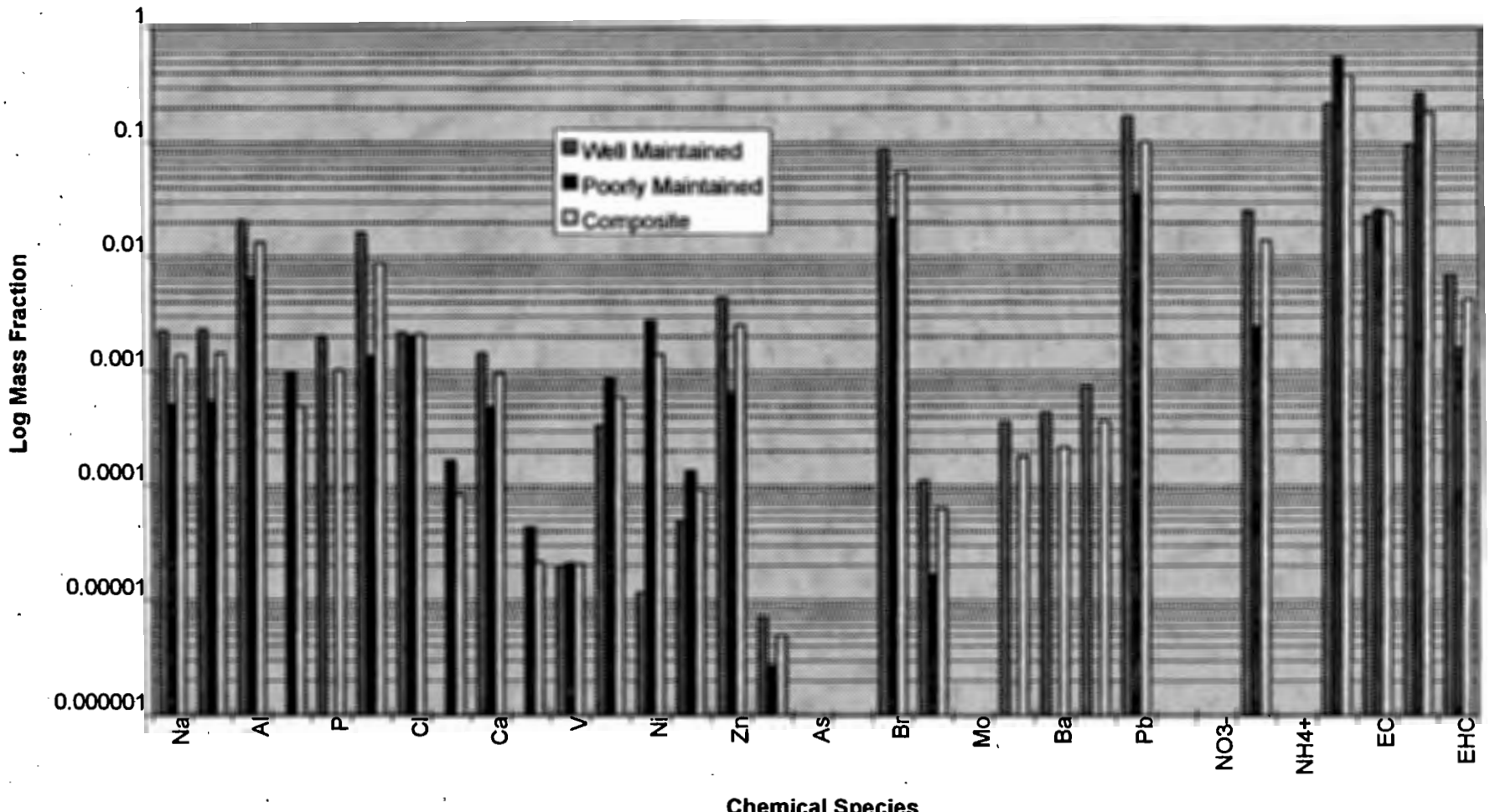
NAME	DIVEH [%]	uncertainty [%]	DIES2 [%]	uncertainty [%]
Na	0.001078516	0.001335742	0.001078516	0.001335742
Mg	0.000298047	0.000699023	0.000298047	0.000699023
Al	0.000353906	0.000399023	0.000353906	0.000399023
Si	0.002292383	0.000119922	0.002292383	0.000119922
S	0.007339453	0.000116406	0.007339453	0.000116406
Cl	0.0001125	0.000226758	0.0001125	0.000226758
K	0	0.000156055	0	0.000156055
Ca	0.000961328	7.89062E-05	0.000961328	7.89062E-05
V	0	0.000317969	0	0.000317969
Fe	0.000658594	2.46094E-05	0.000658594	2.46094E-05
Ni	4.29687E-06	3.59375E-05	4.29687E-06	3.59375E-05
Cu	5.95703E-05	1.30859E-05	5.95703E-05	1.30859E-05
Zn	0.000441211	1.67969E-05	0.000441211	1.67969E-05
Br	0.00037207	1.875E-05	0.00037207	1.875E-05
Pb	0.00112207	4.6875E-05	0.00112207	4.6875E-05
Cl^-	0	0	0	0
NO_3^-	0.003359375	0.000335937	0.003359375	0.000335937
SO_4^{2-}	0.037363281	0.003736328	0.037363281	0.003736328
Low Temp. Organic Carbon	0.16640625	0.025584447	0.16640625	0.025584447
Low Temp. Elemental Carbon	0.311523437	0.030076223	0.261523437	0.030076223
High Temp. Organic Carbon	0.219140625	0.025976562	0.219140625	0.025976562
High Temp. Elemental Carbon	0.00390625	0.001367187	0.05390625	0.001367187

Graph of Ammonium Nitrate, Portland Cement, Sea Salt and Fly Ash Source Profiles



NAME	MARI1 [%]	uncertainty [%]	KYLAN [%]	uncertainty [%]	SASFA [%]	uncertainty [%]	PCEMT [%]	uncertainty [%]
Na	0.4	0.04	0	0	0.0086	0.0002	0	0
Mg	0.048	0.009	0	0	0.0109	0.0002	0	0
Al	0	0	0	0	0.1563	0.0046	0.02	0
Si	0	0	0	0	0.1764	0.0021	0.102	0
S	0.033	0.013	0	0	0.0026	0.00016	0.0088	0
Cl	0.4	0.1	0	0	0	0.000160195	0	0
K	0.014	0.002	0	0	0.0129	0.0008	0.0014	0
Ca	0.014	0.002	0	0	0.0227	0.0021	0.461	0
V	0	0	0	0	0.0002	0.0001	0	0
Fe	0	0	0	0	0.0122	0.00013	0.0294	0
Ni	0	0	0	0	0.0002	0.00001	0	0
Cu	0	0	0	0	0.0039	0.00029	0	0
Zn	0	0	0	0	0.0061	0.00024	0.00008	0
Br	0	0.002	0	0	0	8.43537E-05	0	0
Pb	0	0	0	0	0.002	0.0009	0	0
Cl^-	0.4	0.1	0	0	0.0011	0.0002	0	0
NO_3^-	0	0	0.775	0	0	0	0	0
SO_4^{2-}	0.1	0.04	0	0	0.0079	0.0055	0	0
Low Temp. Organic Carbon	0	0	0	0	0.0031	0.001473092	0	0
Low Temp. Elemental Carbon	0	0	0	0	0.0003	0.001256981	0	0
High Temp. Organic Carbon	0	0	0	0	0.011	0.0005	0	0
High Temp. Elemental Carbon	0	0	0	0	0.0066	0.0002	0	0

Graph of Petrol Vehicle Profiles



NAME	VEH1 [%]	uncertainty [%]	PETVH [%]	uncertainty [%]	VEH2 [%]	uncertainty [%]
Na	0.002239838	0.004645591	0.000510035	0.000961573	0.001374937	0.002372032
Mg	0.002306156	0.021777514	0.00054468	0.004560867	0.001425418	0.01112499
Al	0.020596149	0.00285334	0.006403631	0.000708775	0.01349989	0.001470026
Si	0	0.002135726	0.000989713	0.000162733	0.000494856	0.001070958
S	0.016441645	0.004810078	0.001350429	0.003018053	0.008896037	0.002839256
Cl	0.002171856	0.000714999	0.002025214	0.000153707	0.002098535	0.000365667
K	0	0.000234847	0.0001647	1.78517E-05	8.235E-05	0.000117762
Ca	0.001434039	0.000113145	0.000475946	2.34997E-05	0.000954992	5.77797E-05
V	1.99667E-05	0.000425244	2.09783E-05	8.17448E-05	2.04725E-05	0.000216515
Fe	0.000332303	2.70977E-05	0.000857791	1.17499E-05	0.000595047	1.47677E-05
Ni	1.16473E-05	5.15807E-05	0.002762632	1.60363E-05	0.00138714	2.7008E-05
Cu	4.8966E-05	5.46708E-05	0.000132879	6.40444E-06	9.09227E-05	2.75223E-05
Zn	0.004388163	4.15973E-05	0.000636006	7.41301E-06	0.002512084	2.11264E-05
Br	0.088554077	0.000447112	0.022060817	9.61674E-05	0.055307447	0.000228669
Pb	0.169173758	0.000435465	0.035386233	9.21836E-05	0.102279996	0.000222557
Cl^-	0	0	0	0	0	0
NO_3^-	0	0	0	0	0	0
SO_4^{2-}	0.025362491	0.002536249	0.002476046	0.000247605	0.013919269	0.001274153
Low Temp. Organic Carbon	0.1209	0.00425	0.294099849	0.042062235	0.207499924	0.020990305
Low Temp. Elemental Carbon	0.0159	0.0001	0.024609178	0.002526973	0.020254589	0.001251059
High Temp. Organic Carbon	0.0982	0.0056	0.27100353	0.031517902	0.184601765	0.016005766
High Temp. Elemental Carbon	0.007	0.0005	0.001613717	0.000453858	0.004306858	0.000337634

APPENDIX G: CHEMICAL MASS BALANCE MODEL PERFORMANCE MEASURES

Source Contribution Estimate

The source contribution estimate (SCE) shows the contribution in $\mu g/m^3$ of each source modelled to the mass on the ambient filter. Negative values of the SCE are not meaningful. Values of the SCE that are less than its standard error show that that calculating a source contribution is beyond the sensitivity of the model. The T-statistic value is the ratio of the SCE to the standard error and a value below 2 also shows that the calculation of a source contribution is outside the sensitivity of the model.

Chi Square

This value is calculated from the weighted sum of squares of the differences between the calculated and measured fitting species. The weighting is inversely proportional to the squares of the precisions in the source profiles and ambient data for each species. A value less than 1 indicates a very good fit while values greater than 4 indicate that one or more species concentrations are not well explained by the source contribution estimates.

R Square

This value is the fraction of the variance in the measured concentration data which is explained by the variance in the calculated species concentrations. It is determined by linear regression of measured versus model-calculated values for the fitting species acceptable values for this diagnostic are between 0.8 and 1. Values below 0.8 suggest that the SCE do not explain the ambient data well.

Percent Mass

The percent mass is the ratio of the sum of the model-calculated SCE to the measured mass concentration on the ambient sample. This value should be 100⊕20 %.

Similarity/Uncertainty Cluster Display

Similarity/uncertainty clusters are groups of sources that the model cannot separate either because their chemical profiles are too similar or their uncertainties are high. The sum of the sources that are collinear is displayed along with their uncertainty. The following steps are recommended if two or more source profiles are collinear:

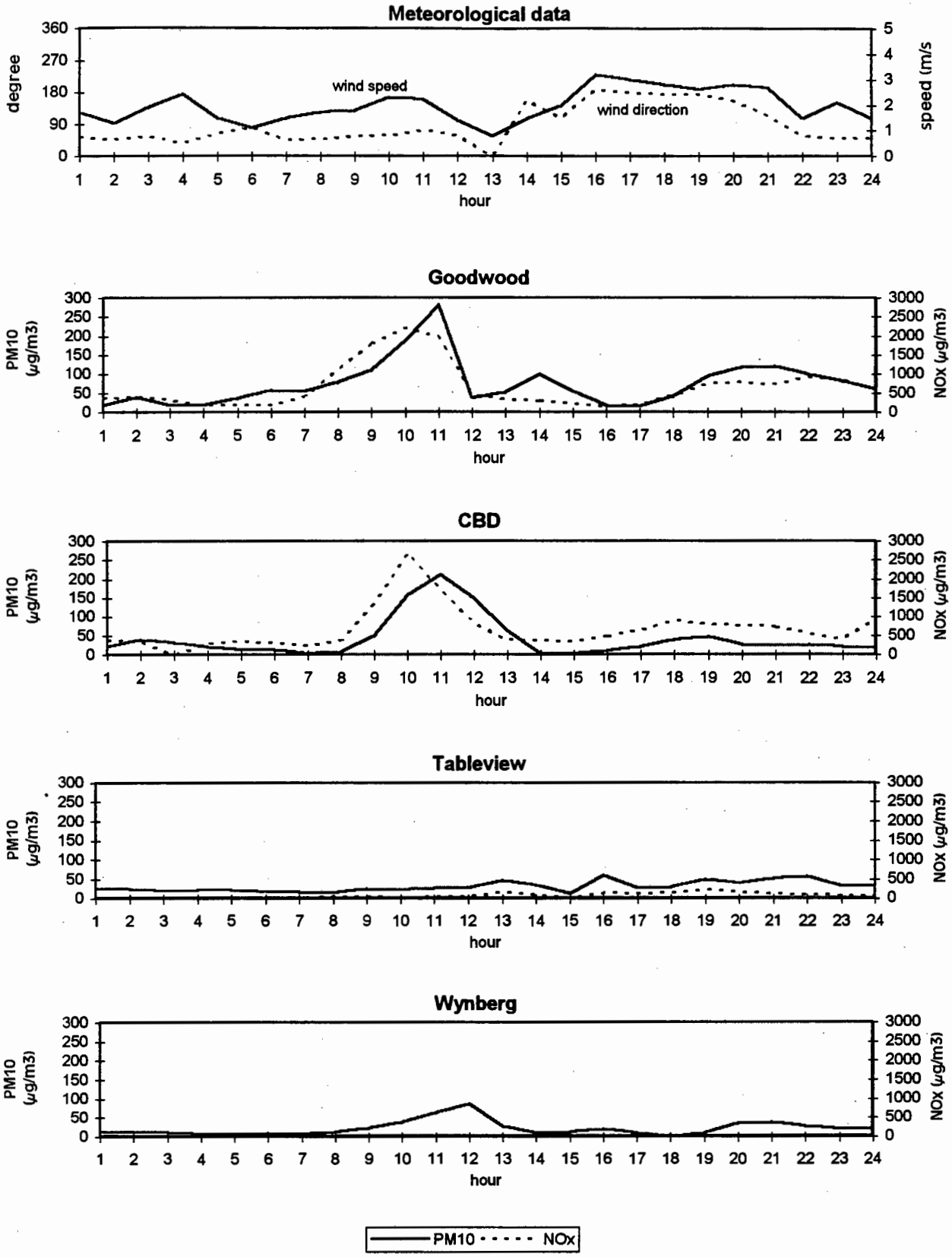
- improve source profiles by measuring additional species,
- reduce the uncertainties in the source profiles of the cluster sources to values that are realistically achievable,
- use an estimate of the sum of the source categories that are collinear as a source profile,
- combine the profiles of the cluster sources into a single composite profile. This will then represent the combined impact of the sources, and
- delete species that are causing similarity in the source profiles from the fit.

R/U Ratio

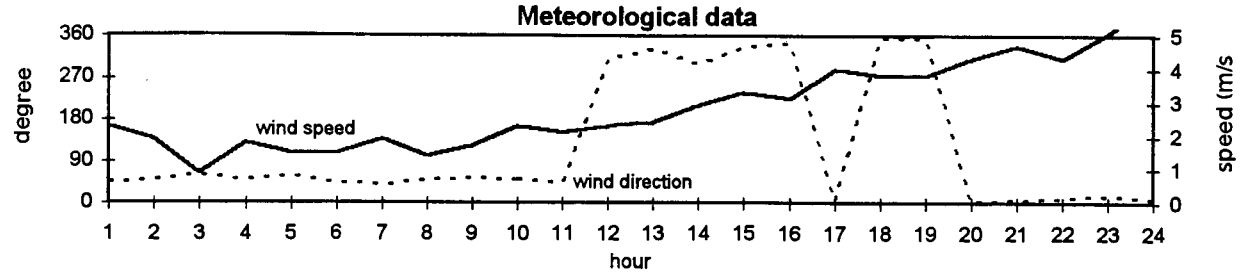
These values are shown in the species concentration display and they represent the number of uncertainty intervals by which the calculated and measured concentrations differ for each chemical species (the residual). If the absolute value of the R/U is much greater than 2 then the residual is significant. A positive value means that either one or more source profiles is contributing too much or the ambient concentration of the particular species is underestimated. A negative value means that there is not contribution by the source profiles to a particular species or the ambient concentration for that species is overestimated. High R/U causes high chi squared and thus reducing high R/U reduces the Chi Squared and thus improves the fit.

APPENDIX H: AMBIENT METEROLOGICAL AND GASEOUS DATA

14/07/1995


Meteorological data
degree
360
270
180
90
0
wind speed
wind direction
speed (m/s
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hour
Goodwood
PM10 (µg/m3)
300
250
200
150
100
50
0
NOx (µg/m3)
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hour
CBD
PM10 (µg/m3)
NOx (µg/m3)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hour
Tableview
PM10 (µg/m3)
NOx (µg/m3)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hour
Wynberg
PM10 (µg/m3)
NOx (µg/m3)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
hour
PM10
NOx

25/07/1995


Meteorological data
degree
360
270
180
90
0
wind speed
wind direction
speed (m/s
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4
3
2
1
0
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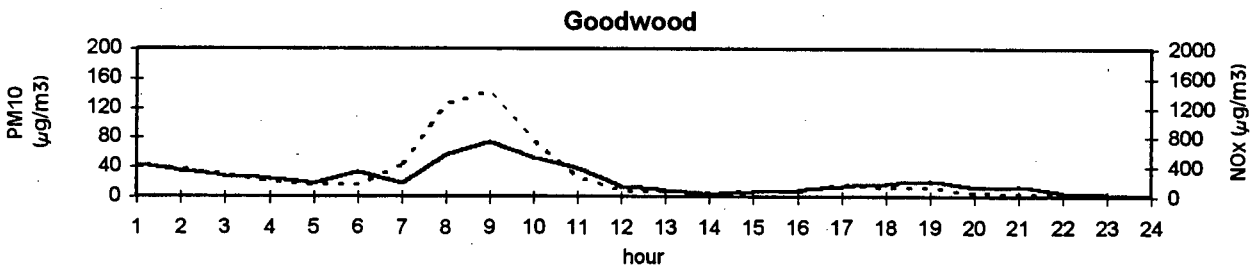
hour


Goodwood
PM10 (µg/m3)
200
160
120
80
40
0
NOx (µg/m3)
2000
1600
1200
800
400
0
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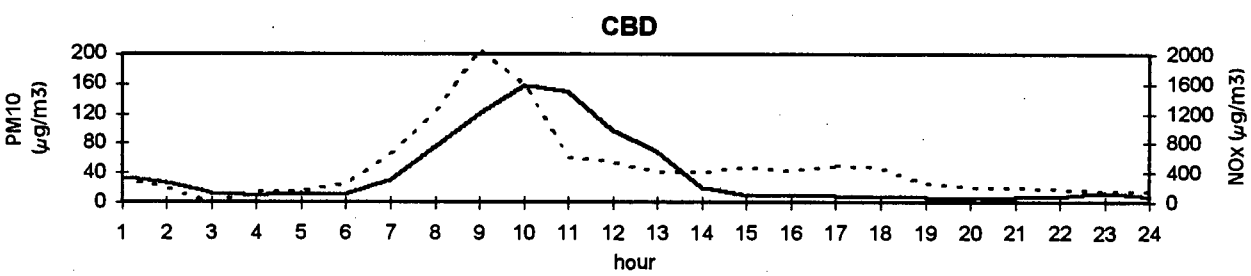
hour


CBD
PM10 (µg/m3)
200
160
120
80
40
0
NOx (µg/m3)
2000
1600
1200
800
400
0
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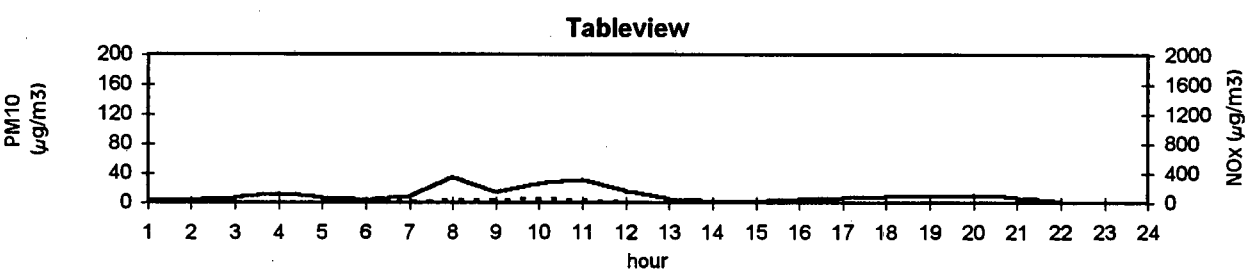
hour


Tableview
PM10 (µg/m3)
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160
120
80
40
0
NOx (µg/m3)
2000
1600
1200
800
400
0
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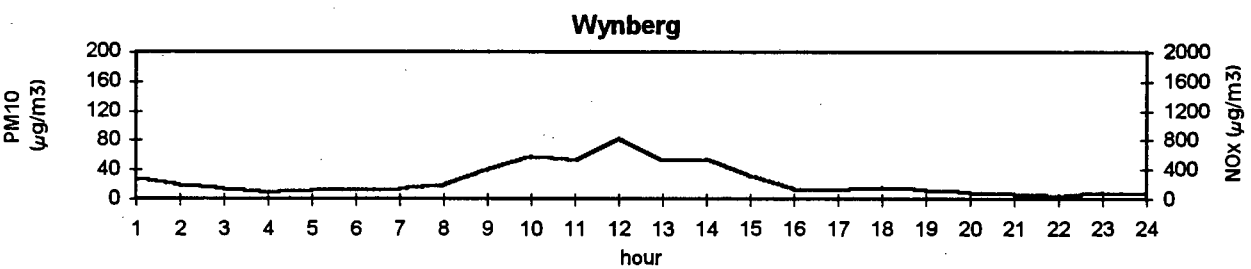
hour


Wynberg
PM10 (µg/m3)
200
160
120
80
40
0
NOx (µg/m3)
2000
1600
1200
800
400
0
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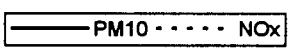
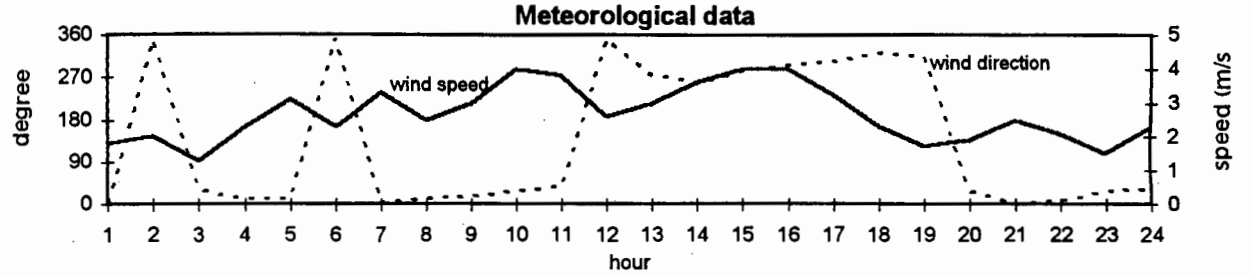
hour


PM10
NOx

18/08/1995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90
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wind speed
wind direction
speed (m/s
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3
2
1
0
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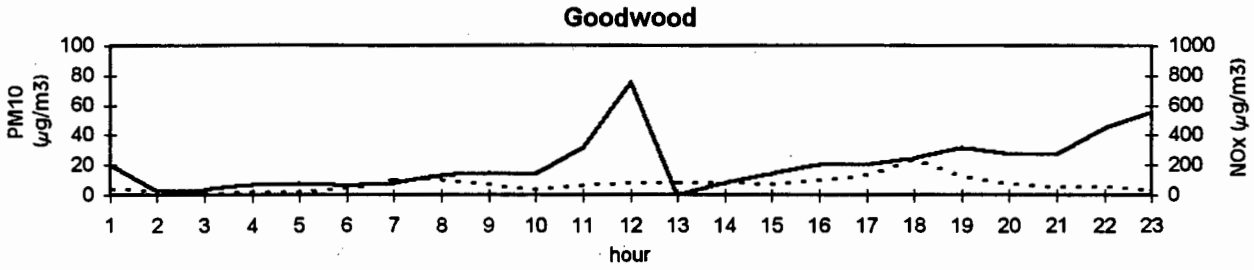
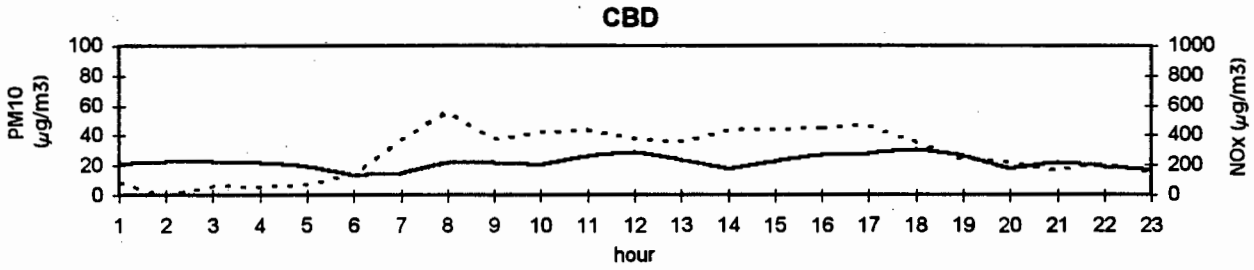
hour


Goodwood
PM10 (µg/m3)
100
80
60
40
20
0
NOx (µg/m3)
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
hour


CBD
PM10 (µg/m3)
100
80
60
40
20
0
NOx (µg/m3)
1000
800
600
400
200
0
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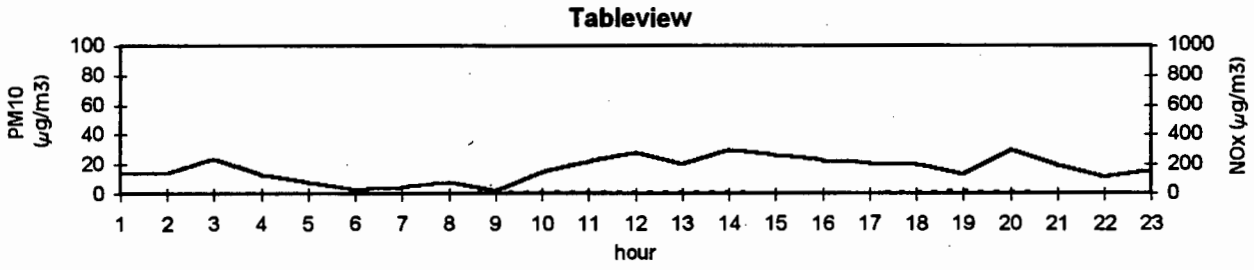
hour


Tableview
PM10 (µg/m3)
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80
60
40
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NOx (µg/m3)
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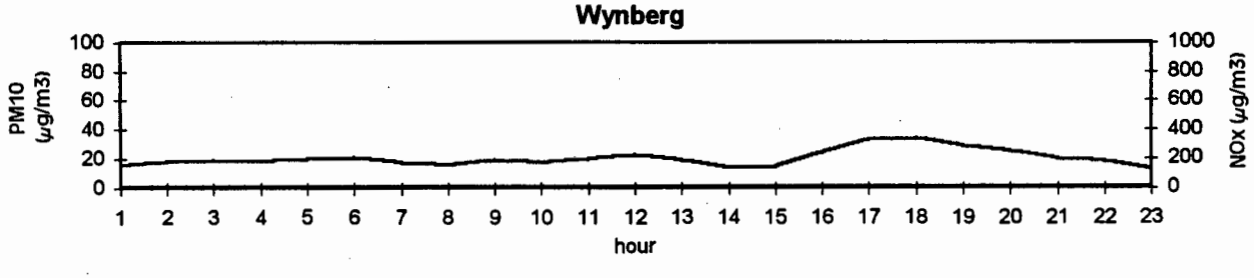
hour


Wynberg
PM10 (µg/m3)
100
80
60
40
20
0
NOx (µg/m3)
1000
800
600
400
200
0
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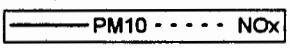
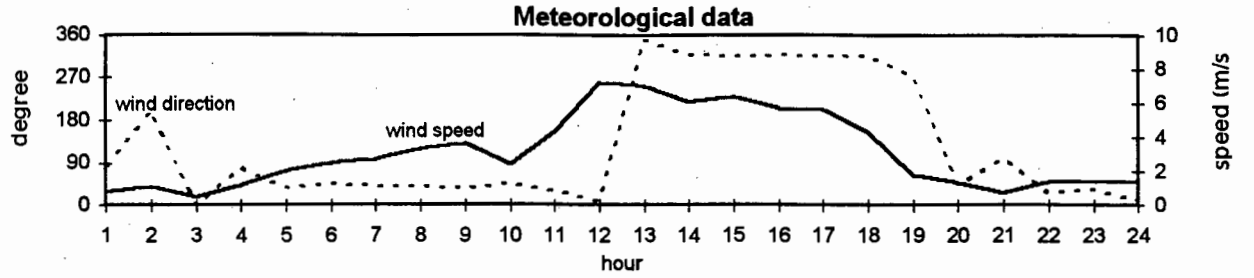
hour


PM10
NOx

30/04/1996


Meteorological data
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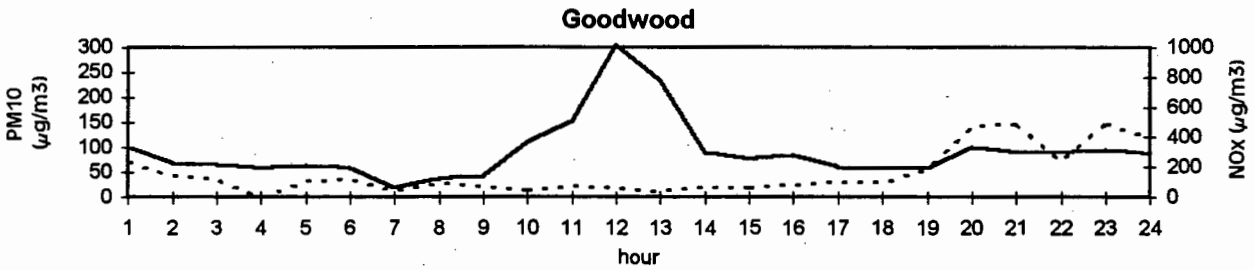
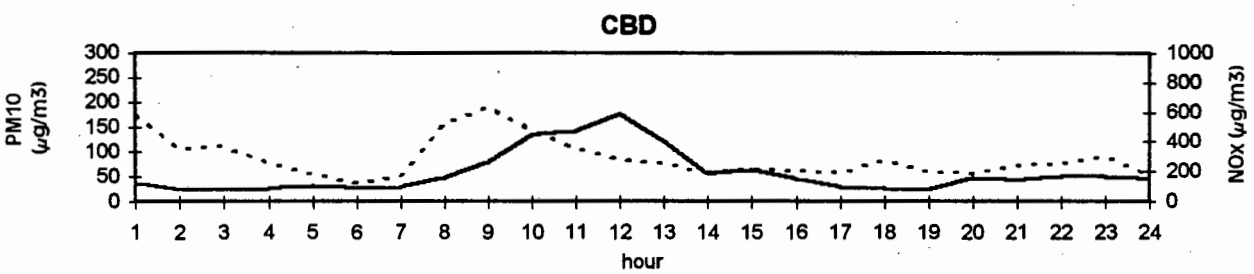
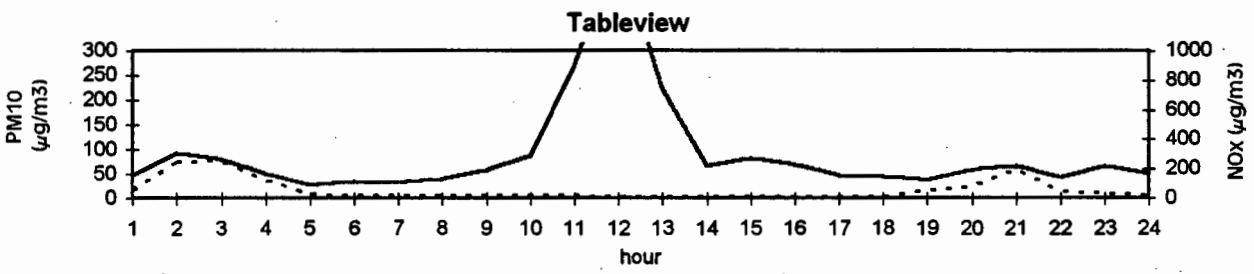
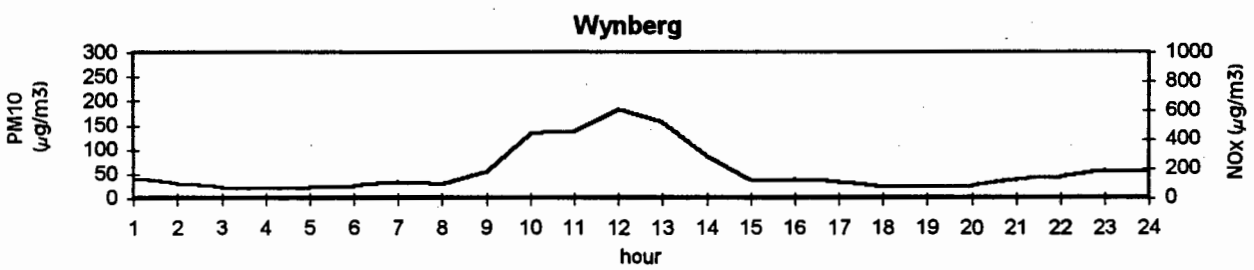
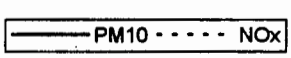
speed (m/s
wind direction
wind speed
hour


Goodwood
PM10 (µg/m3)
NOx (µg/m3)
hour

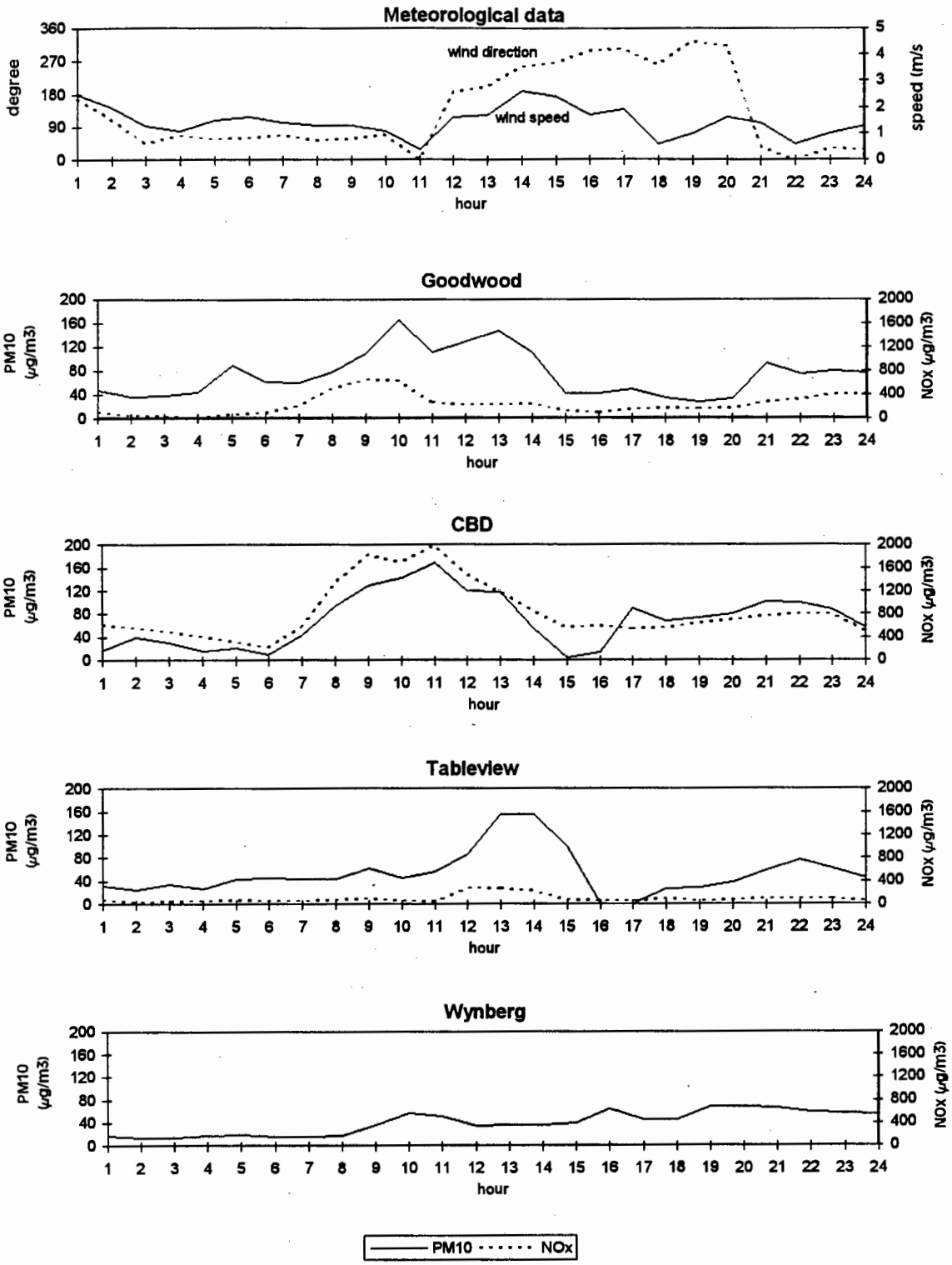

CBD
PM10 (µg/m3)
NOx (µg/m3)
hour


Tableview
PM10 (µg/m3)
NOx (µg/m3)
hour

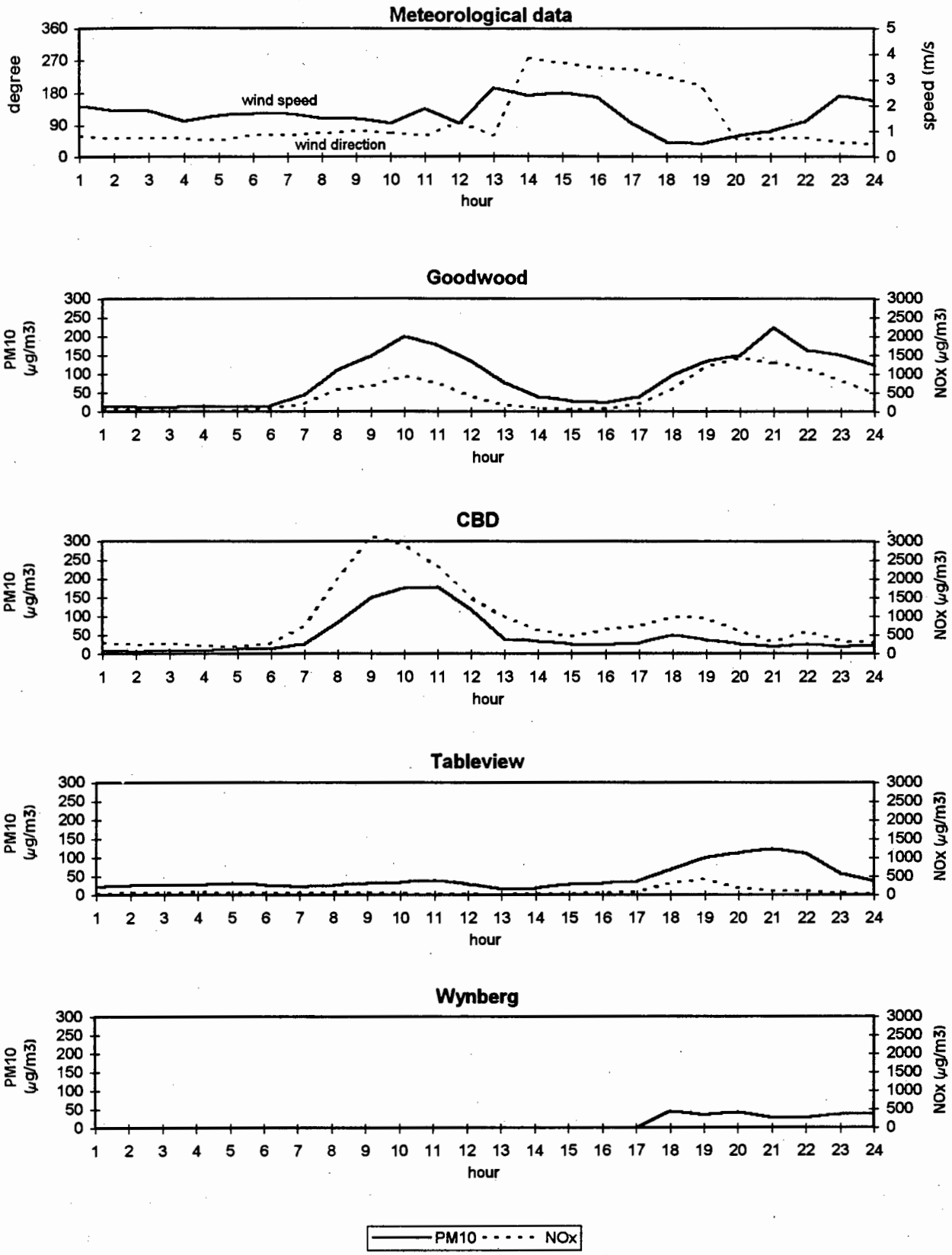

Wynberg
PM10 (µg/m3)
NOx (µg/m3)
hour


PM10
NOx

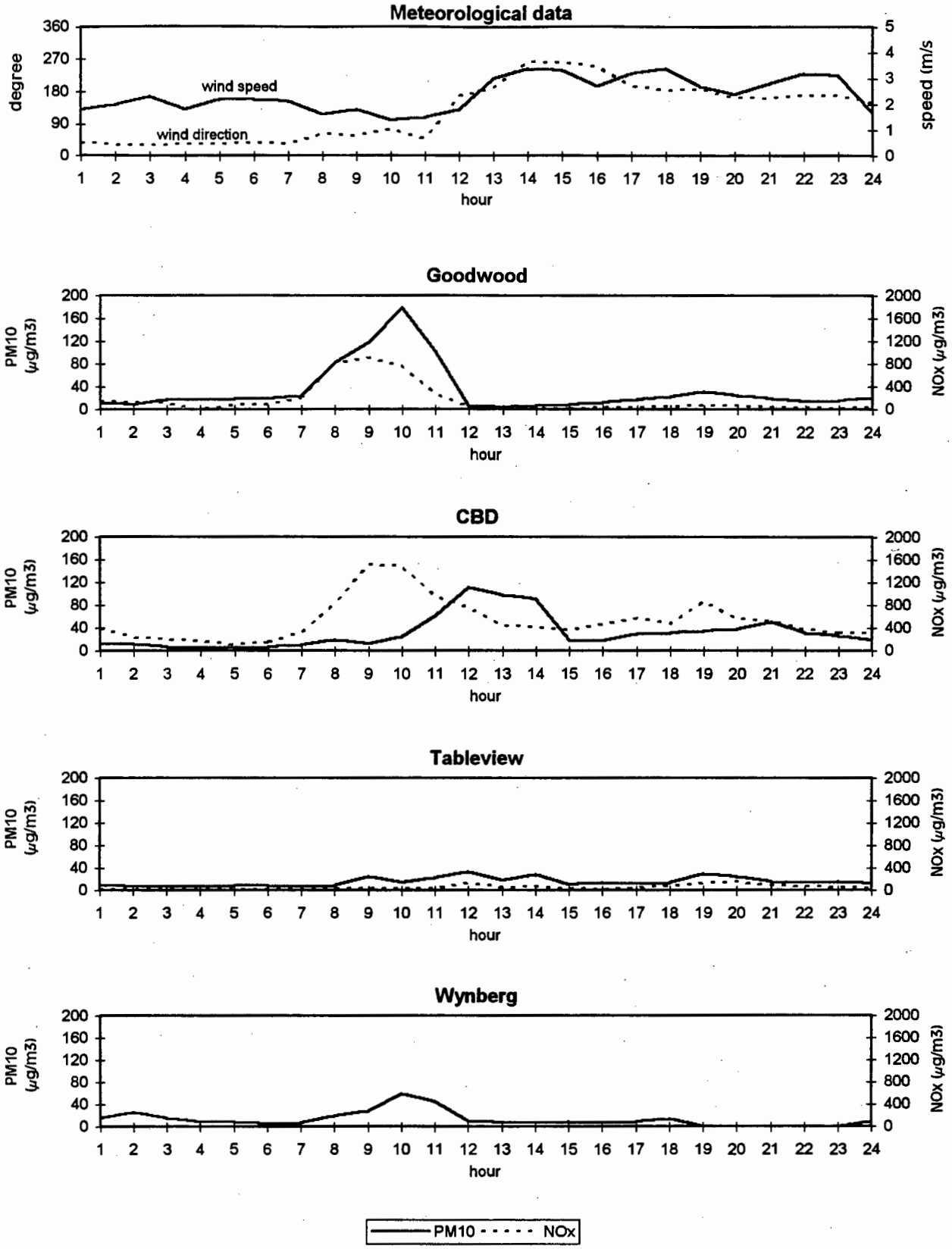
08/05/1996


Meteorological data
degree
speed (m/s
wind direction
wind speed
hour
Goodwood
PM10 (µg/m3)
NOx (µg/m3)
hour
CBD
PM10 (µg/m3)
NOx (µg/m3)
hour
Tableview
PM10 (µg/m3)
NOx (µg/m3)
hour
Wynberg
PM10 (µg/m3)
NOx (µg/m3)
hour
PM10
NOx

27/05/1996


Meteorological data
degree
speed (m/s
wind speed
wind direction
hour
Goodwood
PM10 (µg/m3)
NOx (µg/m3)
hour
CBD
PM10 (µg/m3)
NOx (µg/m3)
hour
Tableview
PM10 (µg/m3)
NOx (µg/m3)
hour
Wynberg
PM10 (µg/m3)
NOx (µg/m3)
hour
PM10
NOx

04/06/1996


Meteorological data
degree
speed (m/s
wind speed
wind direction
hour
Goodwood
PM10 (µg/m3)
NOx (µg/m3)
hour
CBD
PM10 (µg/m3)
NOx (µg/m3)
hour
Tableview
PM10 (µg/m3)
NOx (µg/m3)
hour
Wynberg
PM10 (µg/m3)
NOx (µg/m3)
hour
PM10
NOx

APPENDIX I: AMBIENT FILTER CONCENTRATIONS

CBD [all concentrations in μg/m³]															
DATE	**04/06/96**	**30/04/96**	**20/05/96**	**16/02/96**	**15/07/95**	**18/08/95**	**29/08/95**	**20/09/95**	**23/04/96**	**15/09/95**	**14/07/95**	**01/08/95**	**27/05/96**	**08/05/96**	**25/07/95**
Total Concentration	6.0978	17.2265	12.4430	11.9155	15.9807	17.8700	20.2617	24.7136	19.7250	24.2144	28.8525	25.3232	25.3126	34.0464	51.2087
Na	0.0857	0.1247	0.0114	0.1611	0.2183	0.2839	0.2130	0.3298	0.2053	0.3270	0.1720	0.1087	0.1146	0.1125	0.2170
Mg	0.0384	0.0532	0.0294	0.0353	0.0625	0.0687	0.0340	0.1151	0.0278	0.0792	0.0495	0.0276	0.0495	0.1206	0.1064
Al	0.1228	0.1520	0.0138	0.0635	0.1190	0.0455	0.0835	0.0000	0.1333	0.1043	0.1670	0.1153	0.1736	0.2747	0.2860
Si	0.0899	0.3584	0.0181	0.0870	0.3102	0.1157	0.0975	0.0292	0.0419	0.0859	0.1015	0.1043	0.0495	0.1329	0.2008
S	0.4273	1.7567	0.0058	0.4765	0.3849	1.5433	0.8582	0.0122	0.5573	1.2874	0.3018	1.5021	0.5042	0.8428	2.4485
Cl	0.0079	0.0000	0.0000	0.0252	0.1578	0.0042	0.0113	0.0059	0.0095	0.0030	0.0334	0.0022	0.0110	0.0228	0.0325
K	0.0854	0.1037	0.0004	0.0837	0.1150	0.0796	0.0752	0.0015	0.0638	0.1039	0.1526	0.0975	0.1092	0.1736	0.1811
Ca	0.0423	0.0560	0.0062	0.0498	0.0959	0.0408	0.0520	0.0186	0.0393	0.0556	0.0395	0.1035	0.0405	0.1038	0.1068
V	0.0020	0.0035	0.0007	0.0079	0.0057	0.0010	0.0191	0.0001	0.0138	0.0225	0.0058	0.0258	0.0023	0.0081	0.0613
Fe	0.1171	0.0814	0.0116	0.0542	0.1060	0.0423	0.0918	0.0008	0.0702	0.0879	0.1277	0.1186	0.1330	0.2845	0.5192
Ni	0.0047	0.0010	0.0002	0.0022	0.0007	0.0002	0.0057	0.0000	0.0052	0.0076	0.0025	0.0087	0.0013	0.0096	0.0215
Cu	0.0064	0.0028	0.0003	0.0025	0.0025	0.0006	0.0066	0.0000	0.0051	0.0072	0.0101	0.0074	0.0087	0.0135	0.0137
Zn	0.0534	0.0081	0.0000	0.0180	0.0152	0.0126	0.0371	0.0000	0.0221	0.0233	0.0358	0.0488	0.0432	0.0707	0.1199
Br	0.2783	0.1651	0.0000	0.1326	0.1502	0.0763	0.3055	0.0000	0.3696	0.2803	0.5974	0.4061	0.6422	0.8396	0.8764
Pb	0.5245	0.3195	0.0016	0.3338	0.2560	0.1888	0.6253	0.0000	0.6542	0.5943	1.0722	0.7522	1.1508	1.5816	1.4652
Cl^-	0.0000	0.1673	0.0471	0.1355	0.5596	0.3406	0.1642	0.6934	0.2099	0.1855	0.9307	0.3852	0.1186	0.5839	1.0036
NO_3^-	0.0000	0.2464	0.5632	0.2023	0.4532	0.6296	0.9428	0.0000	0.5809	1.1648	0.6630	1.6991	0.8343	1.9718	2.7007
SO_4^{2-}	0.0000	4.9088	3.0789	1.3724	1.4446	4.1606	2.7646	2.2810	1.7609	4.3917	1.8674	4.3025	1.3950	5.5403	7.0316
Organic Carbon	3.3556	8.9619	6.9292	6.7699	9.3775	8.8808	11.2530	18.7956	11.7802	12.5811	18.6942	11.5707	14.5985	16.0787	23.6010
Elemental Carbon	0.7401	1.3382	2.3114	2.4305	2.8792	2.9197	3.3455	3.6699	3.8727	4.0957	4.2985	4.8594	5.8293	7.2182	11.4964
High Temp. Organic Carbon	2.6967	5.3933	4.4657	4.4857	5.2616	6.1131	6.5187	9.0633	6.5693	7.5223	10.2595	7.9346	8.9416	11.1618	17.3560
High Temp. Elemental Carbon	0.4968	0.5779	0.7198	1.1644	1.2368	1.6322	1.0848	1.7640	0.7806	1.0645	2.5142	0.7367	0.3650	0.5981	2.5750

Goodwood [all concentrations in $\mu g/m^3$]

DATE	04/06/96	08/05/96	14/07/95	14/08/95	15/07/95	15/09/95	16/02/96	20/05/96	20/09/95	27/05/96	28/08/95	30/04/96
Total Concentration	21.8025	35.2627	50.9489	15.2620	15.5613	15.0518	8.5608	15.9739	23.6586	38.5805	34.8723	22.5931
Na	0.1628	0.4788	0.1099	0.3204	0.0901	0.3057	0.3373	0.0708	0.3498	0.1826	0.1745	0.2593
Mg	0.0600	0.1159	0.0804	0.0557	0.0221	0.0687	0.0291	0.0257	0.0891	0.0677	0.0940	0.1070
Al	0.1878	0.2025	0.2468	0.0501	0.1208	0.0064	0.0190	0.0833	0.0644	0.3178	0.1982	0.3416
Si	0.0966	0.2632	0.1071	0.0658	0.2221	0.1163	0.0476	0.1404	0.1103	0.1909	0.0618	0.6114
S	0.5304	1.0796	0.7002	1.0737	0.6146	0.7601	0.3713	1.1118	0.6885	1.0109	1.5128	1.7479
Cl	0.0519	0.0310	0.1338	0.0157	0.0368	0.0873	0.3268	0.0023	0.0451	0.2002	0.0185	0.0092
K	0.0912	0.2887	0.3634	0.0556	0.1413	0.1227	0.1389	0.1258	0.0514	0.3377	0.0741	0.2392
Ca	0.0497	0.0973	0.0555	0.0321	0.0679	0.1184	0.0862	0.0431	0.1108	0.1060	0.0361	0.0802
V	0.0107	0.0243	0.0284	0.0000	0.0000	0.0084	0.0035	0.0052	0.0000	0.0142	0.0362	0.0098
Fe	0.1881	0.2623	0.2013	0.0267	0.0872	0.0471	0.0256	0.1030	0.0598	0.3602	0.1158	0.1737
Ni	0.0144	0.0217	0.0164	0.0019	0.0021	0.0021	0.0005	0.0035	0.0033	0.0192	0.0089	0.0074
Cu	0.0309	0.0216	0.0247	0.0022	0.0072	0.0039	0.0022	0.0101	0.0012	0.0229	0.0000	0.0079
Zn	0.1451	0.1995	0.1653	0.0208	0.0253	0.0231	0.0184	0.0425	0.0310	0.2480	0.0817	0.0729
Br	0.4278	0.4327	0.6579	0.0816	0.2261	0.0211	0.0355	0.2095	0.1927	1.0544	0.6538	0.5055
Pb	0.7283	0.9021	1.1501	0.1837	0.3698	0.0749	0.0913	0.3572	0.3486	1.7437	1.1971	0.8029
Cl^-	0.4562	0.3984	1.9100	0.6448	0.7482	0.3863	0.4066	0.2905	0.6995	1.0554	0.6387	0.3863
NO_3^-	0.7522	2.1361	1.9951	0.7634	0.7512	0.6174	0.2481	1.1653	1.1253	1.0168	1.1010	0.7847
SO_4^{2-}	1.5318	4.6431	2.5669	3.0322	2.1381	2.6855	0.9162	4.1129	2.3540	2.7788	4.7993	4.4556
Organic Carbon	12.9968	15.1561	32.5426	8.4550	9.4891	8.8504	5.0520	7.1523	16.3423	24.2498	19.4850	11.1212
Elemental Carbon	4.1363	8.3029	9.7324	1.6727	1.6930	1.5714	0.9671	2.1340	2.0681	5.2818	4.1971	2.6764
High Temp. Organic Carbon	7.1472	11.0706	23.5401	3.9234	5.1703	4.4607	3.1623	4.7090	6.0422	16.8390	8.5564	6.5896
High Temp. Elemental Carbon	0.3345	1.2064	1.6829	1.3078	0.5576	0.8617	0.5726	0.4359	1.2774	0.1926	2.8386	0.5981

Tableview [all concentrations in μg/m³]									
DATE	14/07/95	18/08/95	15/07/95	14/07/95	25/07/95	28/08/95	20/05/96	27/05/96	04/06/96
Total Concentration	18.5093	12.8946	11.3103	27.3857	31.2092	17.3856	10.4655	17.2590	19.1890
Na	0.2795	0.3549	0.1381	0.1457	0.3930	0.4623	0.1170	0.1470	0.1457
Mg	0.0309	0.0656	0.0000	0.0555	0.0371	0.1298	0.0052	0.0356	0.0000
Al	0.0988	0.0555	0.0585	0.1263	0.0191	0.0794	0.0399	0.1036	0.0425
Si	0.2077	0.1529	0.1913	0.1852	0.0787	0.1139	0.0999	0.1665	0.1068
S	0.4291	1.4895	0.2837	0.5293	0.5611	0.6991	0.9142	0.5232	0.4029
Cl	0.0301	0.0016	0.0089	0.0404	0.0000	0.7561	0.0031	0.0997	0.0301
K	0.1224	0.0724	0.0979	0.1828	0.0672	0.0688	0.1396	0.1810	0.0814
Ca	0.0307	0.0345	0.0342	0.0754	0.0000	0.0398	0.0281	0.0461	0.0267
V	0.0047	0.0015	0.0000	0.0096	0.0067	0.0037	0.0032	0.0065	0.0065
Fe	0.0431	0.0462	0.0512	0.0951	0.0143	0.0367	0.0395	0.0736	0.0489
Ni	0.0011	0.0014	0.0007	0.0006	0.0040	0.0008	0.0014	0.0025	0.0054
Cu	0.0018	0.0050	0.0134	0.0106	0.0002	0.0018	0.0067	0.0048	0.0039
Zn	0.0394	0.0091	0.0093	0.0691	0.0219	0.0083	0.0093	0.0513	0.0937
Br	0.0592	0.0075	0.0221	0.2186	0.0171	0.0552	0.0129	0.0864	0.0459
Pb	0.1670	0.0381	0.0587	0.4854	0.0673	0.0949	0.0425	0.2100	0.1266
Cl^-	0.9124	0.5627	0.6144	1.1131	0.7664	1.3260	0.3680	1.9191	3.2908
NO_3^-	1.3625	0.5292	0.4319	2.0925	1.8066	1.0401	0.6635	0.9621	4.6695
SO_4^{2-}	2.0985	4.9240	1.2530	2.1594	8.6496	1.7032	2.9192	1.5805	1.9333
Organic Carbon	10.2190	5.1399	7.7859	16.3017	16.9100	11.2936	5.3629	11.2936	10.3913
Elemental Carbon	3.6902	0.9935	1.0543	4.2579	3.6699	1.0543	0.6944	1.9465	1.5714
High Temp. Organic Carbon	7.2182	3.3455	4.5418	8.9213	11.9424	5.8800	2.9045	5.8496	4.7242
High Temp. Elemental Carbon	2.0479	0.6184	0.4359	1.3990	2.5750	0.9530	0.1419	0.2332	0.4055

Wynberg [all concentrations in $\mu g/m^3$]

DATE	06/07/95	14/07/95	15/07/95	14/07/95	01/08/95	25/07/95	14/08/95	18/08/95	28/08/95	16/02/96	23/04/96	30/04/96	08/05/96	20/05/96	04/06/96
Total Concentration	26.3101	28.9571	16.4765	25.4988	20.2988	32.3146	14.5223	17.4396	23.9668	7.2488	8.3459	17.6128	23.8930	18.0302	14.5341
Na	0.6779	0.0929	0.2395	0.2317	0.1717	0.5579	0.3844	0.1492	0.1976	0.2638	0.3635	0.0813	0.1528	0.1389	0.1972
Mg	0.1596	0.0396	0.0848	0.0631	0.0516	0.0000	0.0643	0.0186	0.1212	0.0369	0.0452	0.0594	0.0390	0.0510	0.0000
Al	0.1662	0.3280	0.1590	0.2038	0.0936	0.2255	0.0571	0.0400	0.2265	0.0233	0.0187	0.2904	0.2583	0.0821	0.0445
Si	0.1986	0.0420	0.3732	0.0301	0.0915	0.1508	0.0759	0.0923	0.0806	0.0383	0.0332	0.9258	0.1981	0.0699	0.0233
S	0.5394	0.3452	0.3740	0.2430	1.3691	1.0633	0.8935	1.5883	0.5915	0.3058	0.1834	1.8922	0.5276	1.1876	0.2356
Cl	0.5749	0.0295	0.1455	0.0547	0.0000	0.0027	0.1909	0.0000	0.0293	0.3989	0.5054	0.0188	0.0223	0.0125	0.0860
K	0.1549	0.0718	0.1121	0.1436	0.1112	0.1452	0.0499	0.0803	0.0871	0.0670	0.0277	0.1484	0.1924	0.1449	0.0570
Ca	0.0941	0.0381	0.1200	0.0422	0.0301	0.0619	0.0261	0.0245	0.0254	0.0444	0.0242	0.0844	0.0870	0.0354	0.0167
V	0.0156	0.0121	0.0053	0.0076	0.0140	0.0319	0.0097	0.0069	0.0053	0.0021	0.0000	0.0037	0.0031	0.0099	0.0057
Fe	0.1341	0.1558	0.1295	0.1215	0.0681	0.1398	0.0328	0.0491	0.0568	0.0141	0.0105	0.1746	0.1653	0.0777	0.0332
Ni	0.0067	0.0030	0.0025	0.0004	0.0058	0.0129	0.0033	0.0028	0.0049	0.0007	0.0002	0.0042	0.0050	0.0087	0.0027
Cu	0.0096	0.0088	0.0054	0.0085	0.0069	0.0110	0.0021	0.0033	0.0066	0.0005	0.0000	0.0025	0.0101	0.0067	0.0054
Zn	0.0385	0.0465	0.0122	0.0216	0.0391	0.0653	0.0118	0.0134	0.0225	0.0029	0.0000	0.0132	0.0429	0.0247	0.0232
Br	0.3240	1.2174	0.1225	0.7607	0.3253	0.6894	0.1088	0.1128	0.4768	0.0172	0.0164	0.0757	0.7489	0.2683	0.1993
Pb	0.5497	1.6094	0.2071	1.0635	0.6223	1.1607	0.2165	0.2592	0.7833	0.0384	0.0329	0.1747	1.2454	0.4173	0.3304
Cl^-	0.9854	0.6083	0.6083	0.7908	0.2413	0.6387	0.4532	0.3832	0.2920	0.3779	0.4836	0.1946	0.0000	0.0852	0.5109
NO_3^-	1.2652	0.7056	0.4380	0.0000	1.0219	1.4538	0.7451	0.9033	0.0000	0.0000	0.0000	0.1582	0.7066	1.7858	0.4298
SO_4^{2-}	1.7518	1.4842	1.6210	1.4355	3.6152	3.4732	2.4453	4.3248	2.4696	0.8303	0.5657	5.3710	2.8761	4.1449	1.2459
Organic Carbon	16.6667	17.8629	8.7895	18.0049	10.6380	16.8086	8.3029	8.4550	16.6058	4.9502	6.2044	8.6476	12.3986	8.3688	10.1176
Elemental Carbon	3.2238	5.1298	2.2912	3.3861	3.0414	7.1979	1.5612	1.8350	2.7981	0.4327	0.3852	0.8212	4.0146	1.8045	1.8248
High Temp. Organic Carbon	8.7997	9.3471	4.9676	9.5093	6.8329	13.0170	5.4846	5.9712	7.6845	2.5578	2.6663	4.7749	8.8808	5.0791	4.9473
High Temp. Elemental Carbon	1.1760	2.8792	1.1557	1.4801	0.8516	2.5547	1.0645	1.2875	2.0884	0.3245	0.2230	0.4157	0.7908	0.1977	0.3041

Guguletu [all concentrations in $\mu g/m^3$]	
DATE	22/08/96
Total Concentration	75.46102377
Na	0.385434213
Mg	0.03998222
Al	0.228429721
Si	0.12018061
S	1.169731424
Cl	3.61288134
K	1.16860846
Ca	0.066863185
V	0.018903238
Fe	0.083660865
Ni	0.006597417
Cu	0.014107243
Zn	0.217200075
Br	0.649728617
Pb	0.98668819
Cl^-	7.994104436
NO_3^-	3.469492794
SO_4^{2-}	4.608833988
Organic Carbon	35.91147296
Elemental Carbon	21.10237694
High Temp. Organic Carbon	30.08609395
High Temp. Elemental Carbon	1.193149916

APPENDIX J: CHEMICAL MASS BALANCE MODEL RESULTS FOR EACH EPISODE

J.1. Modelling at the Goodwood Site

SOURCE CONTRIBUTION ESTIMATES - SITE: 67 DATE: 14/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE 1.00 PERCENT MASS 121.7 CHI SQUARE 3.26 DF 32

SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8 RDUST	.4117	.1474	2.7922
13 DIVEH	26.3749	4.3778	6.0247
16 SO4	1.1401	.2132	5.3481
17 NO3	1.9065	.2765	6.8954
25 WBURN	7.0834	.5825	12.1597
28 OHC	12.1912	6.8128	1.7895
30 EHC	1.4752	.7989	1.8465
34 VEH2	11.2961	.0870	129.8524
36 COMPB	.1255	.3406	.3684

MEASURED CONCENTRATION FOR SIZE: FINE 50.9+- 3.9

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	50.94889+- 3.92273	62.00455+- 7.51705	1.22+- .17	1.3
C11	Na	*	.10985< .19100	.10680< .04700	.97< 1.74	-.0
C12	Mg	*	.08041< .16983	.03193< .12723	.40< 1.79	-.2
C13	Al	*	.24676+- .03157	.19610+- .01971	.79+- .13	-1.4
C14	Si	*	.10714+- .01464	.12547+- .01255	1.17+- .20	1.0
C15	P	*	.06409+- .00947	.01299+- .00610	.20+- .10	-4.5
C16	S	*	.70022+- .03550	.70022+- .04954	1.00+- .09	.0
C17	Cl		.13378+- .01204	.38242+- .00789	2.86+- .26	17.3
C19	K	*	.36340+- .03028	.37888+- .00487	1.04+- .09	.5
C20	Ca	*	.05547+- .00858	.06859+- .00495	1.24+- .21	1.3
C22	Ti	*	.00012< .07997	.00367< .02249	30.18< *****	.0
C23	V	*	.02843< .03287	.00272< .00911	.10< .34	-.8
C24	Cr	*	.00655< .00797	.00224< .00202	.34< .52	-.5
C25	Mn	*	.01723+- .00217	.00322+- .00152	.19+- .09	-5.3
C26	Fe	*	.20128+- .02771	.06559+- .00072	.33+- .05	-4.9
C27	Co	*	.00000< .00535	.00020< .00121	.00< .00	.0
C28	Ni	*	.01642+- .00152	.01680+- .00104	1.02+- .11	.2
C29	Cu		.02466+- .00162	.00304+- .00052	.12+- .02	-12.7
C30	Zn		.16531+- .00255	.04567+- .00052	.28+- .01	-45.9
C31	Ga	*	.00000< .01429	.00083< .01037	.00< .00	.0
C33	As	*	.00000< .18149	.00045< .15292	.00< .00	.0
C34	Se	*	.00000< .00683	.00010< .00437	.00< .00	.0
C35	Br	*	.65791+- .00564	.63690+- .00263	.97+- .01	-3.4
C48	Cd		.00000< .03467	.00599< .00938	.00< .00	.2
C49	In	*	.00000< .04039	.00000< .01063	.00< .00	.0
C50	Sn	*	.00722< .05049	.00007< .01374	.01< 1.90	-.1
C51	Sb	*	.05424< .06042	.00373< .01635	.07< .31	-.8
C56	Ba	*	.00000< .22297	.00293< .06009	.00< .00	.0
C57	La	*	.00000< .29767	.00861< .07943	.00< .00	.0
C79	Au	*	.00000< .01312	.00081< .00381	.00< .00	.1
C80	Hg	*	.00000< .01054	.00310< .00443	.00< .00	.3
C81	Tl	*	.00000< .03305	.00000< .02634	.00< .00	.0
C82	Pb	*	1.15014+- .01075	1.18775+- .00290	1.03+- .01	3.4
C92	U	*	.00000< .01417	.00001< .00855	.00< .00	.0
C201	Cl-		1.90998+- .19100	.95771+- .07241	.50+- .06	-4.7
C202	NO3-	*	1.99513+- .19951	1.99513+- .19086	1.00+- .14	.0
C203	SO4--		2.56691+- .25669	2.41726+- .15157	.94+- .11	-.5
C204	Ca++		.62044+- .06204	.15508+- .01344	.25+- .03	-7.3
C205	K+		.33455+- .03345	.33787+- .03362	1.01+- .14	.1
C206	Mg++		.14599+- .01460	.00121+- .00009	.01+- .00	-9.9
C207	Na+		.57178+- .05718	.00167+- .00010	.00+- .00	-10.0
C208	NH4+		.77251+- .07725	.29816+- .02769	.39+- .05	-5.8
C209	OCTU		32.54258+- 2.04785	18.71979+- .73433	.58+- .04	-6.4
C210	ECTU		9.73236+- 1.23682	9.18261+- .56409	.94+- .13	-.4
C211	OHTU	*	23.54015+- 2.77778	23.54014+- 6.14330	1.00+- .29	.0
C212	EHTU	*	1.68289+- .30414	1.68289+- .73857	1.00+- .47	.0
C213	OLTU	*	9.00243+- .81935	7.37081+- .72711	.82+- .11	-1.5
C214	ELTU	*	8.04947+- 1.72248	8.97493+- .79684	1.11+- .26	.5

SOURCE CONTRIBUTION ESTIMATES - SITE: 122 DATE: 16/02/96 CMB7 33889
SAMPLE DURATION 19 START HOUR 0 SIZE: FINE
R SQUARE .98 PERCENT MASS 81.4 CHI SQUARE 3.04 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8	RDUST	.2590	.0181	14.2709
13	DIVEH	1.3447	.4799	2.8022
16	SO4	.9654	.1038	9.3017
17	NO3	.2436	.0348	6.9977
20	MARI1	.7626	.1065	7.1608
23	PCEMT	.1200	.0098	12.2015
25	WBURN	2.4052	.0867	27.7302
34	VEH2	.8645	.0195	44.2342

MEASURED CONCENTRATION FOR SIZE: FINE 8.6+- .7

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	8.56075+- .74692	6.96502+- .47809	.81+- .09	-1.8
C11	Na	*	.33732+- .02950	.32910+- .03110	.98+- .13	-.2
C12	Mg	*	.02912< .03241	.04124< .01212	1.42< 1.63	.4
C13	Al	*	.01905+- .00602	.03324+- .00147	1.74+- .56	2.3
C14	Si	*	.04763+- .00428	.04685+- .00101	.98+- .09	-.2
C15	P	*	.01505+- .00295	.00177+- .00083	.12+- .06	-4.3
C16	S	*	.37127+- .00547	.37127+- .03346	1.00+- .09	.0
C17	Cl		.32678+- .00699	.42802+- .07627	1.31+- .24	1.3
C19	K	*	.13891+- .00391	.14044+- .00172	1.01+- .03	.4
C20	Ca	*	.08618+- .00316	.08630+- .00215	1.00+- .04	.0
C22	Ti	*	.00103< .02331	.00192< .00245	1.87< 42.29	.0
C23	V	*	.00353< .00950	.00015< .00100	.04< .31	-.4
C24	Cr	*	.00108< .00221	.00040< .00019	.37< .77	-.3
C25	Mn	*	.00008< .00160	.00071< .00014	8.57< *****	.4
C26	Fe	*	.02565+- .00083	.02553+- .00010	1.00+- .03	-.1
C27	Co	*	.00011< .00127	.00002< .00027	.16< 2.95	-.1
C28	Ni	*	.00050< .00114	.00133< .00012	2.65< 6.01	.7
C29	Cu	*	.00218+- .00041	.00037+- .00009	.17+- .05	-4.3
C30	Zn		.01845+- .00057	.00504+- .00005	.27+- .01	-23.6
C31	Ga	*	.00081< .00216	.00007< .00081	.09< 1.03	-.3
C33	As	*	.00062< .01486	.00008< .01170	.12< 18.99	-.0
C34	Se	*	.00030< .00130	.00004< .00035	.12< 1.27	-.2
C35	Br		.03552+- .00278	.05065+- .00043	1.43+- .11	5.4
C47	Ag	*	.00076< .00961	.00011< .00099	.14< 2.20	-.1
C48	Cd		.00000< .01010	.00036< .00106	.00< .00	.0
C49	In	*	.00509< .01152	.00000< .00119	.00< .23	-.4
C50	Sn	*	.01495+- .00492	.00003+- .00153	.00+- .10	-2.9
C51	Sb	*	.00876< .01726	.00074< .00185	.08< .27	-.5
C56	Ba	*	.00000< .06470	.00049< .00677	.00< .00	.0
C57	La	*	.00000< .08668	.00195< .00902	.00< .00	.0
C79	Au	*	.00207< .00321	.00016< .00038	.08< .22	-.6
C80	Hg	*	.00036< .00266	.00020< .00039	.57< 4.41	-.1
C81	Tl	*	.00000< .00373	.00000< .00202	.00< .00	.0
C82	Pb	*	.09134+- .00190	.09128+- .00032	1.00+- .02	-.0
C92	U	*	.00000< .00261	.00000< .00068	.00< .00	.0
C201	Cl-		.40658+- .04066	.63019+- .08013	1.55+- .25	2.5
C202	NO3-	*	.24814+- .02481	.24814+- .02437	1.00+- .14	.0
C203	SO4--		.91623+- .09162	1.14077+- .10140	1.25+- .17	1.6
C204	Ca++		.22906+- .02291	.06654+- .00489	.29+- .04	-6.9
C205	K+		.12216+- .01222	.12542+- .01152	1.03+- .14	.2
C206	Mg++		.06681+- .00668	.03715+- .00686	.56+- .12	-3.1
C207	Na+		.23287+- .02329	.30554+- .07626	1.31+- .35	.9
C208	NH4+		.09544+- .00954	.02192+- .00157	.23+- .03	-7.6
C209	OCTU		5.05197+- .34995	2.26874+- .07214	.45+- .03	-7.8
C210	ECTU		.96713+- .12725	.64398+- .03382	.67+- .09	-2.5
C211	OHTU	*	3.16225+- .40085	1.64687+- .10426	.52+- .07	-3.7
C212	EHTU	*	.57264+- .10180	.02831+- .00394	.05+- .01	-5.3
C213	OLTU		1.88972+- .29025	.62187+- .05906	.33+- .06	-4.3
C214	ELTU	*	.39449+- .14840	.61567+- .04766	1.56+- .60	1.4

SOURCE CONTRIBUTION ESTIMATES - SITE: 139 DATE: 30/04/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 136.7 CHI SQUARE 4.77 DF 34

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
7	CALCT	2.4244	.0930	26.0559
8	RDUST	1.1526	.0885	13.0179
16	SO4	4.7137	.4830	9.7593
17	NO3	.7478	.1086	6.8891
25	WBURN	4.2926	.1186	36.2044
32	VEH1	4.1532	.0753	55.1201
33	PETVH	2.4273	.3092	7.8493
35	DIES2	10.9653	1.3473	8.1389

MEASURED CONCENTRATION FOR SIZE: FINE 22.6+- 1.7

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	22.59307+- 1.71113	30.87703+- 1.38189	1.37+- .12	3.8
C11	Na	*	.25935+- .04331	.06417+- .02665	.25+- .11	-3.8
C12	Mg	*	.10703< .11722	.02137< .09158	.20< .88	-.6
C13	Al	*	.34160+- .02256	.39150+- .01284	1.15+- .08	1.9
C14	Si	*	.61144+- .01326	.60887+- .00906	1.00+- .03	-.2
C15	P	*	.01730< .02023	.01339< .00291	.77< .92	-.2
C16	S	*	1.74785+- .02568	1.74785+- .15701	1.00+- .09	.0
C17	Cl		.00925< .03248	.23241< .00433	25.14< 88.31	6.8
C19	K	*	.23923+- .00571	.24133+- .00240	1.01+- .03	.3
C20	Ca	*	.08015+- .00468	.09331+- .00289	1.16+- .08	2.4
C22	Ti	*	.01842< .03943	.01565< .01041	.85< 1.90	-.1
C23	V	*	.00980< .01610	.00609< .00424	.62< 1.11	-.2
C24	Cr	*	.00267< .00375	.00240< .00093	.90< 1.32	-.1
C25	Mn	*	.00975+- .00104	.00252+- .00070	.26+- .08	-5.8
C26	Fe	*	.17374+- .01233	.10874+- .00038	.63+- .04	-5.3
C27	Co	*	.00037< .00354	.00011< .00119	.30< 4.38	-.1
C28	Ni	*	.00739+- .00071	.00807+- .00049	1.09+- .12	.8
C29	Cu	*	.00791+- .00073	.00197+- .00031	.25+- .05	-7.5
C30	Zn		.07290+- .00120	.03081+- .00027	.42+- .01	-34.3
C31	Ga	*	.00212< .00935	.00040< .00745	.19< 3.62	-.1
C33	As	*	.00000< .12652	.00024< .11084	.00< .00	.0
C34	Se	*	.00000< .00423	.00006< .00310	.00< .00	.0
C35	Br	*	.50548+- .02356	.42700+- .00188	.84+- .04	-3.3
C46	Pd	*	.00000< .01403	.00194< .00354	.00< .00	.1
C47	Ag	*	.00422< .01650	.00086< .00418	.20< 1.27	-.2
C48	Cd		.00000< .01687	.00304< .00447	.00< .00	.2
C49	In	*	.00000< .01945	.00008< .00507	.00< .00	.0
C50	Sn	*	.00000< .02521	.00011< .00653	.00< .00	.0
C51	Sb	*	.00000< .02977	.00261< .00771	.00< .00	.1
C56	Ba	*	.00000< .10958	.00351< .02811	.00< .00	.0
C57	La	*	.00000< .14600	.01624< .03716	.00< .00	.1
C79	Au	*	.00125< .00659	.00045< .00223	.36< 2.61	-.1
C80	Hg	*	.00000< .00563	.00152< .00291	.00< .00	.2
C81	Tl	*	.00000< .02245	.00000< .01905	.00< .00	.0
C82	Pb	*	.80289+- .00623	.80579+- .00195	1.00+- .01	.4
C92	U	*	.00000< .00938	.00003< .00602	.00< .00	.0
C201	Cl-		.38625+- .03863	.58970+- .04389	1.53+- .19	3.5
C202	NO3-	*	.78467+- .07847	.78467+- .07487	1.00+- .14	.0
C203	SO4--		4.45560+- .44556	5.31843+- .47329	1.19+- .16	1.3
C204	Ca++		.28589+- .02859	.13007+- .00936	.45+- .06	-5.2
C205	K+		.23723+- .02372	.20809+- .02038	.88+- .12	-.9
C206	Mg++		.04866+- .00487	.00307+- .00025	.06+- .01	-9.4
C207	Na+		.15511+- .01551	.00632+- .00047	.04+- .01	-9.6
C208	NH4+		.01521+- .00152	.14089+- .01159	9.27+- 1.20	10.7
C209	OCTU		11.12125+- .72993	9.22065+- .31673	.83+- .06	-2.4
C210	ECTU		2.67640+- .34469	3.99392+- .23570	1.49+- .21	3.2
C211	OHTU	*	6.58962+- .80089	5.71606+- .34331	.87+- .12	-1.0
C212	EHTU	*	.59813+- .11152	.67202+- .01653	1.12+- .21	.7
C213	OLTU	*	4.53163+- .65127	3.50459+- .30952	.77+- .13	-1.4
C214	ELTU	*	2.07826+- .47453	3.32190+- .33292	1.60+- .40	2.1

SOURCE CONTRIBUTION ESTIMATES - SITE: 142 DATE: 08/05/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .98 PERCENT MASS 123.3 CHI SQUARE 3.17 DF 31

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8	RDUST	.5420	.1547	3.5044
13	DIVEH	22.0925	2.4884	8.8782
16	SO4	2.1617	.2537	8.5222
17	NO3	2.0618	.2971	6.9401
20	MARI1	.9533	.1818	5.2429
22	SASFA	.7225	.1143	6.3224
25	WBURN	4.9291	.1676	29.4022
34	VEH2	8.2403	.1386	59.4511
36	COMPB	1.7633	.2177	8.1010

MEASURED CONCENTRATION FOR SIZE: FINE 35.3+- 2.1

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	35.26269+- 2.09488	43.46654+- 2.40708	1.23+- .10	2.6
C11	Na	*	.47875+- .04941	.46967+- .05332	.98+- .15	-.1
C12	Mg	*	.11587< .12755	.07910< .09352	.68< 1.10	-.2
C13	Al	*	.20253+- .01992	.27362+- .01538	1.35+- .15	2.8
C14	Si	*	.26319+- .01068	.25291+- .00938	.96+- .05	-.7
C15	P	*	.06356+- .00671	.01399+- .00498	.22+- .08	-5.9
C16	S	*	1.07960+- .02761	1.07960+- .07614	1.00+- .08	.0
C17	Cl		.03103+- .00877	.64913+- .09554	20.92+- 6.66	6.4
C19	K	*	.28873+- .00716	.28937+- .00440	1.00+- .03	.1
C20	Ca	*	.09731+- .00522	.09818+- .00436	1.01+- .07	.1
C22	Ti	*	.01451< .04180	.00546< .01851	.38< 1.67	-.2
C23	V	*	.02428+- .00575	.03090+- .00748	1.27+- .43	.7
C24	Cr	*	.00795+- .00145	.00211+- .00185	.27+- .24	-2.5
C25	Mn		.01856+- .00124	.00525+- .00149	.28+- .08	-6.9
C26	Fe		.26227+- .02283	.07488+- .00111	.29+- .03	-8.2
C27	Co	*	.00000< .00481	.00017< .00105	.00< .00	.0
C28	Ni	*	.02166+- .00091	.02135+- .00086	.99+- .06	-.3
C29	Cu	*	.02161+- .00290	.00534+- .00214	.25+- .10	-4.5
C30	Zn		.19949+- .00178	.03991+- .00178	.20+- .01	-63.2
C31	Ga	*	.00135< .01041	.00068< .00760	.51< 6.86	-.1
C33	As	*	.00000< .14205	.00036< .11158	.00< .00	.0
C34	Se	*	.00452< .00477	.00009< .00321	.02< .71	-.8
C35	Br	*	.43274+- .01358	.46755+- .00199	1.08+- .03	2.5
C46	Pd	*	.00074< .01471	.00227< .00603	3.06< 61.42	.1
C48	Cd		.00000< .01847	.00489< .00768	.00< .00	.2
C49	In	*	.01292< .02137	.00000< .00871	.00< .67	-.6
C50	Sn	*	.00343< .02705	.00052< .01126	.15< 3.50	-.1
C51	Sb	*	.01196< .03242	.00286< .01342	.24< 1.30	-.3
C56	Ba	*	.00000< .11638	.00248< .04938	.00< .00	.0
C57	La	*	.00000< .15548	.00694< .06525	.00< .00	.0
C79	Au	*	.00151< .00972	.00063< .00300	.42< 3.36	-.1
C80	Hg	*	.00585< .00650	.00242< .00337	.41< .74	-.5
C81	Tl	*	.00000< .02514	.00000< .01924	.00< .00	.0
C82	Pb	*	.90207+- .01663	.87228+- .00228	.97+- .02	-1.8
C92	U	*	.00160< .00870	.00001< .00631	.01< 3.94	-.1
C201	Cl-		.39842+- .03984	1.06164+- .10784	2.66+- .38	5.8
C202	NO3-	*	2.13605+- .21361	2.13605+- .20632	1.00+- .14	.0
C203	SO4--		4.64315+- .46431	3.70126+- .23725	.80+- .09	-1.8
C204	Ca++		.15714+- .01571	.19825+- .01174	1.26+- .15	2.1
C205	K+		.18451+- .01845	.25883+- .02349	1.40+- .19	2.5
C206	Mg++		.16930+- .01693	.05185+- .00859	.31+- .06	-6.2
C207	Na+		1.30069+- .13007	.39460+- .09534	.30+- .08	-5.6
C208	NH4+		2.00020+- .20002	.25076+- .02318	.13+- .02	-8.7
C209	OCTU		15.15612+- 1.03406	14.78147+- .60328	.98+- .08	-.3
C210	ECTU		8.30292+- .55758	7.61367+- .47185	.92+- .08	-.9
C211	OHTU	*	11.07056+- 1.30779	8.91040+- .62182	.80+- .11	-1.5
C212	EHTU	*	1.20641+- .32441	.17096+- .03120	.14+- .05	-3.2
C213	OLTU	*	4.08556+- .65442	5.87107+- .59818	1.44+- .27	2.0
C214	ELTU	*	7.09651+- .71872	7.44271+- .66657	1.05+- .14	.4

SOURCE CONTRIBUTION ESTIMATES - SITE: 150 DATE: 27/05/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE 1.00 PERCENT MASS 111.3 CHI SQUARE 3.23 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8	RDUST	1.2966	.1050	12.3490
13	DIVEH	16.7656	2.1330	7.8599
16	SO4	2.1472	.3035	7.0748
17	NO3	.9605	.1402	6.8523
25	WBURN	6.1615	.1459	42.2295
32	VEH1	8.7212	.1053	82.8485
33	PETVH	6.8938	.4175	16.5132

MEASURED CONCENTRATION FOR SIZE: FINE 38.6+- 2.7

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	38.58053+- 2.69732	42.94631+- 2.07522	1.11+- .09	1.3
C11	Na	*	.18257+- .05291	.09687+- .04885	.53+- .31	-1.2
C12	Mg	*	.06769< .23286	.03825< .19298	.57< 3.45	-.1
C13	Al	*	.31783+- .03780	.31541+- .02627	.99+- .14	-.1
C14	Si	*	.19094+- .01297	.18367+- .01880	.96+- .12	-.3
C15	P	*	.02624+- .00715	.02151+- .00481	.82+- .29	-.5
C16	S	*	1.01089+- .05077	1.01089+- .08496	1.00+- .10	.0
C17	Cl		.20015+- .01205	.34595+- .00785	1.73+- .11	10.1
C19	K	*	.33766+- .00656	.33934+- .00386	1.00+- .02	.2
C20	Ca	*	.10596+- .00510	.11655+- .00422	1.10+- .07	1.6
C22	Ti	*	.00000< .03778	.00779< .01701	.00< .00	.2
C23	V	*	.01415< .01556	.00079< .00691	.06< .49	-.8
C24	Cr	*	.01206+- .00138	.00207+- .00153	.17+- .13	-4.9
C25	Mn		.01923+- .00120	.00298+- .00115	.15+- .06	-9.8
C26	Fe	*	.36021+- .03324	.10769+- .00056	.30+- .03	-7.6
C27	Co	*	.00000< .00614	.00023< .00143	.00< .00	.0
C28	Ni	*	.01923+- .00083	.01959+- .00080	1.02+- .06	.3
C29	Cu		.02290+- .00086	.00322+- .00057	.14+- .03	-19.1
C30	Zn		.24801+- .00194	.05777+- .00048	.23+- .00	-95.4
C31	Ga	*	.00278< .01886	.00062< .01571	.22< 5.86	-.1
C33	As	*	.00155< .27405	.00035< .23415	.23< *****	.0
C34	Se	*	.00370< .00808	.00009< .00652	.02< 1.76	-.3
C35	Br		1.05441+- .00601	.93282+- .00397	.88+- .01	-16.9
C48	Cd		.00467< .01730	.00505< .00748	1.08< 4.31	.0
C49	In	*	.00000< .01904	.00000< .00848	.00< .00	.0
C50	Sn	*	.01841< .02494	.00013< .01088	.01< .59	-.7
C51	Sb	*	.02194< .02897	.00469< .01273	.21< .65	-.5
C56	Ba	*	.05057< .10411	.00529< .04606	.10< .94	-.4
C57	La	*	.04151< .13854	.01135< .06100	.27< 1.73	-.2
C79	Au	*	.00132< .01174	.00063< .00432	.48< 5.36	-.1
C80	Hg	*	.00915+- .00286	.00323+- .00591	.35+- .65	-.9
C81	Tl	*	.00000< .04749	.00000< .04021	.00< .00	.0
C82	Pb	*	1.74369+- .00901	1.74383+- .00398	1.00+- .01	.0
C92	U	*	.00000< .01748	.00002< .01266	.00< .00	.0
C201	Cl-		1.05535+- .10554	.83439+- .06299	.79+- .10	-1.8
C202	NO3-	*	1.01683+- .10168	1.01683+- .09622	1.00+- .14	.0
C203	SO4--		2.77879+- .27788	3.11370+- .22486	1.12+- .14	.9
C204	Ca++		.21188+- .02119	.16908+- .01275	.80+- .10	-1.7
C205	K+		.25750+- .02575	.29539+- .02925	1.15+- .16	1.0
C206	Mg++		.28183+- .02818	.00270+- .00027	.01+- .00	-9.9
C207	Na+		1.85422+- .18542	.00251+- .00025	.00+- .00	-10.0
C208	NH4+		.08719+- .00872	.19794+- .01765	2.27+- .30	5.6
C209	OCTU		24.24980+- 1.61192	15.96494+- .52730	.66+- .05	-4.9
C210	ECTU		5.28183+- .36496	6.17992+- .36011	1.17+- .11	1.8
C211	OHTU	*	16.83901+- 1.97689	9.51726+- .54911	.57+- .07	-3.6
C212	EHTU	*	.19262+- .06083	.18952+- .02518	.98+- .34	-.0
C213	OLTU	*	7.41079+- 1.13513	6.44768+- .53143	.87+- .15	-.8
C214	ELTU	*	5.08921+- .51254	5.99039+- .50866	1.18+- .16	1.2

SOURCE CONTRIBUTION ESTIMATES - SITE: 154 DATE: 04/06/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 110.3 CHI SQUARE 3.43 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8	RDUST	.5362	.0673	7.9663
16	SO4	1.1273	.1507	7.4825
17	NO3	.7141	.1039	6.8742
20	MARI1	.2574	.1114	2.3099
25	WBURN	1.5638	.0924	16.9244
32	VEH1	3.1155	.0787	39.5697
33	PETVH	5.3686	.3328	16.1319
35	DIES2	11.3624	1.2710	8.9399

MEASURED CONCENTRATION FOR SIZE: FINE 21.8+- 1.7

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	21.80250+- 1.70749	24.04530+- 1.24185	1.10+- .10	1.1
C11	Na	*	.16276+- .03828	.13937+- .02422	.86+- .25	-.5
C12	Mg	*	.06001< .10336	.02879< .07262	.48< 1.47	-.2
C13	Al	*	.18779+- .01807	.13670+- .01069	.73+- .09	-2.4
C14	Si	*	.09659+- .00801	.08572+- .00686	.89+- .10	-1.0
C15	P	*	.00546< .01477	.00789< .00268	1.44< 3.93	.2
C16	S	*	.53035+- .02218	.53035+- .04341	1.00+- .09	.0
C17	Cl		.05186+- .00648	.20124+- .02599	3.88+- .70	5.6
C19	K	*	.09124+- .00412	.09242+- .00205	1.01+- .05	.3
C20	Ca	*	.04973+- .00416	.05551+- .00148	1.12+- .10	1.3
C22	Ti	*	.02178< .03879	.00313< .00967	.14< .51	-.5
C23	V	*	.01067< .01588	.00033< .00392	.03< .37	-.6
C24	Cr	*	.00743+- .00133	.00097+- .00087	.13+- .12	-4.1
C25	Mn	*	.01102+- .00109	.00128+- .00066	.12+- .06	-7.6
C26	Fe		.18812+- .01242	.04689+- .00031	.25+- .02	-11.4
C27	Co	*	.00020< .00375	.00012< .00068	.58< 11.26	-.0
C28	Ni	*	.01436+- .00081	.01502+- .00045	1.05+- .07	.7
C29	Cu		.03092+- .00395	.00188+- .00024	.06+- .01	-7.3
C30	Zn		.14507+- .00155	.02468+- .00024	.17+- .00	-76.7
C31	Ga	*	.00187< .00861	.00037< .00591	.20< 3.30	-.1
C33	As	*	.01572< .11480	.00017< .08775	.01< 5.58	-.1
C34	Se	*	.00000< .00393	.00002< .00247	.00< .00	.0
C35	Br	*	.42778+- .01329	.39967+- .00151	.93+- .03	-2.1
C47	Ag	*	.00000< .01588	.00089< .00380	.00< .00	.1
C48	Cd		.00000< .01704	.00276< .00407	.00< .00	.2
C49	In	*	.00000< .01924	.00000< .00462	.00< .00	.0
C50	Sn	*	.00578< .02484	.00005< .00596	.01< 1.03	-.2
C51	Sb	*	.00379< .02914	.00154< .00705	.41< 3.63	-.1
C56	Ba	*	.03452< .10736	.00198< .02583	.06< .77	-.3
C57	La	*	.00000< .14197	.00378< .03412	.00< .00	.0
C79	Au	*	.00000< .00805	.00027< .00187	.00< .00	.0
C80	Hg	*	.00377< .00566	.00201< .00228	.53< 1.00	-.3
C81	Tl	*	.00000< .02047	.00000< .01509	.00< .00	.0
C82	Pb	*	.72827+- .00595	.73195+- .00155	1.01+- .01	.6
C92	U	*	.00106< .00832	.00001< .00489	.01< 4.59	-.1
C201	Cl-		.45620+- .04562	.31521+- .03030	.69+- .10	-2.6
C202	NO3-	*	.75223+- .07522	.75223+- .07151	1.00+- .14	.0
C203	SO4--		1.53183+- .15318	1.69821+- .12118	1.11+- .14	.9
C204	Ca++		.00000+- .00000	.05502+- .00371	.00+- .00	14.8
C205	K+		.05677+- .00568	.07905+- .00744	1.39+- .19	2.4
C206	Mg++		.15105+- .01511	.01347+- .00232	.09+- .02	-9.0
C207	Na+		1.88767+- .18877	.10401+- .02574	.06+- .01	-9.4
C208	NH4+		.00000+- .00000	.12540+- .01191	.00+- .00	10.5
C209	OCTU		12.99676+- .89213	9.06067+- .35685	.70+- .06	-4.1
C210	ECTU		4.13625+- .28386	3.92662+- .24237	.95+- .09	-.6
C211	OHTU	*	7.14720+- .87186	5.06305+- .34654	.71+- .10	-2.2
C212	EHTU	*	.33455+- .10138	.65690+- .01597	1.96+- .60	3.1
C213	OLTU	*	5.84955+- .91196	3.99762+- .36948	.68+- .12	-1.9
C214	ELTU	*	3.80170+- .38843	3.26972+- .34240	.86+- .13	-1.0

SOURCE CONTRIBUTION ESTIMATES - SITE: 78 DATE: 25/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE 1.00 PERCENT MASS 120.2 CHI SQUARE .67 DF 31

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	5.6793	.3165	17.9462
8	RDUST	1.1062	.1483	7.4593
13	DIVEH	22.0804	4.1107	5.3715
16	SO4	6.4079	.6747	9.4975
17	NO3	2.6266	.3771	6.9659
28	OHC	6.6893	2.4623	2.7166
30	EHC	2.4042	.5258	4.5721
34	VEH2	14.0320	.1291	108.6630
36	COMPB	.5515	.3282	1.6805

MEASURED CONCENTRATION FOR SIZE: FINE 51.2+- 3.9

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	51.20867+- 3.85697	61.57735+- 3.89815	1.20+- .12	1.9
C11	Na	*	.21697< .25227	.12670< .04524	.58< .71	-.4
C12	Mg	*	.10641< .21847	.03398< .15705	.32< 1.61	-.3
C13	Al	*	.28601+- .03852	.27404+- .02249	.96+- .15	-.3
C14	Si	*	.20081+- .01811	.19112+- .01532	.95+- .11	-.4
C15	P	*	.03275< .03629	.01778< .00554	.54< .63	-.4
C16	S	*	2.44852+- .04647	2.44852+- .21520	1.00+- .09	.0
C17	Cl		.03254< .04998	.27138< .00774	8.34< 12.81	4.7
C19	K	*	.18114+- .00827	.18243+- .00422	1.01+- .05	.1
C20	Ca	*	.10683+- .00872	.10971+- .00225	1.03+- .09	.3
C22	Ti	*	.00401< .08749	.00795< .01993	1.98< 43.43	.0
C23	V	*	.06129+- .01807	.01038+- .00808	.17+- .14	-2.6
C24	Cr	*	.00057< .01709	.00222< .00175	3.91< *****	.1
C25	Mn	*	.01328+- .00268	.00412+- .00131	.31+- .12	-3.1
C26	Fe		.51918+- .04562	.11218+- .00071	.22+- .02	-8.9
C27	Co	*	.00000< .00953	.00024< .00146	.00< .00	.0
C28	Ni	*	.02147+- .00156	.02288+- .00093	1.07+- .09	.8
C29	Cu		.01371+- .00150	.00354+- .00050	.26+- .05	-6.4
C30	Zn		.11989+- .00229	.05270+- .00050	.44+- .01	-28.7
C31	Ga	*	.00136< .01738	.00080< .01279	.59< 12.06	-.0
C33	As	*	.00631< .23086	.00041< .18990	.06< 30.21	-.0
C34	Se	*	.00000< .00797	.00009< .00533	.00< .00	.0
C35	Br	*	.87638+- .06663	.78667+- .00324	.90+- .07	-1.3
C48	Cd		.00485< .03467	.00559< .00844	1.15< 8.44	.0
C49	In	*	.00000< .03982	.00000< .00959	.00< .00	.0
C50	Sn	*	.00253< .05201	.00025< .01237	.10< 5.30	-.0
C51	Sb	*	.03550< .06091	.00479< .01462	.13< .47	-.5
C56	Ba	*	.00000< .22117	.00435< .05348	.00< .00	.0
C57	La	*	.10568< .29556	.01293< .07081	.12< .75	-.3
C79	Au	*	.00000< .01281	.00054< .00398	.00< .00	.0
C80	Hg	*	.00000< .01142	.00333< .00503	.00< .00	.3
C81	Tl	*	.00000< .04130	.00000< .03265	.00< .00	.0
C82	Pb	*	1.46523+- .01200	1.46586+- .00331	1.00+- .01	.1
C92	U	*	.00000< .01713	.00002< .01041	.00< .00	.0
C201	Cl-		1.00365+- .10036	1.06756+- .10609	1.06+- .15	.4
C202	NO3-	*	2.70073+- .27007	2.70073+- .26276	1.00+- .14	.0
C203	SO4--		7.03163+- .70316	7.66910+- .64648	1.09+- .14	.7
C204	Ca++		.48054+- .04805	.28089+- .02194	.58+- .07	-3.8
C205	K+		.29197+- .02920	.54485+- .05391	1.87+- .26	4.1
C206	Mg++		.12774+- .01277	.00386+- .00027	.03+- .00	-9.7
C207	Na+		.47445+- .04745	.00596+- .00035	.01+- .00	-9.9
C208	NH4+		1.87348+- .18735	.26882+- .02335	.14+- .02	-8.5
C209	OCTU		23.60097+- 1.52068	17.60942+- .66156	.75+- .06	-3.6
C210	ECTU		11.49635+- 1.45985	7.86221+- .47511	.68+- .10	-2.4
C211	OHTU	*	17.35604+- 2.06813	17.35605+- .97851	1.00+- .13	.0
C212	EHTU	*	2.57502+- .46634	2.57502+- .24245	1.00+- .20	.0
C213	OLTU	*	6.24493+- .58974	6.94262+- .66819	1.11+- .15	.8
C214	ELTU	*	8.92133+- 2.01119	7.69134+- .24283	.86+- .20	-.6

SOURCE CONTRIBUTION ESTIMATES - SITE: 123 DATE: 16/02/96 CMB7 33889
SAMPLE DURATION 19 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 120.4 CHI SQUARE 2.76 DF 33

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8	RDUST	.7814	.0235	33.2668
13	DIVEH	6.0132	1.1072	5.4310
16	SO4	1.1682	.1271	9.1941
17	NO3	.1821	.0276	6.6109
20	MARI1	.2527	.0673	3.7580
25	WBURN	1.3865	.0733	18.9068
28	OHC	2.0332	.6496	3.1298
32	VEH1	1.7381	.0419	41.4801
33	PETVH	.7870	.1761	4.4696

MEASURED CONCENTRATION FOR SIZE: FINE 11.9+- 1.0

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	11.91546+- .98694	14.34247+- 1.02166	1.20+- .13	1.7
C11	Na	*	.16114+- .02321	.12508+- .01569	.78+- .15	-1.3
C12	Mg	*	.03533< .05100	.02178< .03835	.62< 1.40	-.2
C13	Al	*	.06350+- .00807	.09151+- .00556	1.44+- .20	2.9
C14	Si	*	.08702+- .00508	.09116+- .00380	1.05+- .08	.7
C15	P	*	.00765< .00937	.00570< .00140	.74< .93	-.2
C16	S	*	.47650+- .01089	.47650+- .03966	1.00+- .09	.0
C17	Cl		.02520+- .00414	.17806+- .02535	7.07+- 1.54	6.0
C19	K	*	.08371+- .00351	.08472+- .00123	1.01+- .04	.3
C20	Ca	*	.04981+- .00281	.06072+- .00115	1.22+- .07	3.6
C22	Ti	*	.00291< .02438	.00408< .00522	1.40< 11.89	.0
C23	V	*	.00792< .01000	.00025< .00213	.03< .27	-.8
C24	Cr	*	.00207< .00239	.00065< .00047	.31< .43	-.6
C25	Mn	*	.00221+- .00060	.00093+- .00036	.42+- .20	-1.8
C26	Fe	*	.05420+- .00110	.05210+- .00020	.96+- .02	-1.9
C27	Co	*	.00066< .00160	.00005< .00072	.07< 1.10	-.4
C28	Ni	*	.00220+- .00043	.00234+- .00024	1.06+- .23	.3
C29	Cu	*	.00246+- .00043	.00101+- .00013	.41+- .09	-3.2
C30	Zn		.01797+- .00058	.01398+- .00013	.78+- .03	-6.7
C31	Ga	*	.00123< .00422	.00021< .00312	.17< 2.61	-.2
C33	As	*	.00169< .05263	.00011< .04626	.07< 27.41	-.0
C34	Se	*	.00000< .00199	.00002< .00130	.00< .00	.0
C35	Br	*	.13265+- .01151	.17461+- .00080	1.32+- .11	3.6
C48	Cd		.00213< .01078	.00152< .00220	.72< 3.78	-.1
C49	In	*	.00737< .01237	.00000< .00250	.00< .34	-.6
C50	Sn	*	.00000< .01551	.00008< .00323	.00< .00	.0
C51	Sb	*	.00113< .01806	.00103< .00382	.91< 15.02	.0
C56	Ba	*	.00000< .06796	.00167< .01400	.00< .00	.0
C57	La	*	.00000< .08997	.00295< .01850	.00< .00	.0
C79	Au	*	.00004< .00351	.00018< .00100	4.12< *****	.0
C80	Hg	*	.00036< .00321	.00066< .00126	1.81< 16.34	.1
C81	Tl	*	.00000< .00963	.00000< .00795	.00< .00	.0
C82	Pb	*	.33384+- .00324	.33162+- .00082	.99+- .01	-.7
C92	U	*	.00000< .00354	.00001< .00253	.00< .00	.0
C201	Cl-		.13553+- .01355	.28998+- .02898	2.14+- .30	4.8
C202	NO3-	*	.20233+- .02023	.20233+- .01832	1.00+- .13	.0
C203	SO4--		1.37243+- .13724	1.49286+- .11948	1.09+- .14	.7
C204	Ca++		.18897+- .01890	.06168+- .00416	.33+- .04	-6.6
C205	K+		.09735+- .00973	.07113+- .00660	.73+- .10	-2.2
C206	Mg++		.03627+- .00363	.01376+- .00228	.38+- .07	-5.3
C207	Na+		.12598+- .01260	.10261+- .02528	.81+- .22	-.8
C208	NH4+		.03436+- .00344	.06980+- .00631	2.03+- .27	4.9
C209	OCTU		6.76989+- .44539	4.03638+- .16189	.60+- .05	-5.8
C210	ECTU		2.43055+- .30541	2.07397+- .12844	.85+- .12	-1.1
C211	OHTU	*	4.48569+- .54083	4.48569+- .26396	1.00+- .13	.0
C212	EHTU	*	1.16437+- .20997	.05039+- .00853	.04+- .01	-5.3
C213	OLTU	*	2.28420+- .32287	1.58389+- .15962	.69+- .12	-1.9
C214	ELTU	*	1.26617+- .37744	2.02358+- .18145	1.60+- .50	1.8

SOURCE CONTRIBUTION ESTIMATES - SITE: 138 DATE: 30/04/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 118.3 CHI SQUARE 2.42 DF 33

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
7	CALCT	1.2429	.0614	20.2516
8	RDUST	1.0620	.0346	30.7145
13	DIVEH	2.2139	.7747	2.8576
16	SO4	5.1266	.5155	9.9453
17	NO3	.2389	.0344	6.9403
25	WBURN	1.7487	.0852	20.5154
28	OHC	3.3749	.7847	4.3008
29	OLC	2.3688	.5994	3.9521
34	VEH2	2.9966	.0293	102.3086

MEASURED CONCENTRATION FOR SIZE: FINE 17.2+- 1.4

SPECIES			MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	17.22648+- 1.39425	20.37333+- 1.18060	1.18+- .12	1.7
C11	Na	*	.12473+- .04018	.02462+- .00933	.20+- .10	-2.4
C12	Mg	*	.05320< .06589	.00945< .03345	.18< .67	-.6
C13	Al	*	.15197+- .01402	.21567+- .00457	1.42+- .13	4.3
C14	Si	*	.35837+- .01059	.34699+- .00330	.97+- .03	-1.0
C15	P	*	.00347< .01884	.00680< .00089	1.96< 10.66	.2
C16	S	*	1.75674+- .01457	1.75674+- .16939	1.00+- .10	.0
C17	Cl		.00000< .02949	.09612< .00145	.00< .00	3.3
C19	K	*	.10371+- .00439	.10467+- .00077	1.01+- .04	.2
C20	Ca	*	.05596+- .00449	.07166+- .00116	1.28+- .10	3.4
C22	Ti	*	.00528< .04248	.01021< .00285	1.93< 15.55	.1
C23	V	*	.00355< .01726	.00319< .00123	.90< 4.38	-.0
C24	Cr	*	.00208< .00398	.00114< .00025	.55< 1.06	-.2
C25	Mn	*	.00327+- .00102	.00117+- .00019	.36+- .13	-2.0
C26	Fe	*	.08141+- .00175	.07843+- .00018	.96+- .02	-1.7
C27	Co	*	.00000< .00254	.00004< .00094	.00< .00	.0
C28	Ni	*	.00100< .00209	.00483< .00014	4.81< 10.01	1.8
C29	Cu	*	.00279+- .00074	.00104+- .00011	.37+- .11	-2.3
C30	Zn		.00810+- .00082	.01282+- .00008	1.58+- .16	5.7
C31	Ga	*	.00000< .00506	.00013< .00272	.00< .00	.0
C33	As	*	.00000< .05081	.00009< .04055	.00< .00	.0
C34	Se	*	.00000< .00274	.00003< .00113	.00< .00	.0
C35	Br	*	.16506+- .00202	.16731+- .00069	1.01+- .01	1.1
C48	Cd		.00145< .01788	.00085< .00130	.58< 7.27	-.0
C49	In	*	.00000< .02116	.00004< .00147	.00< .00	.0
C50	Sn	*	.00000< .02716	.00010< .00188	.00< .00	.0
C51	Sb	*	.00239< .03235	.00106< .00220	.44< 6.03	-.0
C56	Ba	*	.01896< .11838	.00208< .00794	.11< .80	-.1
C57	La	*	.00000< .15870	.00815< .01049	.00< .00	.1
C79	Au	*	.00000< .00591	.00016< .00075	.00< .00	.0
C80	Hg	*	.00000< .00528	.00059< .00101	.00< .00	.1
C81	Tl	*	.00000< .01024	.00000< .00696	.00< .00	.0
C82	Pb	*	.31951+- .00429	.31308+- .00070	.98+- .01	-1.5
C92	U	*	.00000< .00575	.00003< .00220	.00< .00	.0
C201	Cl-		.16727+- .01673	.24241+- .01788	1.45+- .18	3.1
C202	NO3-	*	.24635+- .02464	.24635+- .02390	1.00+- .14	.0
C203	SO4--		4.90876+- .49088	5.29312+- .51275	1.08+- .15	.5
C204	Ca++		.34367+- .03437	.07752+- .00546	.23+- .03	-7.6
C205	K+		.17336+- .01734	.08630+- .00830	.50+- .07	-4.5
C206	Mg++		.06691+- .00669	.00256+- .00022	.04+- .01	-9.6
C207	Na+		.12774+- .01277	.00415+- .00029	.03+- .00	-9.7
C208	NH4+		.18248+- .01825	.03700+- .00245	.20+- .02	-7.9
C209	OCTU		8.96188+- .60827	3.21821+- .09194	.36+- .03	-9.3
C210	ECTU		1.33820+- .18248	.92948+- .04902	.69+- .10	-2.2
C211	OHTU	*	5.39335+- .67924	5.39335+- .35309	1.00+- .14	.0
C212	EHTU	*	.57786+- .11152	.04440+- .00427	.08+- .02	-4.8
C213	OLTU	*	3.56853+- .52785	3.56853+- .25367	1.00+- .16	.0
C214	ELTU	*	.76034+- .23273	.88509+- .06919	1.16+- .37	.5

SOURCE CONTRIBUTION ESTIMATES - SITE: 141 DATE: 08/05/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE 1.00 PERCENT MASS 117.9 CHI SQUARE 1.65 DF 34

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	5.4974	.2216	24.8028
8	RDUST	1.0005	.0887	11.2846
13	DIVEH	20.2469	1.9633	10.3125
14	PETVE	1.3783	.1725	7.9913
16	SO4	1.6040	.2518	6.3712
17	NO3	1.9038	.2743	6.9418
32	VEH1	8.5038	.1036	82.1192

MEASURED CONCENTRATION FOR SIZE: FINE 34.0+- 2.5

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	34.04638+- 2.47373	40.13466+- 1.91417	1.18+- .10	1.9
C11	Na	*	.11247< .12299	.12248< .04863	1.09< 1.27	.1
C12	Mg	*	.12063< .21074	.03415< .18650	.28< 1.62	-.3
C13	Al	*	.27466+- .03074	.27306+- .02573	.99+- .15	-.0
C14	Si	*	.13287+- .01133	.17068+- .01837	1.28+- .18	1.8
C15	P	*	.02571+- .00637	.02045+- .00529	.80+- .28	-.6
C16	S	*	.84283+- .04603	.84283+- .06770	1.00+- .10	.0
C17	Cl		.02279< .02791	.25918< .00813	11.37< 13.93	8.1
C19	K	*	.17364+- .00510	.17517+- .00412	1.01+- .04	.2
C20	Ca	*	.10383+- .00482	.10127+- .00218	.98+- .05	-.5
C22	Ti	*	.00051< .04480	.00721< .01924	14.21< *****	.1
C23	V	*	.00806< .02761	.00082< .00781	.10< 1.03	-.3
C24	Cr	*	.00400< .00868	.00203< .00168	.51< 1.18	-.2
C25	Mn	*	.00912+- .00137	.00388+- .00127	.43+- .15	-2.8
C26	Fe		.28448+- .02292	.10043+- .00068	.35+- .03	-8.0
C27	Co	*	.00000< .00508	.00021< .00137	.00< .00	.0
C28	Ni	*	.00958+- .00075	.00979+- .00090	1.02+- .12	.2
C29	Cu	*	.01345+- .00180	.00294+- .00055	.22+- .05	-5.6
C30	Zn		.07073+- .00120	.05552+- .00051	.78+- .02	-11.7
C31	Ga	*	.00303< .01722	.00075< .01518	.25< 5.20	-.1
C33	As	*	.00000< .24815	.00038< .22602	.00< .00	.0
C34	Se	*	.00000< .00730	.00008< .00631	.00< .00	.0
C35	Br	*	.83960+- .00543	.83667+- .00384	1.00+- .01	-.4
C48	Cd		.00000< .01762	.00559< .00829	.00< .00	.3
C49	In	*	.00341< .02068	.00000< .00942	.00< 2.77	-.1
C50	Sn	*	.00722< .02619	.00010< .01212	.01< 1.68	-.2
C51	Sb	*	.00379< .03063	.00518< .01424	1.37< 11.67	.0
C56	Ba	*	.00000< .11261	.00485< .05183	.00< .00	.0
C57	La	*	.06982< .15124	.01353< .06867	.19< 1.07	-.3
C79	Au	*	.00000< .00754	.00050< .00437	.00< .00	.1
C80	Hg	*	.00936+- .00274	.00265+- .00586	.28+- .63	-1.0
C81	Tl	*	.00000< .04313	.00000< .03883	.00< .00	.0
C82	Pb	*	1.58158+- .00861	1.58505+- .00385	1.00+- .01	.4
C92	U	*	.00000< .01439	.00002< .01222	.00< .00	.0
C201	Cl-		.58394+- .05839	1.02922+- .10269	1.76+- .25	3.8
C202	NO3-	*	1.97182+- .19718	1.97182+- .19050	1.00+- .14	.0
C203	SO4--		5.54035+- .55403	2.69853+- .17890	.49+- .06	-4.9
C204	Ca++		.00000+- .00000	.24783+- .02108	.00+- .00	11.8
C205	K+		.05373+- .00537	.52412+- .05218	9.75+- 1.38	9.0
C206	Mg++		.05981+- .00598	.00209+- .00021	.03+- .00	-9.6
C207	Na+		1.30069+- .13007	.00194+- .00019	.00+- .00	-10.0
C208	NH4+		.33354+- .03335	.24715+- .02143	.74+- .10	-2.2
C209	OCTU		16.07867+- 1.09489	13.51342+- .56237	.84+- .07	-2.1
C210	ECTU		7.21817+- .48662	7.52458+- .43692	1.04+- .09	.5
C211	OHTU	*	11.16180+- 1.32806	8.58116+- .63390	.77+- .11	-1.8
C212	EHTU	*	.59813+- .16221	.16421+- .02880	.27+- .09	-2.6
C213	OLTU	*	4.91687+- .79613	4.93225+- .23024	1.00+- .17	.0
C214	ELTU	*	6.62003+- .66879	7.36037+- .22756	1.11+- .12	1.0

SOURCE CONTRIBUTION ESTIMATES - SITE: 149 DATE: 27/05/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE 1.00 PERCENT MASS 103.1 CHI SQUARE 2.29 DF 35

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	3.6475	.1788	20.4002
8	RDUST	.2450	.0736	3.3296
16	SO4	.8895	.1683	5.2850
17	NO3	.7922	.1152	6.8751
32	VEH1	6.4097	.1601	40.0435
33	PETVH	1.5755	.7268	2.1677
35	DIES2	12.5374	1.4267	8.7877

MEASURED CONCENTRATION FOR SIZE: FINE 25.3+- 2.1

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	25.31260+- 2.05790	26.09684+- 1.44112	1.03+- .10	.3
C11	Na	*	.11456+- .03744	.08112+- .03456	.71+- .38	-.7
C12	Mg	*	.04949< .15568	.02269< .14013	.46< 3.18	-.1
C13	Al	*	.17355+- .02466	.16752+- .01902	.97+- .18	-.2
C14	Si	*	.04948+- .00912	.07168+- .01380	1.45+- .39	1.3
C15	P	*	.01886+- .00526	.01401+- .00347	.74+- .28	-.8
C16	S	*	.50422+- .03372	.50422+- .04286	1.00+- .11	.0
C17	Cl		.01096< .02168	.17146< .00571	15.65< 30.96	7.2
C19	K	*	.10920+- .00453	.11189+- .00272	1.02+- .05	.5
C20	Ca	*	.04052+- .00439	.04191+- .00143	1.03+- .12	.3
C22	Ti	*	.00166< .04161	.00274< .01260	1.65< 41.91	.0
C23	V	*	.00227< .01689	.00047< .00511	.21< 2.72	-.1
C24	Cr	*	.00097< .00382	.00123< .00110	1.26< 5.08	.1
C25	Mn	*	.00476+- .00102	.00240+- .00084	.50+- .21	-1.8
C26	Fe	*	.13304+- .02210	.04255+- .00043	.32+- .05	-4.1
C27	Co	*	.00000< .00306	.00014< .00073	.00< .00	.0
C28	Ni	*	.00126< .00202	.00469< .00060	3.73< 6.01	1.6
C29	Cu	*	.00875+- .00177	.00163+- .00039	.19+- .06	-3.9
C30	Zn		.04317+- .00104	.03814+- .00035	.88+- .02	-4.6
C31	Ga	*	.00000< .01285	.00046< .01141	.00< .00	.0
C33	As	*	.00000< .18080	.00023< .17000	.00< .00	.0
C34	Se	*	.00000< .00561	.00005< .00473	.00< .00	.0
C35	Br	*	.64216+- .01439	.60847+- .00288	.95+- .02	-2.3
C48	Cd		.00000< .01760	.00369< .00551	.00< .00	.2
C49	In	*	.00662< .02020	.00000< .00626	.00< .95	-.3
C50	Sn	*	.00740< .02607	.00002< .00804	.00< 1.09	-.3
C51	Sb	*	.01097< .03145	.00367< .00940	.33< 1.29	-.2
C56	Ba	*	.02626< .11591	.00306< .03405	.12< 1.40	-.2
C57	La	*	.00000< .15448	.00906< .04513	.00< .00	.1
C79	Au	*	.00000< .00671	.00031< .00315	.00< .00	.0
C80	Hg	*	.00720+- .00237	.00167+- .00434	.23+- .61	-1.1
C81	Tl	*	.00000< .03169	.00000< .02919	.00< .00	.0
C82	Pb	*	1.15075+- .00742	1.15625+- .00286	1.00+- .01	.7
C92	U	*	.00000< .01151	.00000< .00915	.00< .00	.0
C201	Cl-		.11861+- .01186	.68193+- .06814	5.75+- .81	8.1
C202	NO3-	*	.83435+- .08343	.83435+- .07933	1.00+- .14	.0
C203	SO4--		1.39497+- .13950	1.58866+- .10202	1.14+- .14	1.1
C204	Ca++		.04765+- .00476	.14724+- .01376	3.09+- .42	6.8
C205	K+		.10848+- .01085	.34680+- .03462	3.20+- .45	6.6
C206	Mg++		.27879+- .02788	.00051+- .00005	.00+- .00	-10.0
C207	Na+		.00000+- .00000	.00047+- .00005	.00+- .00	10.0
C208	NH4+		.00000+- .00000	.15306+- .01329	.00+- .00	11.5
C209	OCTU		14.59854+- .99351	9.35297+- .35628	.64+- .05	-5.0
C210	ECTU		5.82928+- .39538	4.48991+- .27046	.77+- .07	-2.8
C211	OHTU	*	8.94161+- 1.07461	5.81763+- .40449	.65+- .09	-2.7
C212	EHTU	*	.36496+- .10138	.73613+- .01799	2.02+- .56	3.6
C213	OLTU	*	5.65693+- .90517	3.53533+- .35321	.62+- .12	-2.2
C214	ELTU	*	5.46431+- .54988	3.75377+- .38207	.69+- .10	-2.6

J.3. Modelling at the Tableview Site

SOURCE CONTRIBUTION ESTIMATES - SITE: 59 DATE: 14/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE .96 PERCENT MASS 111.9 CHI SQUARE 2.77 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
3	CALOB	2.3527	1.7042	1.3805
5	TVDST	1.1612	.0920	12.6150
13	DIVEH	7.4880	1.7491	4.2811
16	SO4	.7022	.2488	2.8228
17	NO3	1.3374	.1910	7.0010
20	MARI1	.4951	.1350	3.6688
25	WBURN	2.0232	.1507	13.4283
28	OHC	4.0973	1.1691	3.5048
34	VEH2	1.0634	.0352	30.1804

MEASURED CONCENTRATION FOR SIZE: FINE 18.5+- 2.1

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	18.50928+- 2.09051	20.72040+- 2.09825	1.12+- .17	.7
C11	Na	*	.27946+- .04925	.22963+- .02526	.82+- .17	-.9
C12	Mg	*	.03094< .06805	.03555< .01443	1.15< 2.57	.1
C13	Al	*	.09884+- .01385	.05105+- .00358	.52+- .08	-3.3
C14	Si	*	.20773+- .01148	.20564+- .00190	.99+- .06	-.2
C15	P	*	.01792< .01857	.00334< .00223	.19< .23	-.8
C16	S	*	.42906+- .01067	.42906+- .02427	1.00+- .06	.0
C17	Cl		.03013+- .00752	.30378+- .04959	10.08+- 3.01	5.5
C19	K	*	.12245+- .00740	.12266+- .00191	1.00+- .06	.0
C20	Ca	*	.03070+- .00762	.04923+- .00212	1.60+- .40	2.3
C22	Ti	*	.00000< .07818	.00425< .00754	.00< .00	.1
C23	V	*	.00470< .03173	.01648< .00265	3.50< 23.64	.4
C24	Cr	*	.00223< .00710	.00086< .00089	.38< 1.29	-.2
C25	Mn	*	.00375< .00539	.00107< .00052	.29< .43	-.5
C26	Fe		.04315+- .00225	.03143+- .00028	.73+- .04	-5.2
C27	Co	*	.00057< .00385	.00009< .00048	.16< 1.39	-.1
C28	Ni	*	.00114< .00369	.00624< .00032	5.50< 17.87	1.4
C29	Cu	*	.00176< .00383	.00104< .00025	.59< 1.29	-.2
C30	Zn		.03936+- .00168	.00805+- .00016	.20+- .01	-18.5
C31	Ga	*	.00069< .00655	.00022< .00114	.32< 3.46	-.1
C33	As	*	.00260< .02835	.00012< .01447	.05< 5.60	-.1
C34	Se	*	.00041< .00408	.00003< .00056	.07< 1.54	-.1
C35	Br	*	.05921+- .00189	.06331+- .00043	1.07+- .03	2.1
C48	Cd		.00000< .03305	.00145< .00319	.00< .00	.0
C49	In	*	.00000< .03759	.00018< .00361	.00< .00	.0
C50	Sn	*	.03392< .04884	.00126< .00469	.04< .15	-.7
C51	Sb	*	.02512< .05710	.00066< .00558	.03< .23	-.4
C56	Ba	*	.00000< .21397	.00023< .02069	.00< .00	.0
C57	La	*	.00000< .28352	.00152< .02750	.00< .00	.0
C79	Au	*	.00140< .01048	.00023< .00103	.16< 1.44	-.1
C80	Hg	*	.00000< .00886	.00057< .00094	.00< .00	.1
C81	Tl	*	.00000< .01018	.00002< .00262	.00< .00	.0
C82	Pb	*	.16697+- .00927	.11835+- .00079	.71+- .04	-5.2
C92	U	*	.00000< .00866	.00000< .00114	.00< .00	.0
C201	Cl-		.91241+- .09124	.50910+- .05374	.56+- .08	-3.8
C202	NO3-	*	1.36253+- .13625	1.36253+- .13376	1.00+- .14	.0
C203	SO4--		2.09854+- .20985	1.93322+- .11611	.92+- .11	-.7
C204	Ca++		.51703+- .05170	.25116+- .01824	.49+- .06	-4.8
C205	K+		.29197+- .02920	.13500+- .00997	.46+- .06	-5.1
C206	Mg++		.12774+- .01277	.03969+- .00462	.31+- .05	-6.5
C207	Na+		.36496+- .03650	.22295+- .04956	.61+- .15	-2.3
C208	NH4+		.20073+- .02007	.09447+- .00791	.47+- .06	-4.9
C209	OCTU		10.21898+- .81103	4.86662+- .20381	.48+- .04	-6.4
C210	ECTU		3.69019+- .48662	2.60239+- .16035	.71+- .10	-2.1
C211	OHTU	*	7.21817+- .99351	7.21817+- .46284	1.00+- .15	.0
C212	EHTU	*	2.04785+- .36496	.07249+- .01184	.04+- .01	-5.4
C213	OLTU	*	3.00081+- .57313	1.74572+- .19882	.58+- .13	-2.1
C214	ELTU	*	1.64234+- .58343	2.52991+- .22646	1.54+- .56	1.4

SOURCE CONTRIBUTION ESTIMATES - SITE: 68 DATE: 18/08/95 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .95 PERCENT MASS 96.1 CHI SQUARE 3.81 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
3	CALOB	2.0254	.8917	2.2713
6	RKBRN	2.0461	.1527	13.4000
7	CALCT	.4299	.0456	9.4248
8	RDUST	.4620	.0424	10.9027
13	DIVEH	1.7903	.5218	3.4313
16	SO4	4.0807	.4284	9.5256
17	NO3	.5232	.0744	7.0284
20	MARI1	.7034	.1127	6.2423
34	VEH2	.3256	.0242	13.4720

MEASURED CONCENTRATION FOR SIZE: FINE 12.9+- 1.1

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	12.89459+- 1.06869	12.38671+- .96803	.96+- .11	-.4
C11	Na	*	.35493+- .04069	.31615+- .02968	.89+- .13	-.8
C12	Mg	*	.06557+- .01532	.03967+- .00861	.61+- .19	-1.5
C13	Al	*	.05554+- .00954	.07859+- .00129	1.42+- .24	2.4
C14	Si	*	.15290+- .00809	.14730+- .00090	.96+- .05	-.7
C15	P	*	.00000< .01690	.00243< .00156	.00< .00	.1
C16	S	*	1.48953+- .01025	1.48953+- .13498	1.00+- .09	.0
C17	Cl		.00160< .02596	.36862< .07037	*****< *****	4.9
C19	K	*	.07245+- .00388	.07691+- .00176	1.06+- .06	1.0
C20	Ca	*	.03453+- .00408	.04391+- .00180	1.27+- .16	2.1
C22	Ti	*	.00620< .04122	.00468< .00457	.75< 5.07	-.0
C23	V	*	.00154< .01672	.01518< .00124	9.85< *****	.8
C24	Cr	*	.00066< .00377	.00073< .00062	1.11< 6.42	.0
C25	Mn	*	.00548+- .00101	.00124+- .00029	.23+- .07	-4.0
C26	Fe	*	.04619+- .00143	.04503+- .00021	.97+- .03	-.8
C27	Co	*	.00000< .00220	.00006< .00050	.00< .00	.0
C28	Ni	*	.00136< .00202	.00473< .00017	3.48< 5.17	1.7
C29	Cu	*	.00505+- .00073	.00052+- .00019	.10+- .04	-6.0
C30	Zn		.00905+- .00080	.00484+- .00009	.53+- .05	-5.2
C31	Ga	*	.00000< .00330	.00011< .00047	.00< .00	.0
C33	As	*	.00000< .00762	.00008< .00445	.00< .00	.0
C34	Se	*	.00003< .00213	.00003< .00027	.96< 67.46	.0
C35	Br		.00752+- .00073	.02095+- .00040	2.79+- .28	16.1
C48	Cd		.00000< .01711	.00040< .00195	.00< .00	.0
C49	In	*	.00000< .02009	.00001< .00219	.00< .00	.0
C50	Sn	*	.00000< .02551	.00103< .00287	.00< .00	.0
C51	Sb	*	.00000< .03029	.00086< .00339	.00< .00	.0
C56	Ba	*	.00000< .11277	.00067< .01263	.00< .00	.0
C57	La	*	.00000< .15127	.00460< .01694	.00< .00	.0
C79	Au	*	.00126< .00550	.00010< .00062	.08< .61	-.2
C80	Hg	*	.00098< .00476	.00014< .00053	.14< .89	-.2
C81	Tl	*	.00000< .00471	.00000< .00091	.00< .00	.0
C82	Pb	*	.03812+- .00233	.03810+- .00057	1.00+- .06	.0
C92	U	*	.00000< .00460	.00001< .00056	.00< .00	.0
C201	Cl-		.56265+- .05627	.69082+- .08009	1.23+- .19	1.3
C202	NO3-	*	.52920+- .05292	.52920+- .05232	1.00+- .14	.0
C203	SO4--		4.92397+- .49240	5.00319+- .41573	1.02+- .13	.1
C204	Ca++		.55961+- .05596	.25714+- .01711	.46+- .06	-5.2
C205	K+		.18248+- .01825	.22583+- .01958	1.24+- .16	1.6
C206	Mg++		.08212+- .00821	.04477+- .00641	.55+- .10	-3.6
C207	Na+		.39842+- .03984	.30006+- .07036	.75+- .19	-1.2
C208	NH4+		.59611+- .05961	.04158+- .00235	.07+- .01	-9.3
C209	OCTU		5.13990+- .40551	2.37410+- .09393	.46+- .04	-6.6
C210	ECTU		.99351+- .14193	.77942+- .04561	.78+- .12	-1.4
C211	OHTU	*	3.34550+- .46634	1.79981+- .14186	.54+- .09	-3.2
C212	EHTU	*	.61841+- .12165	.02609+- .00507	.04+- .01	-4.9
C213	OLTU	*	1.79440+- .33378	.57429+- .08979	.32+- .08	-3.5
C214	ELTU	*	.37510+- .15965	.75333+- .06430	2.01+- .87	2.2

SOURCE CONTRIBUTION ESTIMATES - SITE: 71 DATE: 14/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE .98 PERCENT MASS 113.4 CHI SQUARE 2.51 DF 33

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
8	RDUST	1.3872	.0579	23.9617
13	DIVEH	11.0476	2.4922	4.4329
16	SO4	1.1657	.1452	8.0295
17	NO3	2.0553	.2934	7.0041
25	WBURN	3.2213	.1629	19.7703
28	OHC	4.5278	1.3935	3.2491
29	OLC	4.8897	1.2824	3.8130
32	VEH1	2.7605	.0591	46.6726

MEASURED CONCENTRATION FOR SIZE: FINE 27.4+- 2.7

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	27.38568+- 2.65768	31.05515+- 2.29527	1.13+- .14	1.0
C11	Na	*	.14570< .17249	.04820< .02114	.33< .42	-.6
C12	Mg	*	.05545< .09424	.01646< .06071	.30< 1.21	-.3
C13	Al	*	.12626+- .01865	.14795+- .00908	1.17+- .19	1.0
C14	Si	*	.18518+- .01249	.16353+- .00609	.88+- .07	-1.6
C15	P	*	.01354< .02214	.00948< .00259	.70< 1.16	-.2
C16	S	*	.52926+- .01782	.52926+- .04072	1.00+- .08	.0
C17	Cl		.04041+- .00860	.17122+- .00349	4.24+- .91	14.1
C19	K	*	.18279+- .00825	.18398+- .00212	1.01+- .05	.1
C20	Ca	*	.07541+- .00829	.10155+- .00225	1.35+- .15	3.0
C22	Ti	*	.00355< .08096	.00733< .00960	2.07< 47.21	.0
C23	V	*	.00957< .03295	.00043< .00392	.05< .44	-.3
C24	Cr	*	.00182< .00748	.00120< .00086	.66< 2.74	-.1
C25	Mn	*	.00689+- .00197	.00178+- .00065	.26+- .12	-2.5
C26	Fe	*	.09513+- .00288	.09340+- .00036	.98+- .03	-.6
C27	Co	*	.00057< .00442	.00007< .00129	.12< 2.45	-.1
C28	Ni	*	.00065< .00391	.00032< .00044	.49< 3.04	-.1
C29	Cu	*	.01062+- .00146	.00163+- .00024	.15+- .03	-6.1
C30	Zn		.06914+- .00197	.02315+- .00023	.33+- .01	-23.2
C31	Ga	*	.00000< .00868	.00039< .00495	.00< .00	.0
C33	As	*	.00000< .07772	.00022< .07315	.00< .00	.0
C34	Se	*	.00223< .00501	.00005< .00207	.02< .93	-.4
C35	Br		.21863+- .00318	.24985+- .00125	1.14+- .02	9.1
C48	Cd		.00517< .03459	.00269< .00403	.52< 3.57	-.1
C49	In	*	.00000< .03907	.00000< .00457	.00< .00	.0
C50	Sn	*	.00000< .05065	.00013< .00590	.00< .00	.0
C51	Sb	*	.01476< .06117	.00188< .00702	.13< .71	-.2
C56	Ba	*	.00000< .22571	.00282< .02574	.00< .00	.0
C57	La	*	.03773< .30217	.00542< .03403	.14< 1.46	-.1
C79	Au	*	.00292< .01150	.00037< .00172	.13< .78	-.2
C80	Hg	*	.00000< .00961	.00086< .00208	.00< .00	.1
C81	Tl	*	.00000< .01652	.00000< .01259	.00< .00	.0
C82	Pb	*	.48544+- .00956	.48484+- .00135	1.00+- .02	-.1
C92	U	*	.00000< .00996	.00003< .00403	.00< .00	.0
C201	Cl-		1.11314+- .11131	.43785+- .03293	.39+- .05	-5.8
C202	NO3-	*	2.09246+- .20925	2.09246+- .20557	1.00+- .14	.0
C203	SO4--		2.15937+- .21594	1.71012+- .12392	.79+- .10	-1.8
C204	Ca++		.72384+- .07238	.11751+- .00831	.16+- .02	-8.3
C205	K+		.31630+- .03163	.15605+- .01529	.49+- .07	-4.6
C206	Mg++		.13382+- .01338	.00289+- .00029	.02+- .00	-9.8
C207	Na+		.45012+- .04501	.00268+- .00027	.01+- .00	-9.9
C208	NH4+		.97324+- .09732	.12999+- .01161	.13+- .02	-8.6
C209	OCTU		16.30170+- 1.11517	6.88424+- .29673	.42+- .03	-8.2
C210	ECTU		4.25791+- .54745	3.81775+- .23643	.90+- .13	-.7
C211	OHTU	*	8.92133+- 1.15572	8.92133+- .55212	1.00+- .14	.0
C212	EHTU	*	1.39903+- .26358	.09219+- .01590	.07+- .02	-4.9
C213	OLTU	*	7.38037+- 1.07308	7.38037+- .56804	1.00+- .16	.0
C214	ELTU	*	2.85888+- .72795	3.72555+- .33398	1.30+- .35	1.1

SOURCE CONTRIBUTION ESTIMATES - SITE: 151 DATE: 27/05/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .97 PERCENT MASS 104.5 CHI SQUARE 4.45 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
7	CALCT	.5188	.0673	7.7083
8	RDUST	.4927	.1053	4.6792
13	DIVEH	5.6821	.8060	7.0501
16	SO4	1.2031	.1460	8.2424
17	NO3	.9430	.1348	6.9978
20	MARI1	1.5346	.4312	3.5586
25	WBURN	2.9462	.1631	18.0686
28	OHC	2.7520	.8257	3.3328
34	VEH2	1.9679	.0356	55.2696

MEASURED CONCENTRATION FOR SIZE: FINE 17.3+- 1.3

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	17.25903+- 1.29592	18.04037+- 1.06675	1.05+- .10	.5
C11	Na		.14698+- .03363	.64972+- .06239	4.42+- 1.10	7.1
C12	Mg	*	.03563< .04753	.08231< .02638	2.31< 3.17	.9
C13	Al	*	.10361+- .00968	.10731+- .00374	1.04+- .10	.4
C14	Si	*	.16645+- .00737	.16719+- .00228	1.00+- .05	.1
C15	P	*	.01580+- .00438	.00379+- .00152	.24+- .12	-2.6
C16	S	*	.52315+- .00933	.52315+- .04479	1.00+- .09	.0
C17	Cl		.09968+- .00640	.76717+- .15347	7.70+- 1.62	4.3
C19	K	*	.18095+- .00584	.18267+- .00334	1.01+- .04	.3
C20	Ca	*	.04611+- .00414	.06199+- .00362	1.34+- .14	2.9
C22	Ti	*	.00458< .03676	.00497< .00530	1.08< 8.77	.0
C23	V	*	.00654< .01495	.00143< .00215	.22< .60	-.3
C24	Cr	*	.00134< .00334	.00093< .00046	.70< 1.77	-.1
C25	Mn	*	.00453+- .00088	.00122+- .00035	.27+- .09	-3.5
C26	Fe	*	.07356+- .00760	.04480+- .00019	.61+- .06	-3.8
C27	Co	*	.00000< .00216	.00004< .00052	.00< .00	.0
C28	Ni	*	.00250+- .00059	.00314+- .00025	1.25+- .31	1.0
C29	Cu	*	.00479+- .00063	.00088+- .00014	.18+- .04	-6.1
C30	Zn		.05130+- .00102	.01077+- .00012	.21+- .00	-39.3
C31	Ga	*	.00237< .00391	.00021< .00183	.09< .78	-.5
C33	As	*	.00000< .03377	.00014< .02665	.00< .00	.0
C34	Se	*	.00259+- .00076	.00004+- .00078	.02+- .30	-2.3
C35	Br		.08635+- .00149	.11506+- .00090	1.33+- .03	16.5
C48	Cd		.00565< .01594	.00128< .00222	.23< .75	-.3
C49	In	*	.00712< .01828	.00002< .00250	.00< .35	-.4
C50	Sn	*	.00921< .02346	.00005< .00324	.01< .35	-.4
C51	Sb	*	.00000< .02697	.00109< .00388	.00< .00	.0
C56	Ba	*	.00000< .10079	.00108< .01426	.00< .00	.0
C57	La	*	.00000< .13287	.00496< .01888	.00< .00	.0
C79	Au	*	.00279< .00544	.00027< .00082	.10< .35	-.5
C80	Hg	*	.00204< .00440	.00060< .00087	.29< .76	-.3
C81	Tl	*	.00000< .00730	.00000< .00461	.00< .00	.0
C82	Pb	*	.20999+- .00348	.20996+- .00060	1.00+- .02	.0
C92	U	*	.00000< .00428	.00001< .00154	.00< .00	.0
C201	Cl-		1.91910+- .19191	1.01420+- .15639	.53+- .10	-3.7
C202	NO3-	*	.96208+- .09621	.96208+- .09432	1.00+- .14	.0
C203	SO4--		1.58049+- .15805	1.64550+- .13678	1.04+- .14	.3
C204	Ca++		.00000+- .00000	.09755+- .00665	.00+- .00	14.7
C205	K+		.15714+- .01571	.16281+- .01432	1.04+- .14	.3
C206	Mg++		.16930+- .01693	.07483+- .01381	.44+- .09	-4.3
C207	Na+	*	1.92113+- .19211	.61567+- .15346	.32+- .09	-5.3
C208	NH4+		.19972+- .01997	.07178+- .00601	.36+- .05	-6.1
C209	OCTU		11.29359+- .79075	4.73578+- .16863	.42+- .03	-8.1
C210	ECTU		1.94647+- .14193	2.08868+- .12297	1.07+- .10	.8
C211	OHTU	*	5.84955+- .72993	5.84955+- .33575	1.00+- .14	.0
C212	EHTU	*	.23317+- .07097	.05733+- .00890	.25+- .08	-2.5
C213	OLTU	*	5.44404+- .84723	1.63822+- .16065	.30+- .06	-4.4
C214	ELTU	*	1.71330+- .18776	2.03135+- .17368	1.19+- .16	1.2

J.4. Modelling at the Wynberg Site

SOURCE CONTRIBUTION ESTIMATES - SITE: 63 DATE: 14/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE 1.00 PERCENT MASS 103.8 CHI SQUARE 2.05 DF 33

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	2.2111	.2571	8.6013
13	DIVEH	13.7419	2.3141	5.9382
16	SO4	.1791	.2244	.7984
17	NO3	.6594	.0970	6.7983
22	SASFA	.5855	.1672	3.5019
30	EHC	2.7470	1.4713	1.8670
32	VEH1	9.4356	.0789	119.6221
36	COMPB	.4941	.6541	.7553

MEASURED CONCENTRATION FOR SIZE: FINE 29.0+- 3.2

SPECIES			MEAS		CALC		RATIO C/M		RATIO R/U
C1	TOT	T	28.95708+-	3.20274	30.05359+-	2.70474	1.04+- .15		.3
C11	Na	*	.09294<	.17257	.07343<	.04763	.79<	1.55	-.1
C12	Mg	*	.03960<	.22301	.03411<	.20573	.86<	7.11	-.0
C13	Al	*	.32802+-	.04560	.29529+-	.02761	.90+- .15		-.6
C14	Si	*	.04195<	.04240	.14775<	.02026	3.52<	3.59	2.3
C15	P	*	.00501<	.02336	.02249<	.00400	4.49<	20.96	.7
C16	S	*	.34521+-	.04730	.34521+-	.04580	1.00+- .19		.0
C17	Cl		.02946<	.03197	.11447<	.00752	3.89<	4.22	2.6
C19	K	*	.07182+-	.00663	.07385+-	.00320	1.03+- .10		.3
C20	Ca	*	.03812+-	.00754	.04356+-	.00201	1.14+- .23		.7
C22	Ti	*	.00627<	.07362	.00225<	.01484	.36<	4.84	-.1
C23	V	*	.01206<	.03003	.00896<	.00602	.74<	1.91	-.1
C24	Cr	*	.00337<	.00702	.00133<	.00137	.40<	.92	-.3
C25	Mn	*	.00395<	.00531	.00407<	.00103	1.03<	1.41	.0
C26	Fe		.15584+-	.01333	.03084+-	.00046	.20+- .02		-9.4
C27	Co	*	.00024<	.00468	.00017<	.00077	.70<	13.87	-.0
C28	Ni	*	.00304<	.00369	.00304<	.00070	1.00<	1.24	.0
C29	Cu	*	.00878+-	.00134	.00371+-	.00057	.42+- .09		-3.5
C30	Zn		.04647+-	.00170	.05281+-	.00048	1.14+- .04		3.6
C31	Ga	*	.00708<	.01863	.00047<	.01675	.07<	2.37	-.3
C33	As	*	.00000<	.25375	.00020<	.24991	.00<	.00	.0
C34	Se	*	.00000<	.00831	.00004<	.00693	.00<	.00	.0
C35	Br	*	1.21742+-	.09756	.84152+-	.00423	.69+- .06		-3.8
C48	Cd		.00032<	.03220	.00458<	.00669	14.10<	*****	.1
C49	In	*	.00000<	.03749	.00000<	.00761	.00<	.00	.0
C50	Sn	*	.01371<	.04848	.00013<	.00973	.01<	.71	-.3
C51	Sb	*	.02553<	.05564	.00425<	.01124	.17<	.57	-.4
C56	Ba	*	.00000<	.20505	.00410<	.04032	.00<	.00	.0
C57	La	*	.00000<	.27222	.00956<	.05343	.00<	.00	.0
C79	Au	*	.00099<	.01117	.00028<	.00440	.29<	5.47	-.1
C80	Hg	*	.00000<	.01089	.00175<	.00626	.00<	.00	.1
C81	Tl	*	.00000<	.04493	.00000<	.04290	.00<	.00	.0
C82	Pb	*	1.60941+-	.01243	1.61370+-	.00420	1.00+- .01		.3
C92	U	*	.00000<	.02137	.00000<	.01339	.00<	.00	.0
C201	Cl-		.60827+-	.06083	.41737+-	.04131	.69+- .10		-2.6
C202	NO3-	*	.70560+-	.07056	.70560+-	.06610	1.00+- .14		.0
C203	SO4--		1.48418+-	.14842	1.09218+-	.06036	.74+- .08		-2.4
C204	Ca++		.57786+-	.05779	.10277+-	.00852	.18+- .02		-8.1
C205	K+		.25547+-	.02555	.21277+-	.02099	.83+- .12		-1.3
C206	Mg++		.11557+-	.01156	.00139+-	.00012	.01+- .00		-9.9
C207	Na+		.33455+-	.03345	.00342+-	.00025	.01+- .00		-9.9
C208	NH4+		.15815+-	.01582	.15747+-	.01444	1.00+- .14		-.0
C209	OCTU		17.86294+-	1.21654	8.73977+-	.36527	.49+- .04		-7.2
C210	ECTU		5.12977+-	.64882	4.77317+-	.29375	.93+- .13		-.5
C211	OHTU	*	9.34712+-	1.19627	5.17682+-	.38729	.55+- .08		-3.3
C212	EHTU	*	2.87916+-	.52717	2.87916+-	1.37363	1.00+- .51		.0
C213	OLTU	*	8.51581+-	1.23649	3.56295+-	.36246	.42+- .07		-3.8
C214	ELTU	*	2.25061+-	.75102	4.64100+-	.41498	2.06+- .71		2.8

SOURCE CONTRIBUTION ESTIMATES - SITE: 75 DATE: 14/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 117.8 CHI SQUARE 2.12 DF 32

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	4.6846	.2754	17.0117
8	RDUST	.6592	.1173	5.6180
13	DIVEH	4.5896	1.8705	2.4537
16	SO4	.2342	.1722	1.3599
28	OHC	5.2533	2.9444	1.7841
29	OLC	6.6907	3.5790	1.8694
30	EHC	1.3999	.7554	1.8532
32	VEH1	6.2575	.0650	96.3250
36	COMPB	.2776	.7148	.3883

MEASURED CONCENTRATION FOR SIZE: FINE 25.5+- 2.9

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	25.49884+- 2.85547	30.04664+- 4.81864	1.18+- .23	.8
C11	Na	*	.23165+- .06490	.08727+- .03043	.38+- .17	-2.0
C12	Mg	*	.06310< .15908	.02113< .13645	.33< 2.32	-.2
C13	Al	*	.20375+- .03268	.17845+- .01800	.88+- .17	-.7
C14	Si	*	.03013< .03654	.09658< .01342	3.21< 3.91	1.7
C15	P	*	.02277+- .00730	.01485+- .00276	.65+- .24	-1.0
C16	S	*	.24298+- .03206	.24298+- .03109	1.00+- .18	.0
C17	Cl		.05470+- .00959	.21116+- .00518	3.86+- .68	14.4
C19	K	*	.14361+- .00779	.14692+- .00220	1.02+- .06	.4
C20	Ca	*	.04219+- .00803	.05993+- .00124	1.42+- .27	2.2
C22	Ti	*	.00053< .08372	.00509< .00912	9.65< *****	.1
C23	V	*	.00764< .03406	.00536< .00371	.70< 3.16	-.1
C24	Cr	*	.00221< .00781	.00109< .00073	.49< 1.77	-.1
C25	Mn	*	.00091< .00584	.00253< .00055	2.77< 17.73	.3
C26	Fe	*	.12149+- .01314	.06435+- .00038	.53+- .06	-4.3
C27	Co	*	.00000< .00462	.00012< .00082	.00< .00	.0
C28	Ni	*	.00043< .00408	.00187< .00045	4.39< 42.01	.4
C29	Cu	*	.00845+- .00150	.00122+- .00036	.14+- .05	-4.7
C30	Zn		.02159+- .00166	.03505+- .00030	1.62+- .13	8.0
C31	Ga	*	.00000< .01367	.00029< .01110	.00< .00	.0
C33	As	*	.00000< .16819	.00019< .16573	.00< .00	.0
C34	Se	*	.00000< .00667	.00007< .00460	.00< .00	.0
C35	Br	*	.76073+- .05588	.55775+- .00280	.73+- .05	-3.6
C48	Cd		.01162< .03583	.00229< .00422	.20< .71	-.3
C49	In	*	.00000< .04041	.00000< .00481	.00< .00	.0
C50	Sn	*	.00107< .05306	.00014< .00614	.13< 8.53	-.0
C51	Sb	*	.00000< .06221	.00407< .00707	.00< .00	.1
C56	Ba	*	.00000< .23360	.00349< .02521	.00< .00	.0
C57	La	*	.00000< .31204	.01066< .03362	.00< .00	.0
C79	Au	*	.00000< .01172	.00024< .00288	.00< .00	.0
C80	Hg	*	.00000< .01105	.00094< .00413	.00< .00	.1
C81	Tl	*	.00000< .03106	.00000< .02845	.00< .00	.0
C82	Pb	*	1.06346+- .01050	1.06770+- .00275	1.00+- .01	.4
C92	U	*	.00000< .01582	.00001< .00887	.00< .00	.0
C201	Cl-		.79075+- .07908	.87869+- .08751	1.11+- .16	.7
C202	NO3-		.00000+- .00000	.01542+- .00154	.00+- .00	10.0
C203	SO4--		1.43552+- .14355	.71756+- .03443	.50+- .06	-4.9
C204	Ca++		.48054+- .04805	.21426+- .01786	.45+- .06	-5.2
C205	K+		.32238+- .03224	.44781+- .04447	1.39+- .20	2.3
C206	Mg++		.13382+- .01338	.00216+- .00015	.02+- .00	-9.8
C207	Na+		.38929+- .03893	.00320+- .00019	.01+- .00	-9.9
C208	NH4+		.13382+- .01338	.07785+- .00551	.58+- .07	-3.9
C209	OCTU		18.00487+- 1.21654	6.06084+- .21229	.34+- .03	-9.7
C210	ECTU		3.38605+- .44607	2.04292+- .11260	.60+- .09	-2.9
C211	OHTU	*	9.50933+- 1.21654	9.50933+- 2.64640	1.00+- .31	.0
C212	EHTU	*	1.48013+- .28386	1.48013+- .69999	1.00+- .51	.0
C213	OLTU	*	8.49554+- 1.21654	8.49554+- 3.35166	1.00+- .42	.0
C214	ELTU	*	1.90592+- .56336	1.96265+- .15900	1.03+- .32	.1

SOURCE CONTRIBUTION ESTIMATES - SITE: 82 DATE: 25/07/95 CMB7 33889
SAMPLE DURATION 6 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 114.5 CHI SQUARE 3.76 DF 34

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	4.3641	.3003	14.5308
8	RDUST	.8144	.1145	7.1130
13	DIVEH	13.3274	2.4237	5.4989
16	SO4	2.4826	.2958	8.3931
17	NO3	1.4090	.2027	6.9523
20	MARI1	.8880	.1915	4.6361
30	EHC	2.4367	1.3047	1.8676
34	VEH2	11.2901	.1046	107.9700

MEASURED CONCENTRATION FOR SIZE: FINE 32.3+- 3.0

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	32.31464+- 2.95231	37.01228+- 2.66845	1.15+- .13	1.2
C11	Na	*	.55795+- .06073	.44853+- .04832	.80+- .12	-1.4
C12	Mg	*	.00000< .17887	.06805< .12633	.00< .00	.3
C13	Al	*	.22551+- .03234	.21337+- .01747	.95+- .16	-.3
C14	Si	*	.15083+- .01543	.13402+- .01224	.89+- .12	-.9
C15	P	*	.06302+- .00989	.01402+- .00373	.22+- .07	-4.6
C16	S	*	1.06328+- .03629	1.06328+- .08875	1.00+- .09	.0
C17	Cl		.00274< .03116	.56431< .08897	*****< *****	6.0
C19	K	*	.14524+- .00777	.15218+- .00334	1.05+- .06	.8
C20	Ca	*	.06190+- .00803	.09124+- .00234	1.47+- .19	3.5
C22	Ti	*	.00770< .07906	.00595< .01302	.77< 8.10	-.0
C23	V	*	.03193< .03246	.00070< .00529	.02< .17	-.9
C24	Cr	*	.00373< .00760	.00153< .00111	.41< .89	-.3
C25	Mn	*	.00629+- .00191	.00297+- .00084	.47+- .20	-1.6
C26	Fe	*	.13978+- .01324	.08123+- .00048	.58+- .06	-4.4
C27	Co	*	.00264< .00479	.00018< .00102	.07< .41	-.5
C28	Ni	*	.01288+- .00142	.01600+- .00062	1.24+- .15	2.0
C29	Cu	*	.01101+- .00142	.00252+- .00037	.23+- .04	-5.8
C30	Zn		.06535+- .00191	.03997+- .00035	.61+- .02	-13.1
C31	Ga	*	.00647< .01444	.00052< .01026	.08< 1.60	-.3
C33	As	*	.00215< .18319	.00028< .15277	.13< 71.92	.0
C34	Se	*	.00000< .00673	.00006< .00427	.00< .00	.0
C35	Br	*	.68942+- .01576	.63120+- .00315	.92+- .02	-3.6
C48	Cd		.00000< .03437	.00371< .00562	.00< .00	.1
C49	In	*	.00000< .03871	.00000< .00639	.00< .00	.0
C50	Sn	*	.00000< .04943	.00008< .00822	.00< .00	.0
C51	Sb	*	.00000< .05971	.00372< .00965	.00< .00	.1
C56	Ba	*	.00000< .21849	.00340< .03513	.00< .00	.0
C57	La	*	.00000< .29284	.00995< .04658	.00< .00	.0
C79	Au	*	.00424< .01164	.00036< .00296	.08< .74	-.3
C80	Hg	*	.00241< .01056	.00245< .00391	1.02< 4.74	.0
C81	Tl	*	.00000< .03333	.00000< .02624	.00< .00	.0
C82	Pb	*	1.16073+- .01077	1.17401+- .00260	1.01+- .01	1.2
C92	U	*	.00000< .01450	.00001< .00832	.00< .00	.0
C201	Cl-		.63869+- .06387	1.17227+- .12054	1.84+- .26	3.9
C202	NO3-	*	1.45377+- .14538	1.45377+- .14097	1.00+- .14	.0
C203	SO4--		3.47324+- .34732	3.30963+- .25620	.95+- .12	-.4
C204	Ca++		.46229+- .04623	.20999+- .01684	.45+- .06	-5.1
C205	K+		.27981+- .02798	.42855+- .04146	1.53+- .21	3.0
C206	Mg++		.11557+- .01156	.04432+- .00799	.38+- .08	-5.1
C207	Na+		.39538+- .03954	.35676+- .08880	.90+- .24	-.4
C208	NH4+		.13382+- .01338	.16753+- .01418	1.25+- .16	1.7
C209	OCTU		16.80860+- 1.15572	12.29177+- .43477	.73+- .06	-3.7
C210	ECTU		7.19789+- .91241	4.89841+- .28866	.68+- .10	-2.4
C211	OHTU	*	13.01703+- 1.60178	7.46633+- .47916	.57+- .08	-3.3
C212	EHTU	*	2.55474+- .46634	2.55474+- 1.21853	1.00+- .51	.0
C213	OLTU	*	3.79157+- .32504	4.82544+- .44316	1.27+- .16	1.9
C214	ELTU	*	4.64315+- 1.20312	4.78041+- .40777	1.03+- .28	.1

SOURCE CONTRIBUTION ESTIMATES - SITE: 140 DATE: 30/04/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .98 PERCENT MASS 117.0 CHI SQUARE 5.50 DF 33

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	4.5254	.1695	26.6925
7	CALCT	3.7707	.0798	47.2668
8	RDUST	1.3676	.0716	19.1004
13	DIVEH	.5715	.5287	1.0810
16	SO4	5.5203	.5536	9.9709
17	NO3	.1562	.0223	7.0052
29	OLC	3.0651	1.6462	1.8620
32	VEH1	.8191	.0595	13.7597
33	PETVH	.8088	.2681	3.0170

MEASURED CONCENTRATION FOR SIZE: FINE 17.6+- 1.4

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	17.61283+- 1.38603	20.60488+- 1.78961	1.17+- .14	1.3
C11	Na	*	.08127< .12102	.07348< .01044	.90< 1.35	-.1
C12	Mg	*	.05939< .05966	.00946< .01952	.16< .37	-.8
C13	Al	*	.29044+- .01495	.44144+- .00324	1.52+- .08	9.9
C14	Si	*	.92575+- .01426	.87037+- .00254	.94+- .01	-3.8
C15	P	*	.00500< .01989	.00818< .00186	1.64< 6.52	.2
C16	S	*	1.89217+- .01253	1.89217+- .18223	1.00+- .10	.0
C17	Cl		.01878< .03253	.19518< .00246	10.40< 18.01	5.4
C19	K	*	.14838+- .00483	.15370+- .00146	1.04+- .04	1.1
C20	Ca	*	.08441+- .00466	.09346+- .00098	1.11+- .06	1.9
C22	Ti	*	.02783< .04150	.02265< .00516	.81< 1.23	-.1
C23	V	*	.00370< .01686	.00930< .00218	2.51< 11.46	.3
C24	Cr	*	.00396+- .00131	.00252+- .00024	.64+- .22	-1.1
C25	Mn	*	.00548+- .00103	.00311+- .00018	.57+- .11	-2.3
C26	Fe	*	.17456+- .00835	.13433+- .00038	.77+- .04	-4.8
C27	Co	*	.00000< .00356	.00004< .00138	.00< .00	.0
C28	Ni	*	.00416+- .00070	.00413+- .00026	.99+- .18	-.0
C29	Cu	*	.00253+- .00070	.00125+- .00010	.49+- .14	-1.8
C30	Zn	*	.01320+- .00082	.01200+- .00013	.91+- .06	-1.4
C31	Ga	*	.00000< .00399	.00017< .00154	.00< .00	.0
C33	As	*	.00000< .02825	.00016< .02217	.00< .00	.0
C34	Se	*	.00000< .00234	.00007< .00067	.00< .00	.0
C35	Br		.07574+- .00137	.09258+- .00039	1.22+- .02	11.8
C48	Cd		.00000< .01748	.00049< .00226	.00< .00	.0
C49	In	*	.00000< .02054	.00013< .00258	.00< .00	.0
C50	Sn	*	.00000< .02660	.00013< .00334	.00< .00	.0
C51	Sb	*	.00000< .03133	.00211< .00398	.00< .00	.1
C56	Ba	*	.00000< .11475	.00251< .01459	.00< .00	.0
C57	La	*	.00000< .15332	.02193< .01936	.00< .00	.1
C79	Au	*	.00000< .00572	.00021< .00082	.00< .00	.0
C80	Hg	*	.00000< .00499	.00030< .00079	.00< .00	.1
C81	Tl	*	.00000< .00700	.00000< .00385	.00< .00	.0
C82	Pb	*	.17472+- .00342	.17435+- .00045	1.00+- .02	-.1
C92	U	*	.00000< .00499	.00004< .00133	.00< .00	.0
C201	Cl-		.19465+- .01946	.86067+- .08455	4.42+- .62	7.7
C202	NO3-	*	.15815+- .01582	.15815+- .01562	1.00+- .14	.0
C203	SO4--		5.37105+- .53710	5.67194+- .55210	1.06+- .15	.4
C204	Ca++		.42275+- .04227	.22952+- .01793	.54+- .07	-4.2
C205	K+		.16423+- .01642	.43538+- .04296	2.65+- .37	5.9
C206	Mg++		.06691+- .00669	.00389+- .00030	.06+- .01	-9.4
C207	Na+		.12470+- .01247	.00901+- .00069	.07+- .01	-9.3
C208	NH4+		.41971+- .04197	.05182+- .00309	.12+- .01	-8.7
C209	OCTU		8.64761+- .58800	3.91494+- .17291	.45+- .04	-7.7
C210	ECTU		.82117+- .12165	.68502+- .05557	.83+- .14	-1.0
C211	OHTU	*	4.77494+- .60827	3.10736+- .28993	.65+- .10	-2.5
C212	EHTU	*	.41565+- .08110	.04607+- .00637	.11+- .03	-4.5
C213	OLTU	*	3.87267+- .56700	3.87267+- 1.54143	1.00+- .42	.0
C214	ELTU	*	.40551+- .15173	.63895+- .07833	1.58+- .62	1.4

SOURCE CONTRIBUTION ESTIMATES - SITE: 143 DATE: 08/05/96 CMB7 33889
SAMPLE DURATION 12 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 116.6 CHI SQUARE 3.89 DF 34

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
6	RKBRN	6.1218	.2036	30.0656
8	RDUST	1.0827	.0792	13.6744
13	DIVEH	10.2623	1.3388	7.6651
16	SO4	.9504	.1802	5.2736
17	NO3	.6721	.0977	6.8805
32	VEH1	6.8990	.0843	81.8843
33	PETVH	1.8815	.3293	5.7135

MEASURED CONCENTRATION FOR SIZE: FINE 23.9+- 1.9

SPECIES		I	MEAS		CALC		RATIO C/M		RATIO R/U
C1	TOT	T	23.89296+-	1.90801	27.86988+-	1.30516	1.17+- .11		1.7
C11	Na	*	.15284+-	.04032	.11641+-	.03599	.76+- .31		-.7
C12	Mg	*	.03897<	.16825	.02735<	.15088	.70< 4.92		-.1
C13	Al	*	.25831+-	.02803	.23310+-	.02023	.90+- .13		-.7
C14	Si	*	.19806+-	.01045	.15715+-	.01485	.79+- .09		-2.3
C15	P	*	.02713+-	.00555	.01738+-	.00379	.64+- .19		-1.5
C16	S	*	.52765+-	.03638	.52765+-	.04604	1.00+- .11		.0
C17	Cl		.02227<	.02230	.27786<	.00628	12.48< 12.50		11.0
C19	K	*	.19236+-	.00525	.19444+-	.00298	1.01+- .03		.3
C20	Ca	*	.08695+-	.00465	.09451+-	.00169	1.09+- .06		1.5
C22	Ti	*	.00000<	.03983	.00779<	.01280	.00< .00		.2
C23	V	*	.00308<	.01627	.00082<	.00521	.27< 2.20		-.1
C24	Cr	*	.00486+-	.00128	.00162+-	.00102	.33+- .23		-2.0
C25	Mn	*	.00343+-	.00096	.00357+-	.00078	1.04+- .37		.1
C26	Fe		.16535+-	.00728	.09957+-	.00054	.60+- .03		-9.0
C27	Co	*	.00000<	.00339	.00016<	.00124	.00< .00		.0
C28	Ni	*	.00505+-	.00068	.00572+-	.00062	1.13+- .20		.7
C29	Cu	*	.01014+-	.00075	.00216+-	.00042	.21+- .04		-9.3
C30	Zn		.04287+-	.00101	.04386+-	.00037	1.02+- .03		.9
C31	Ga	*	.00128<	.01377	.00049<	.01228	.38< 10.46		-.0
C33	As	*	.00000<	.19568	.00030<	.18303	.00< .00		.0
C34	Se	*	.00000<	.00594	.00009<	.00509	.00< .00		.0
C35	Br	*	.74895+-	.02472	.65881+-	.00310	.88+- .03		-3.6
C48	Cd		.00000<	.01699	.00347<	.00568	.00< .00		.2
C49	In	*	.00463<	.01938	.00000<	.00647	.00< 1.40		-.2
C50	Sn	*	.01589<	.02573	.00010<	.00831	.01< .52		-.6
C51	Sb	*	.00518<	.02991	.00485<	.00968	.94< 5.72		-.0
C56	Ba	*	.06370<	.10950	.00425<	.03497	.07< .56		-.5
C57	La	*	.00000<	.14533	.01314<	.04654	.00< .00		.1
C79	Au	*	.00000<	.00660	.00037<	.00335	.00< .00		.1
C80	Hg	*	.00731+-	.00237	.00167+-	.00464	.23+- .64		-1.1
C81	Tl	*	.00000<	.03416	.00000<	.03143	.00< .00		.0
C82	Pb	*	1.24538+-	.00766	1.25106+-	.00307	1.00+- .01		.7
C92	U	*	.00000<	.01294	.00002<	.00984	.00< .00		.0
C201	Cl-		.00000+-	.00000	1.14605+-	.11436	.00+- .00		10.0
C202	NO3-	*	.70661+-	.07066	.70661+-	.06730	1.00+- .14		.0
C203	SO4--		2.87612+-	.28761	1.62930+-	.10448	.57+- .07		-4.1
C204	Ca++		4.35118+-	.43512	.27468+-	.02345	.06+- .01		-9.4
C205	K+		1.10604+-	.11060	.58358+-	.05811	.53+- .07		-4.2
C206	Mg++		1.99412+-	.19941	.00226+-	.00023	.00+- .00		-10.0
C207	Na+		9.37551+-	.93755	.00209+-	.00021	.00+- .00		-10.0
C208	NH4+		1.02088+-	.10209	.14650+-	.01131	.14+- .02		-8.5
C209	OCTU		12.39862+-	.86172	10.34875+-	.35739	.83+- .06		-2.2
C210	ECTU		4.01460+-	.27372	4.02945+-	.23041	1.00+- .09		.0
C211	OHTU	*	8.88078+-	1.06448	6.88334+-	.47723	.78+- .11		-1.7
C212	EHTU	*	.79075+-	.21290	.11549+-	.01624	.15+- .04		-3.2
C213	OLTU	*	3.51784+-	.59330	3.46540+-	.35102	.99+- .19		-.1
C214	ELTU	*	3.22384+-	.32330	3.91396+-	.32546	1.21+- .16		1.5

J.5. Modelling at Guguletu

SOURCE CONTRIBUTION ESTIMATES - SITE: 159 DATE: 22/08/96 CMB7 33889
SAMPLE DURATION 10 START HOUR 0 SIZE: FINE
R SQUARE .99 PERCENT MASS 103.7 CHI SQUARE 3.24 DF 34

	SOURCE	SCE(UG/M3)	STD ERR	TSTAT
13	DIVEH	40.5698	4.5463	8.9237
16	SO4	1.7914	.2959	6.0536
17	NO3	3.3332	.4816	6.9217
20	MARI1	3.8984	.8133	4.7936
25	WBURN	21.1713	.4697	45.0714
32	VEH1	5.1160	.1822	28.0857
33	PETVH	2.3669	.8100	2.9220

MEASURED CONCENTRATION FOR SIZE: FINE 75.5+- 4.4

SPECIES		I	MEAS	CALC	RATIO C/M	RATIO R/U
C1	TOT	T	75.46102+- 4.42659	78.24702+- 4.37443	1.04+- .08	.4
C11	Na		.38543+- .09328	1.80127+- .17332	4.67+- 1.22	7.2
C12	Mg	*	.03998< .16550	.23262< .12270	5.82< 24.28	.9
C13	Al	*	.22843+- .03360	.16323+- .02227	.71+- .14	-1.6
C14	Si	*	.12018+- .01741	.15745+- .01239	1.31+- .22	1.7
C15	P	*	.04087+- .01303	.01130+- .01075	.28+- .28	-1.8
C16	S	*	1.16973+- .03418	1.16973+- .08215	1.00+- .08	.0
C17	Cl	*	3.61288+- .04216	2.64087+- .39008	.73+- .11	-2.5
C19	K	*	1.16861+- .01783	1.17208+- .01212	1.00+- .02	.2
C20	Ca	*	.06686+- .01132	.12463+- .01575	1.86+- .39	3.0
C22	Ti	*	.00826< .08586	.00443< .03750	.54< 7.20	-.0
C23	V	*	.01890< .03505	.00091< .01519	.05< .81	-.5
C24	Cr	*	.00283< .00805	.00410< .00326	1.45< 4.28	.1
C25	Mn	*	.00807+- .00208	.00660+- .00245	.82+- .37	-.5
C26	Fe		.08366+- .00292	.08552+- .00129	1.02+- .04	.6
C27	Co	*	.00000< .00449	.00023< .00204	.00< .00	.0
C28	Ni	*	.00660+- .00145	.00774+- .00174	1.17+- .37	.5
C29	Cu	*	.01411+- .00157	.00364+- .00094	.26+- .07	-5.7
C30	Zn		.21720+- .00299	.05500+- .00082	.25+- .01	-52.2
C31	Ga	*	.00419< .01324	.00132< .00958	.32< 2.50	-.2
C33	As	*	.02920< .15647	.00091< .13639	.03< 4.67	-.1
C34	Se	*	.00030< .00660	.00030< .00421	.99< 25.53	.0
C35	Br	*	.64973+- .02585	.52708+- .00817	.81+- .03	-4.5
C48	Cd		.00931< .03743	.00835< .01561	.90< 3.97	-.0
C49	In	*	.00229< .04183	.00000< .01763	.00< 7.69	-.1
C50	Sn	*	.01708< .05521	.00000< .02284	.00< 1.34	-.3
C51	Sb	*	.04969< .06649	.00677< .02739	.14< .58	-.6
C56	Ba	*	.00000< .23954	.00222< .10079	.00< .00	.0
C57	La	*	.00000< .32145	.01554< .13349	.00< .00	.0
C79	Au	*	.00000< .01458	.00183< .00540	.00< .00	.1
C80	Hg	*	.01514+- .00388	.00307+- .00537	.20+- .36	-1.8
C81	Tl	*	.00000< .02929	.00000< .02374	.00< .00	.0
C82	Pb	*	.98669+- .01081	.99874+- .00367	1.01+- .01	1.1
C92	U	*	.00000< .01455	.00000< .00833	.00< .00	.0
C201	Cl-		7.99410+- .79941	4.41626+- .44589	.55+- .08	-3.9
C202	NO3-	*	3.46949+- .34695	3.46949+- .33360	1.00+- .14	.0
C203	SO4--		4.60883+- .46088	4.13002+- .28286	.90+- .11	-.9
C204	Ca++		.00000+- .00000	.45273+- .04057	.00+- .00	11.2
C205	K+		4.46144+- .44614	1.05942+- .10079	.24+- .03	-7.4
C206	Mg++		.00000+- .00000	.18713+- .03509	.00+- .00	5.3
C207	Na+		.00000+- .00000	1.55938+- .38984	.00+- .00	4.0
C208	NH4+		2.94544+- .29454	.48538+- .04290	.16+- .02	-8.3
C209	OCTU		35.91147+- 2.43309	30.23867+- 1.17966	.84+- .07	-2.1
C210	ECTU		21.10238+- 1.42710	14.71583+- .87810	.70+- .06	-3.8
C211	OHTU	*	30.08609+- 3.55605	20.30387+- 1.35982	.67+- .09	-2.6
C212	EHTU	*	1.19315+- .32753	.35997+- .06338	.30+- .10	-2.5
C213	OLTU	*	5.82538+- .89759	9.93481+- 1.11387	1.71+- .32	2.9
C214	ELTU	*	19.90923+- 1.99147	14.35585+- 1.24019	.72+- .10	-2.4

APPENDIX K: APPORTIONMENT RESULTS FOR EACH EPISODE

Date	14/07/95	14/07/95	25/07/95	18/08/95	16/02/96	30/04/96	05/08/96	27/05/96	06/04/96	22/08/96
Tableview										
Crustal	6	5		4				6		
Diesel Vehicles	40	40		14				33		
Petrol Vehicles	6	10		3				11		
Woodburning	11	12		16				17		
Sea Salt	3	0		5				9		
Boilers	13	0		16				0		
Sulphate	4	4		32				7		
Nitrate	7	8		4				5		
Carbon	22	34		0				16		
% mass	112	113		94				104		
Chi Square	2.77	2.51		3.81				4.45		
Drill Hall										
Crustal		1	2		7	13	3	1		
Diesel Vehicles		60	43		50	13	60	50		
Petrol Vehicles		36	27		21	17	29	32		
Woodburning		10	11		12	10	16	14		
Sea Salt		0	0		2	0	0	0		
Boilers		0	1		0	0	0	0		
Sulphate		1	13		10	30	5	4		
Nitrate		2	5		2	1	6	3		
Carbon		0	18		17	33	0	0		
% mass		110	120		121	117	119	104		
Chi Square		2.51	0.67		2.76	2.42	1.65	2.29		
Goodwood										
Crustal		1			4	16	4	3	2	
Diesel Vehicles		52			16	49	63	43	52	
Petrol Vehicles		22			10	29	23	40	39	
Woodburning		14			28	19	14	16	7	
Sea Salt		0			9	0	3	0	1	
Boilers		0			0	0	5	0	0	
Sulphate		2			11	21	6	6	5	
Nitrate		4			3	3	6	2	3	
Carbon		27			0	0	0	0	0	
% mass		122			81	137	124	110	109	
Chi Square		3.26			3.04	4.77	3.17	3.23	3.43	
Wynberg										
Crustal	0	2	3			29	5			
Diesel Vehicles	47	37	41			3	43			
Petrol Vehicles	33	24	35			9	37			
Woodburning	8	19	14			26	26			
Sea Salt	0	0	3			0	0			
Boilers	4	1	0			0	0			
Sulphate	1	1	8			31	4			
Nitrate	2	0	4			1	3			
Carbon	9	5	8			17	0			
% mass	104	89	116			116	118			
Chi Square	2.05	3.12	3.76			5.5	3.89			
Guguletu										
Crustal										0
Diesel Vehicles										54
Petrol Vehicles										10
Woodburning										28
Sea Salt										5
Boilers										0
Sulphate										2.4
Nitrate										4.4
Carbon										0
% mass										104
Chi Square										3.24

Date	14/07/95	14/07/95	25/07/95	18/08/95	16/02/96	30/04/96	05/08/96	27/05/96	06/04/96	22/08/96
Tableview										
Crustal	5	4		4				6		
Diesel	36	36		18				33		
Petrol	9	13		7				14		
Wood	10	11		17				16		
Sea salt	3	0		5				9		
Boilers	16	5		47				7		
Unknown	20	31		1				16		
Total	100	100		100				100		
Drill Hall										
Crustal		1	2		6	11	3	1		
Diesel		55	37		42	13	51	49		
Petrol		34	26		19	16	28	33		
Wood		9	9		10	9	14	14		
Sea salt		0	0		2	0	0	0		
Boilers		1	11		7	22	5	4		
Unknown		0	16		14	29	1	0		
Total		100	100		100	100	100	100		
Goodwood										
Crustal		1			5	12	3	3	2	
Diesel		43			21	37	52	40	48	
Petrol		20			15	23	22	38	38	
Wood		12			35	14	11	15	6	
Sea salt		0			11	0	2	0	1	
Boilers		2			12	13	9	5	4	
Unknown		23			1	1	1	0	0	
Total		100			100	100	100	100	100	
Wynberg										
Crustal	0	2	3			25	4			
Diesel	45	42	36			5	37			
Petrol	33	27	33			10	33			
Wood	8	21	12			22	22			
Sea salt	0	0	3			0	0			
Boilers	5	2	7			23	3			
Unknown	9	6	7			15	0			
Total	100	100	100			100	100			
Guguletu										
Crustal										0
Diesel										52
Petrol										12
Wood										27
Sea salt										5
Boilers										3
Unknown										1
Total										100

Tableview							
Date	14/07/95	14/07/95	18/08/95	27/05/96			Average
Crustal	2	2	1	2			2
Diesel Vehicles	36	42	7	38			39
Petrol Vehicles	2	4	1	6			4
Woodburning	6	8	6	13			9
Sea Salt	1	0	2	4			2
Boilers	15	0	13	0			5
Sulphate	11	8	64	13			11
Nitrate	13	7	6	5			8
Carbon	12	24	4	12			16
NO2	2	5	1	6			4
Total	100	100	105	99			100
bext [Mm^-1]	182	196	203	110			173
Drill Hall							
Date	14/07/95	25/07/95	16/02/96	30/04/96	05/08/96	27/05/96	Average
Crustal	0	0	2	3	1	0	1
Diesel Vehicles	65	30	51	12	57	54	51
Petrol Vehicles	18	9	9	7	12	14	12
Woodburning	7	5	7	6	10	11	8
Sea Salt	0	0	1	0	0	0	0
Boilers	0	1	0	0	0	0	0
Sulphate	1	33	17	49	8	6	13
Nitrate	2	9	1	1	5	3	4
Carbon	0	11	11	21	0	0	4
NO2	6	1	5.01	5.01	7	12	6
Total	99	99	104.01	104.01	100	100	100
bext [Mm^-1]	199	599	79	124	302	202	276
Goodwood							
Date	14/07/95	16/02/96	30/04/96	05/08/96	27/05/96	06/04/96	Average
Crustal	0	2	4	0	1	1	1
Diesel Vehicles	48	22	42	58	49	54	46
Petrol Vehicles	10	7	11	10	20	18	13
Woodburning	8	25	10	8	11	5	11
Sea Salt	0	5	0	1	0	1	1
Boilers	0	0	0	3	0	0	1
Sulphate	4	34	31	10	10	13	14
Nitrate	3	5	3	5	2	5	4
Carbon	20	0	0	0	0	0	4
NO2	6	5.01	5.01	4	5	3	5
Total	99	105.01	106.01	99	98	100	100
bext [Mm^-1]	391	45	157	298	261	168	233
Wynberg							
Date	14/07/95	14/07/95	25/07/95	05/08/96	30/04/96		Average
Crustal	0	1	1	2	8		1
Diesel Vehicles	51	51	34	50	3		47
Petrol Vehicles	14	13	13	18	4		15
Woodburning	6	18	7	20	17		13
Sea Salt	0	0	1	0	0		0
Boilers	2	1	0	0	0		1
Sulphate	2	1	24	8	55		9
Nitrate	5	0	9	3	1		4
Carbon	19	15	11	0	12		11
NO2	5.01	5.01	5.01	5.01	5.01		5
Total	104.01	105.01	105.01	106.01	105.01		105
bext [Mm^-1]	217	156	337	163	121		218
Guguletu							
Date	22/08/96						
Crustal	0						
Diesel Vehicles	62						
Petrol Vehicles	5						
Woodburning	21						
Sea Salt	2						
Boilers	0						
Sulphate	5						
Nitrate	5						
Carbon	0						
NO2	5.01						
Total	105.01						
bext [Mm^-1]	301						

Tableview						
Date	14/07/95	14/07/95	18/08/95	27/05/96		
Crustal	2	2	1	2		
Diesel	38	43	12	40		
Petrol	11	12	8	13		
Wood	6	8	6	13		
Sea salt	1	0	2	4		
Boilers	28	9	65	13		
Unknown	14	25	6	14		
Total	100	100	100	100		
bext [Mm^-	182	196	203	110		
Drill Hall						
Date	14/07/95	25/07/95	16/02/96	30/04/96	05/08/96	27/05/96
Crustal	0	0	2	3	1	0
Diesel	66	34	51	16	58	55
Petrol	23	17	13	12	20	23
Wood	7	5	7	6	10	11
Sea salt	0	0	1	0	0	0
Boilers	3	31	15	41	9	8
Unknown	1	13	12	22	1	2
Total	100	100	100	100	100	100
bext [Mm^-	199	599	79	124	302	202
Goodwood						
Date	14/07/95	16/02/96	30/04/96	05/08/96	27/05/96	06/04/96
Crustal	0	2	4	0	1	1
Diesel	49	24	43	60	51	56
Petrol	16	14	16	16	25	23
Wood	8	24	10	8	11	5
Sea salt	0	5	0	1	0	1
Boilers	5	29	26	14	10	13
Unknown	21	2	2	1	1	1
Total	100	100	100	100	100	100
bext [Mm^-	391	45	157	298	261	168
Wynberg						
Date	14/07/95	14/07/95	25/07/95	05/08/96	30/04/96	
Crustal	0	1	1	2	8	
Diesel	50	49	35	48	8	
Petrol	19	15	21	22	10	
Wood	6	17	7	19	16	
Sea salt	0	0	1	0	0	
Boilers	6	3	22	8	45	
Unknown	19	15	12	1	13	
Total	100	100	100	100	100	
bext [Mm^-	217	156	337	163	121	
Guguletu						
Date	22/08/96					
Crustal	0					
Diesel	60					
Petrol	11					
Wood	20					
Sea salt	2					
Boilers	6					
Unknown	1					
Total	100					
bext [Mm^-	301					