Report on Ambient PM_{10} and $PM_{2.5}$ Estimates from Monitoring Stations Data

Compiled by:

Jongikhaya Witi
Department of Chemical Engineering
Cape Peninsula University of Technology
Bellville Campus, Bellville
Cape Town, South Africa

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1. Introduction

The aim of this report is to communicate all the methods and data sources used to estimate annual Particulate Matter (PM_{10} and $PM_{2.5}$) estimates. To date, five areas had (Cape Town, Johannesburg and surrounding areas, Ethekwini, Vaal Triangle and Rustenburg in North West have sufficient Particulate matter monitoring data. Except for some stations in Cape Town and Johannesburg, no other monitoring station was identified to have monitored $PM_{2.5}$. In the event of no $PM_{2.5}$ data, necessary assumptions were made to estimate $PM_{2.5}$ from PM_{10} by looking at the nature of the area surrounding the monitoring site. Data sources used to estimate PM ranged from hourly PM_{10} to monthly average PM_{10} concentration. In some cases, there was only one data point observed (i.e. one annual average PM_{10} concentration data point). The report also discusses the nature of each monitoring station as well as the date when some of the stations were commissioned. Therefore one can have an idea of which monitoring stations are currently in operation and which ones are not.

PM estimates from monitoring data are compared with GMAPS model outputs in Appendix A. From this comparison it is evident that the model's prediction of PM10 is extremely inaccurate in almost all the areas where monitoring data was available. With the model however, PM estimates are available for a significant number of urban areas compared to monitoring data which is available only for a limited number of urban areas. It is therefore suggested that model estimates be employed in those areas where monitoring data is unavailable particularly in areas with insignificant pollutant sources where the model predicts low values.

In an attempt to estimate population around each monitoring site, coordinates for each monitoring site have been provided in the appendices. The units of the coordinates are DD^{o}MM'SS" as well as in metres.

2. Cape Town

2.1 Air Pollution Monitoring Status in Cape Town

Cape Town currently has an ambient air quality monitoring network comprising 36 analysers distributed at various sites throughout the CCT. The parameters measured at each sampling site and the duration of the sampling record is indicated in table 2.1. In addition to the monitoring activities indicated in this table, "hot spot" monitoring have been initiated at Bellville and Kraaifontein during 2001 and hydrogen sulphide measurements are to be undertaken at Bothasig and Table View. For the purpose of "hot spot" monitoring the Air Pollution Control Section acquired a new mobile monitoring station fitted to monitor PM_{10}, NO_2, NO, NO_x, O_3, SO_2 and wind speed and direction.

PM represents the most significant criteria pollutant in terms of human health risk potentials within the City of Cape Town (CCT). Elevated PM_{10} concentrations occur over much of the CCT resulting in widespread health risks, with significant health effects anticipated in particular areas (e.g. Khayelitsha).

Table 2.1: Parameters recorded and duration of monitoring for CCT air quality monitoring network stations

Station Name:	Parameters Measured:	Initiation of Monitoring
Oxford Street, Goodwood	SO_2, O_3, NO, NO_2, NO_x	January 1994
	CO	June 1999
	PM10	March 1995
	Wind speed, wind direction	October 1999
City Centre (Darling Street, Drill Hall sites)	SO_2, NO, NO_2, NO_x	January 1985
	PM10	March 1995
	CO	June 1999
	Wind speed, wind direction	November 1995
Bothasig	SO_2, NO, NO_2, NO_x	January 1995

	PM10	May 1995 (to September 1999)
Molteno Reservoir, Oranjezicht	Ozone	June 1992
Khayelitsha	PM10 SO_2	March 1999 Monitoring initiated early 2001
Circle Road, Table View	Wind direction, wind speed, NO, NO_2, NO_x, PM10, SO_2	November 1994
Mobile Station - "Hot Spot" Monitoring Plattekloof Reservoir, Plattekloof (moved to Kilarney, January 2001)	SO_2	1993 - 1994 Jan to Dec 2000

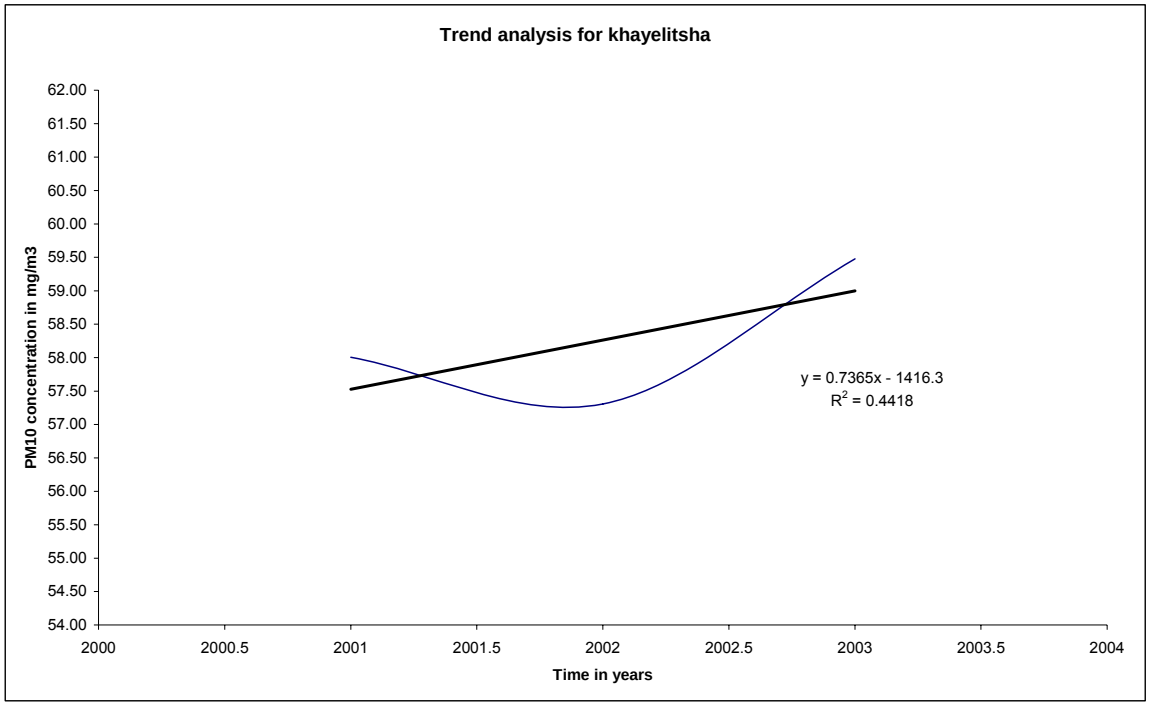
2.2 Identified Monitoring Stations

2.2.1 Khayelitsha Monitoring station

Khayelitsha monitoring station is based in a residential area. Pollutant sources around this area range from fugitive dust, vehicle emission, wood burning as well as influence from areas outside areas.

Information was obtained on PM_{10} concentration data for a period of three years [2001-2003]. This data was presented in terms of hourly averages for each day of the year for the complete period given above. From this data it was then possible to compute daily averages and monthly averages. The annual PM_{10} concentration for each year was then computed from the monthly averages. This meant that seasonal variations in PM_{10} concentrations were taken into consideration. In this way, three data points of annual PM_{10} concentration [$PM_{10, 2001}$, $PM_{10, 2002}$, $PM_{10, 2003}$] were obtained].

Figure 2.1:PM_{10} estimate using regression analysis [Khayelitsha]



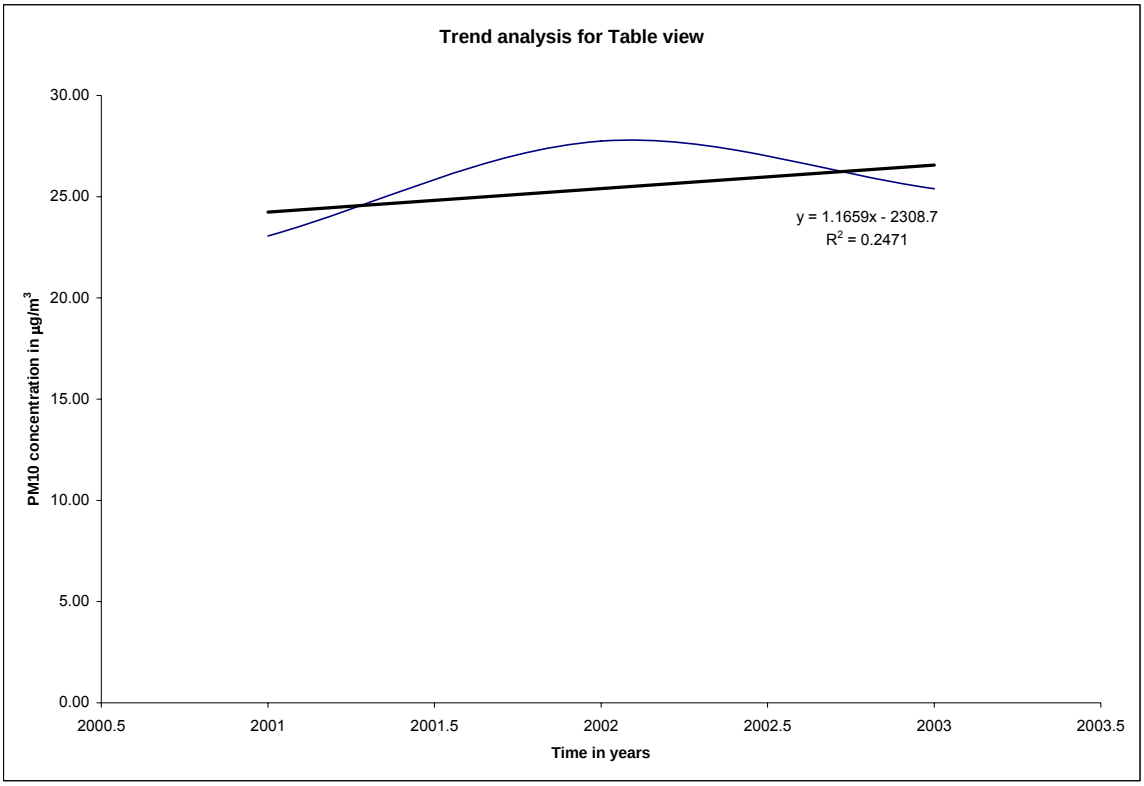
A linear regression model was fitted to the raw annual data observed for the 2003-2004 period in effort to estimate annual average concentration for the year 2000. From figure 2.1 it is observed that only 44% of variability in PM_{10} concentration could be explained by independent variable, in this case time in years. This suggests a poor relationship between the independent and the dependent variable. Working with three data points meant that it was meaningless to use regression diagnostic techniques to remove outliers. Also observed is the insignificant change in PM_{10} concentration [59.5 $\mu g/m^3$ for 2003 and 56.7$\mu g/m^3$ for 2000] even though there is an outlier. Therefore, from regression analysis, the PM_{10} annual average concentration was observed to be 56.76$\mu g/m^3$.

2.2.2 City Centre Monitoring Station

The city centre monitoring station is situated at the Cape Town city hall. It is situated in a commercial area with a significant vehicle density. There is quite a less significant population around the monitoring station (mostly flats).

Information was obtained on PM_{10} concentration data for a period of three years [2001-2003]. This data was presented in terms of hourly averages for each day of the year for the complete period given above. From this data it was then possible to compute daily averages and monthly averages. The annual PM_{10} concentration for each year was then computed from the monthly averages. This meant that seasonal variations in PM_{10} concentrations were taken into consideration. In this way, three data points of annual PM_{10} concentration [$PM_{10,\ 2001}$, $PM_{10,\ 2002}$, $PM_{10,\ 2003}$] were obtained].

Figure 2.2: PM_{10} estimates from regression analysis [City Centre]



Linear regression model was fitted to PM_{10} annual average concentration data for the period [2001-2003]. Basic summary statistics provided a regression coefficient of 0.24 which meant that only 24% variation in PM_{10} concentration could be explained by the independent variable. However, differences in the dependent variable were insignificant [25.39$\mu g/m^3$ for 2003 and 23.1 $\mu g/m^3$ for 2000] to perform any regression diagnostics. The projected annual average PM_{10} concentration for City Centre was found to be 23.1$\mu g/m^3$.

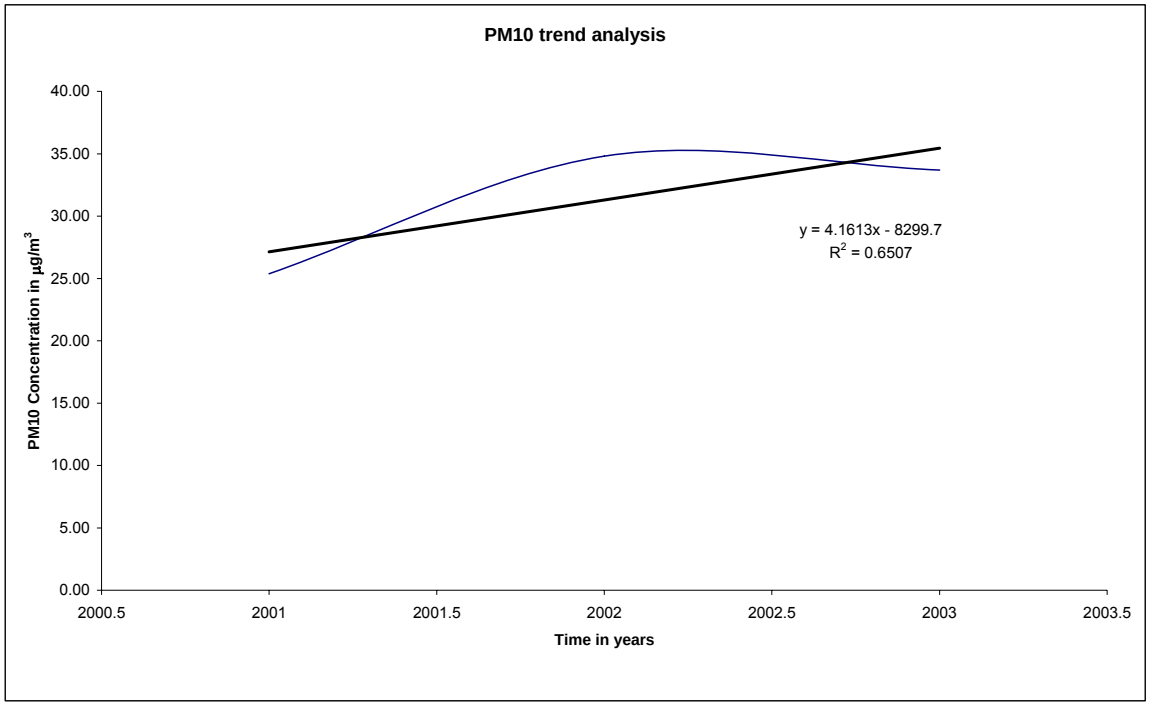
2.2.3 Tableview Monitoring Station

Tableview monitoring station is located in a residential area next to an infrequently used road. It is about one kilometre from the sea and is about two kilometres on the prevailing wind side (north-west) of a large refinery (caltex) and a fertiliser factory (Kynoch). PM monitoring is done using a TEOM (Tapered Element Oscillating Microbalance) PM_{10} continuous monitor.

This continuous sample is capable of sampling PM_{10} from small to large time intervals. Typically, TEOM sample time intervals range from five minutes to 1day. In most cases, air quality scientists are concerned with hourly changes in air pollution concentrations. Thus, all monitoring stations tend to sample air pollutants on hourly basis. This also lowers storage pace required for storing air pollution data and makes data analysis less difficult to achieve.

Information was obtained on PM_{10} concentration data for a period of three years [2001-2003]. This data was presented in terms of hourly averages for each day of the year for the complete period given above. From this data it was then possible to compute daily averages and monthly averages. The annual PM_{10} concentration for each year was then computed from the monthly averages. This meant that seasonal variations in PM_{10} concentrations were taken into consideration. In this way, three data points of annual PM_{10} concentration [$PM_{10,\ 2001}$, $PM_{10,\ 2002}$, $PM_{10,\ 2003}$] were obtained].

Figure 2.3: PM_{10} estimates from regression analysis [Tableview]



A linear regression model fitted on PM_{10} annual concentration raw data provided a regression coefficient of 0.65. This meant that the model could explain 65 % of variation in the dependent variable. Since this is observed to be a reasonable explanation of the dependent variable, the regression model was used to extrapolate PM_{10} concentration for the year 2000. Results from the model suggested an annual PM_{10} concentration of 22.9µg/m^3 for the year 2000.

2.2.4 Goodwood monitoring Station

Goodwood monitoring station is situated in a residential area. Air pollution levels observed at this monitoring site are mainly due to external sources originating from surrounding areas (e.g. Milnerton, Parow and Epping industries) as well as from aeroplane emissions.

PM_{10} data received for Goodwood station was presented in hourly average concentrations for the complete period of 2000. This meant that the data was available by hour by day and by month. Daily average PM_{10} concentrations were then computed from hourly averages. Monthly averages were in turn

computed from daily averages. Eventually the annual average was computed from the monthly averages. This approach ensures that seasonal variations in the concentration of PM_{10} are taken into consideration when computing the annual average. From this exercise, a final estimate of the annual PM_{10} for the year 2000 was computed to be 34.69$\mu g/m^3$.

2.2.5 Bellville South monitoring Station

Bellville South monitoring station is situated in a mix of industrial and residential area. PM_{10} sources in the vicinity of this monitoring site include fugitive emissions from sewage treatment plant as well as from a landfill site, combustion emissions from Console glass and vehicle sources including Thompson boilers.

Table 2.2: Annual PM_{10} concentration estimates for the year 2000

Station	Estimated Annual PM_{10} concentration	Regression coefficient	GMAPS - estimates
Khayelitsha[1]	56.76 $\mu g/m^3$	0.44	10 $\mu g/m^3$
City Centre[1]	23.10 $\mu g/m^3$	0.24	12 $\mu g/m^3$
Tableview[1]	22.90 $\mu g/m^3$	0.65	NA
Goodwood[1]	34.69 $\mu g/m^3$	NA	NA
Bellville South[2]	33.02 $\mu g/m^3$	NA	NA

[1] Data obtained from Scientific Services [Athlone, Cape Town]

[2] Data obtained Yvonne Scorgie report on Air Pollution Impact Assessment Study

NA: Not Available

2.3 Estimating $PM_{2.5}$ from PM_{10} for Cape Town stations

Less frequent or no monitoring of $PM_{2.5}$ has resulted in limited data availability on $PM_{2.5}$. A local study called Brown Haze study conducted in the year 1997 did attempt to compute what is referred to as $PM_{2.5}/PM_{10}$ ratio for each monitoring station. This ratio simply indicates what proportion of PM_{10} is made up of $PM_{2.5}$.

$PM_{2.5}$ is associated with emissions from combustion sources, so a high $PM_{2.5}$:PM_{10} ratio indicates that a large proportion of the ambient PM_{10} is due to contributions from combustion sources. Results of this ratio from the Brown Haze study are presented in the table below.

In a risk assessment study conducted by Cohen et al, $PM_{2.5}$: was estimated from PM_{10} by looking at the nature of the area of concern. In this study a base case ratio estimate of 0.5 was selected and maximum ratio of 0.65 was allowed. This $PM_{2.5}$:PM_{10} ratio range was motivated by the fact that in many studies conducted in urban areas in industrialized nations it was observed that this ratio fluctuates around that range. Evidence from data outside of the industrialized nations suggests similar range for the ratio. For example, a recent study from china reported ratios in the range of 0.51-0.72 for four urban locations.

Table 2.3: PM2.5:PM10 ratios for selected PM10 monitoring sites

Sampling Site	Mean PM2.5:PM10	Standard Deviation
City Centre	0.60	0.21
Tableview	0.57	0.14
Goodwood	0.59	0.17
Cape Town Average	0.59	0.02

[Table adapted from Brown Haze I study, 1997: Dutkiewicz et al]

These ratios were computed for the (July 1995 – July 1996) annual period. Khayelitsha was not included in the estimation of this ratio.

2.3.1 Khayelitsha

Even though there has been occasional monitoring of PM2.5 in Khayelitsha, we could not get any data on that from the scientific services, which is responsible for the entire air quality monitoring network in Cape Town. In estimating the PM2.5:PM10 ratio, we had to rely on the estimates from Cohen et al study.

The chosen PM2.5:PM10 ratio range was used to set lower and upper limits and the Cape Town average ratio from the Brown Haze study was then used as measure of central tendency.

Table 2.4: Summary of $PM_{2.5}$ estimates for Cape Town Monitoring sites

Monitoring Station	**$PM_{2.5}$ estimate at a mean $PM_{2.5}$:PM_{10} = 0.59)**	**Lower limit ($PM_{2.5}$:PM_{10} =0.5)**	**Upper Limit ($PM_{2.5}$:PM_{10} =0.65)**
Khayelitsha	33.49 μg/m^3	28.38 μg/m^3	36.89μg/m^3
City Centre	13.63 μg/m^3	11.50 μg/m^3	15.02 μg/m^3
Tableview	13.51 μg/m^3	11.45 μg/m^3	14.89 μg/m^3
Goodwood	20.47 μg/m^3	17.35 μg/m^3	22.55 μg/m^3
Bellville South	19.48 μg/m^3	16.51 μg/m^3	21.46 μg/m^3

3. Joburg and Surrounding areas

3.1 Air Pollution Monitoring Status in Johannesburg

In the analysis of ambient air quality monitoring data, Scorgie *et al.* (2003) made use of all data to which a reasonable level of accuracy could be attached. Reference was made to data from monitoring campaigns, discontinued sites and currently operating stations. Data were obtained from a wide range of data generators. A list of the data generators and sampling stations for which results are presented in this section is given in table 3.1. It should be noted that this list does not reflect all the monitoring activity currently within the City. Several other monitoring stations have recently been brought on-line (e.g. Particulate and sulphur dioxide monitoring at Ivory Park and Diepsloot Clinic), but the status of

such sites is such that the sampling equipment either had not been calibrated or their results verified or the data made available during the Baseline Assessment.

Table 3.1: Parameters recorded and duration of monitoring for Joburg air quality monitoring network stations

Network Name and Contact Person	Site Name(s)	Pollutants Measured	Date of Commissioning	Current Status
Airkem Eastrand Ellen van Dongen (AEC Modderfontein) Tel: (011) 608 2846 Cell: 082 813 9611	Esterpark (Modderfontein)	NH_3	August 1991	Operational
		NH_x		
		NO		
		NO_2		
		NO_3		
		NO_x		
		SO_2		
	Illiondale	NO	November 1991	Decommissioned in 1993 due to low concentrations being recorded
		NO_2		
		NO_x		
		PM10		
		SO_2		
	Rhodesfield	NO	October 1991	Decommissioned in 1993 due to low concentrations being recorded
		NO_2		
		NO_x		
		PM10		
		SO_2		
	Tembisa (Kempton Park)	PM	1996	Operational
	Ivory Park (Midrand)	PM	1996	Operational
Smoke and SO_2 Sampling - Previously funded by DEAT with monitoring undertaken by Local Authorities (Environmental Health Dept.s) - DEAT funds ended	City Hall (C)	Smoke	1975	prior to 1995
	Fordsburg (I)			Dec-99
	Wemmer			Dec-99
	Marlboro (I)			Mar-96
	Bryanston (R)			prior to 1995
	Alexandra (R)			prior to 1995
	Bedfordview (R)			Sep-95
	Randjespark			Mar-00
	Clayville			Mar-00
	Rabie Ridge			Mar-00
	Blairgowrie (R)			Operational

Network Name and Contact Person	Site Name(s)	Pollutants Measured	Date of Commissioning	Current Status
1999 - Sampling continues at selected sites by Local Authorities (Environmental Health Dept.s within Regions)	Malanshof (I.R)			Operational
	Randparkrif (R)			Mar-00
	Jukskei Park (I/R)			Mar-00
	Zandspruit Informal Settlement (R)			May-97
	Roodepoort CBD (C)			Jun-97
	Florida (R)			Dec-95
	Weltevredenpark (R)			Oct-97
	Wilropark (R)			Sep-97
	Langlaagte		2002	Operational
Mintek On-going Sampling Mr Swanepoel Mintek Tel: (011)709 4748	Gatehouse - Randburg	TSP	1996	Operational
		PM10	1996	Operational
		PM2.5	1998	Operational
DEAT Lead Monitoring Project	Lead Johannesburg	Pb	January 1987	Discontinued in 1999

Network Name and Contact Person	Site Name(s)	Pollutants Measured	Date of Commissioning	Current Status
Johannesburg Monitoring Network (Environmental Management Dept.)	City Hall, JHBurg	CH_4	January 1982	Not operational (Decommissioned during April 1994)
		CO		
		NHC		
		NO		
		NO_2		
		NO_x		
		O_3		
	New Town	CO	April 1992	Not operational (Decommissioned during November 1999)
		NO		
		NO_2		
		NO_x		
		PM10		
		O_3		
	South Hills	CH_4	July 1984	Not operational

Network Name and Contact Person	Site Name(s)	Pollutants Measured	Date of Commissioning	Current Status
		CO		(Decommissioned during November 1999)
		NHC		
		NO		
		NO_2		
		NO_x		
		O_3		
Soweto Air Monitoring (SAM) Project Soweto Health Dept.	Diepkloof	PM	1992	Operational
	Tladi	PM		Operational
	Jabavu	PM		Operational (Decommissioned for 1996)
	Chiawelo	PM		Operational
	Orlando	PM		Operational
	Dhlamini	PM		Decommissioned in 1996
	Meadowlands	PM		Decommissioned, April 1994
	Zondi	PM		Decommissioned, April 1994
	Pimville	PM		Decommissioned, April 1994
	JK Motors	PM	1994	Decommissioned, Dec 1998
	Vista	PM		Decommissioned, Dec 1998
Soweto Air Monitoring Campaign by Eskom TSI Eric Lynch, Eskom TSI Tel: (011) 629 5111	Dhlamini	NO NO_2 NO_x O_3 FPM SO_2	January 1987	Sampling campaign ended in December 1993
	Shanty Clinic	NO NO_2 NO_x O_3 FPM SO_2	January 1983	Sampling campaign ended in December 1983
VOC Sampling Campaign in Johannesburg by CSIR	26 sampling sites throughout JHB(2)	VOCs	9 Sept 1998	21 Oct 1998 (6 week sampling campaign)

Notes:

(1)Indicates whether sites are in (R) rural, (I) industrial, (C) commercial areas

(2)Sampling sites: Sandton, Alexandra, Kew, Highlands North, Zoo, Hillbrow, City Centre, City Hall, Bus Terminal, Selby, City Centre, Harrow Rd, City Deep, Geldenhuis Intersection, Bezuidenhoudts Valley, Cleveland, Crown Intersection, Duplicate of 17, Mayfair, Industria, Soweto, and Northcliff.

3.2 Identified Monitoring stations

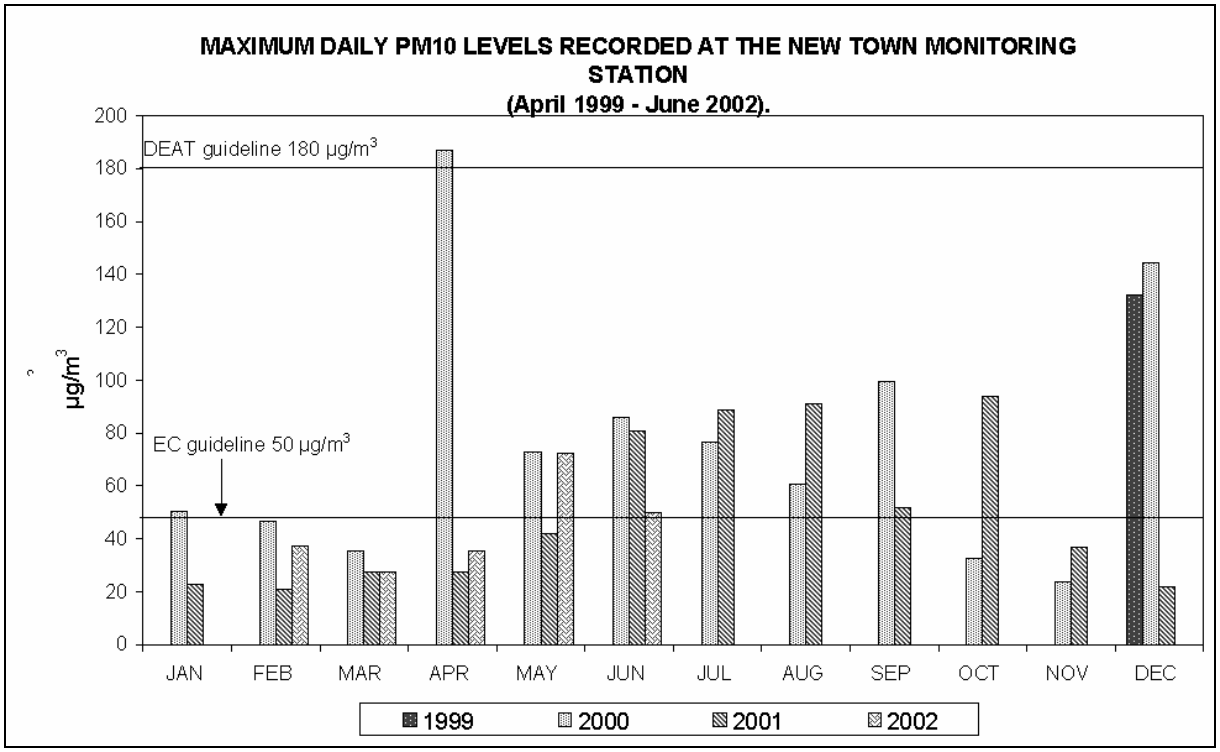
3.2.1 Johannesburg City

3.2.1.1 New Town Monitoring Station

PM_{10} monitoring at New Town monitoring station started in December 1999. This station is situated in the Johannesburg CBD at 271 Main Road. Sources of particulate matter in the vicinity of the monitoring station include the industrial suburbs, such as Selby located to the southeast of the site, and Johannesburg station to the north. Residential settlements to the west of the station include Mayfair and Fordsburg, with the Johannesburg CBD being located to the east. Residential suburbs in the vicinity of the site are electrified. Based on the location of this monitoring station, results recorded should be representative of semi-industrial background PM_{10} levels.

PM_{10} levels recorded at the New Town monitoring station exceeded the South African guideline (180 mg/m3) only once, during April 2000. Exceedances of the EC guideline for maximum daily concentrations (50μg/m3) were recorded more frequently, occurring 6.9% of the time. An annual average PM_{10} concentration of 61.10μg/m^3 for the year 2000 was observed for New Town monitoring station. This data was available from Yvonne Scorgie report on air quality assessment.

Figure 3.1: Daily PM_{10} readings for New Town monitoring station [1999-2002]



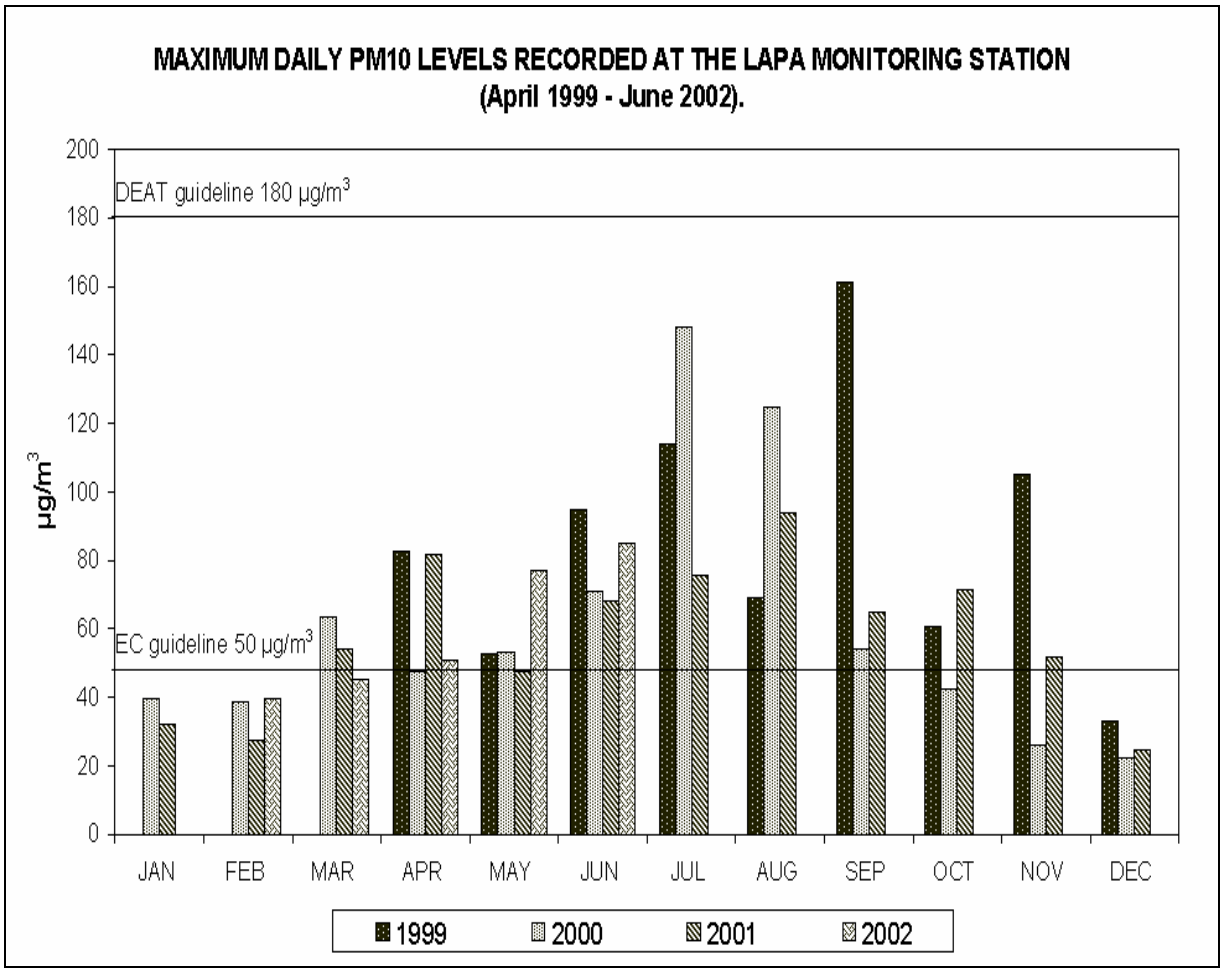
[Graph adapted from the Fridge study conducted by Scorgie et al, 2003]

3.2.1.2 Lapa Monitoring Station

The Lapa monitoring station, recording PM_{10}, was commissioned by the City of Johannesburg's Department of Environmental Management in April 1999 and is operated by the personnel of this department. The site is located in the south of Johannesburg north and northwest of the residential settlements, La Rochelle and Turfontein respectively. Sources of particulate matter in the vicinity of the monitoring station include industries within the Ophirton and Booysens industrial areas located to the west of the site and Selby situated to the northwest. Given that the residential settlements located to the south and southeast of the monitoring site are electrified, PM_{10} data recorded at this station can be considered to be representative of the PM_{10} levels typical of non-coal burning residential areas located in close proximity to industrial operations.

Maximum daily PM_{10} levels recorded at the Lapa monitoring station, between April 1999 and June 2002; do not exceed the South African guideline of 180μg/m^3. However, the EC guideline of 50μg/m^3 is frequently exceeded during the monitoring period (9.6% of the time). From Yvonne Scorgie report on air quality impact assessment, an annual average PM_{10} concentration of 45μg/m^3 for the year 2000 was observed for this monitoring station.

Figure 3.2: Daily PM_{10} readings for Lapa monitoring station [1999-2002]



[Graph adapted from the Fridge study conducted by Scorgie et al, 2003]

3.2.2 Soweto

3.2.2.1 Jabavu Monitoring Station

Jabavu monitoring station is situated in Soweto. It is located in a residential area of Zola. Major PM_{10} sources include combustion emissions from coal and wood burning. Combustion products from vehicle emissions in the nearby national road (N1) also contribute to PM_{10} formation in this area.

PM_{10} data received from the City of Joburg was only for the year 2004. The data was presented in daily average concentrations of PM_{10}. Monthly average PM_{10} were then computed from the daily average concentration. From the monthly average concentrations, annual PM_{10} concentration was computed for the 2004 year period.

This data point was projected back to the year 2000 annual PM_{10} concentration by assuming that there is little or no change in the annual average concentration of PM_{10} in Jabavu for the past four years. This back-projection had to be done in this way, since only one data point was observed for the Jabavu station. As more data is available, more meaningful approximation of PM_{10} annual average concentrations for this station would be possible. Therefore the annual average concentration of PM_{10} for the year 2000 at the Jabavu station was assumed to be $50.02 \mu g/m^3$.

3.2.3 East rand

3.2.3.1 Alexandra station

Recently, extensive ambient air quality monitoring was initiated in Alexandra as part of the Alexandra Renewal Project by the City of Johannesburg. CO, PM_{10}, O_3, SO_2, and NO_2 are measured at the Alexandra sampling station. PM_{10} is measured using beta gauge.

Alexandra station data from 13 April to 10 September 2002 were made available for analysis during the FRIDGE study baseline study. It was observed that the SA guideline for PM_{10} was exceeded on only 1 day during the 148 days for which monitoring was undertaken. The EC limit value for highest daily PM_{10} concentrations was however noted to have exceeded on 64 days, i.e. 43% of the time. Yvonne Scorgie performed further analysis on 2003 data to obtain an annual average PM_{10} concentration of 44$\mu g/m^3$ for that year. This data point was projected back to the year 2000 annual PM_{10} concentration by assuming that there is little or no change in the annual average concentration of PM_{10} in Alexandra for the past four years. This back-projection had to be done in this way, since only one data point was observed for the Alexandra station. As more data is available, more meaningful approximation of PM_{10} annual average concentrations for this station would be possible. Therefore the annual average concentration of PM_{10} for the year 2000 at the Alexandra station was assumed to be 44$\mu g/m^3$.

3.2.3.1 Buccleuch station

PM_{10} data received from the City of Joburg was only for the year 2004. The data was presented in daily average concentrations of PM_{10}. Monthly average PM10 were then computed from the daily average concentration. From the monthly average concentrations, annual PM_{10} concentration was computed for the 2004 year period.

This data point was projected back to the year 2000 annual PM_{10} concentration by assuming that there is little or no change in the annual average concentration of PM_{10} in Buccleuch for the past four years. This back-projection had to be done in this way, since only one data point was observed for the Buccleuch station. As more data is available, more meaningful approximation of PM_{10} annual average concentrations for this station would be possible. Therefore the

annual average concentration of PM_{10} for the year 2000 at the Buccleuch station was assumed to be 55.25$\mu g/m^3$.

3.2.4 Randburg

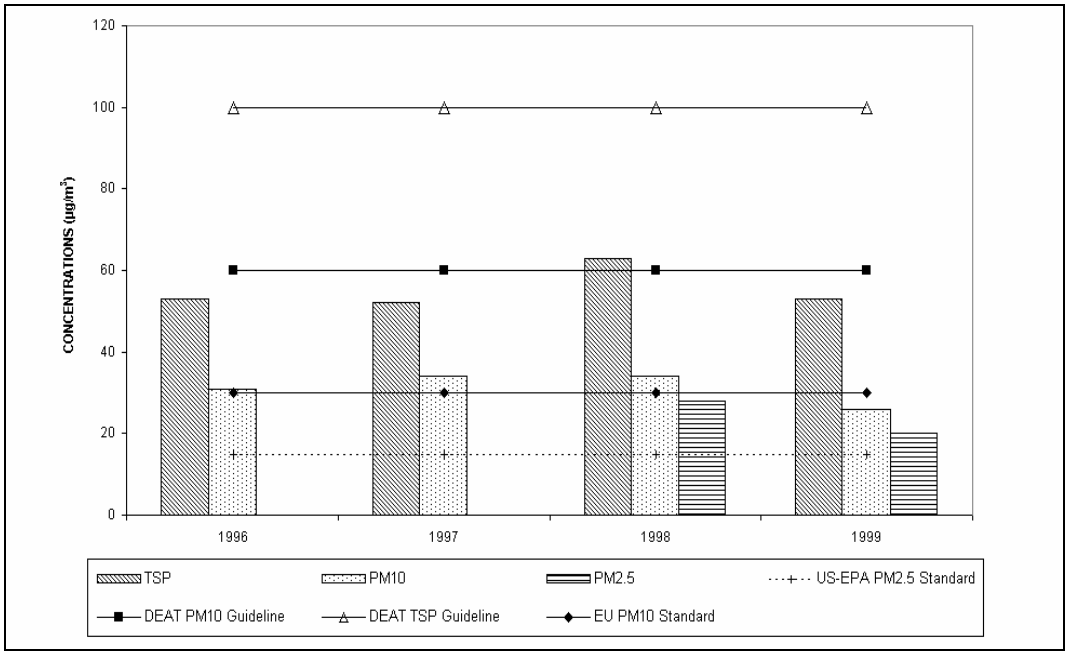
3.2.4.1 Mintek Monitoring Station

Mintek station is situated at Strydom Park. This station monitors TSP (total suspended particulates) and PM_{10}. PM_{10} concentrations recorded by Mintek in Randburg provide a good indication of the particulate levels within the non-domestic coal burning areas of the Johannesburg Metropolitan.

An annual average PM_{10} concentration of 46$\mu g/m^3$ for the year 2000 was observed for this station courtesy of Yvonne Scorgie data on air quality impact assessment.

$PM_{2.5}$ monitoring was also conducted at this station and an annual $PM_{2.5}$ concentration was found to be 26$\mu g/m^3$ for the year 1999. On assuming that $PM_{2.5}$ concentration for Mintek station remained constant between 1999 and 2000, a PM2.5:PM10 ratio of 0.57 was observed. These results are shown in figure 3.3 below. Data analysis done on particulate matter monitoring at Mintek stretches back to the period 1996-1999. It is observed from figure 3.3 that the annual average concentrations for PM_{10} remained fairly constant for the year period between 1996 and 1999 floating around the EU PM_{10} Standard of 30$\mu g/m^3$. $PM_{2.5}$ declined from a value of 29$\mu g/m^3$ in 1998 to a figure of 26$\mu g/m^3$ in 1999.

Figure 3.3: Mean Annual PM_{10} and $PM_{2.5}$ concentrations at the Mintek monitoring site [1996-1999]



[Graph adapted from the Fridge study conducted by Scorgie et al, 2003]

3.2.5 Kempton Park

3.2.5.1 Ester park monitoring station

Kempton Park started measuring PM_{10} in January 2000. It is situated approximately 5.85 km north west of Johannesburg International Airport. Although this site just falls outside of the borders of the City of Johannesburg, data from this site is able to provide an indication of the levels of particulates likely to occur in the eastern non-coal burning suburbs of the city.

Maximum daily average PM_{10} concentrations recorded during 2000 and 2001 were 161$\mu g/m^3$ and 133$\mu g/m^3$ respectively. Although no exceedances of the current DEAT guidelines were recorded to have occurred, the EC limit value of 50 was exceeded for 28% of the time. Annual average concentrations of 42$\mu g/m^3$ for 2000 and 37$\mu g/m^3$ for 2001 were observed to exceed the EC limit value of 30$\mu g/m^3$.

Table 3.2: Summary of PM_{10} estimates for Joburg and surrounding areas

Johannesburg	
Newtown	61.10μg/m^3
Lapa	45.00 μg/m^3
Soweto	
Jabavu	50.02 μg/m^3
Greater Alexandra	
Alexandra	44.00μg/m^3
Buccleuch	55.25μg/m^3
Randburg	
Mintek	46μg/m^3
Kempton Park	
Ester park	42μg/m^3

3.3 Estimating $PM_{2.5}$ from PM_{10} for Johannesburg stations

Various stations have attempted to measure PM2.5 concurrent to PM10 measurement. The Mintek monitoring station for example measured PM2.5 in 1999along with PM10. From estimates of annual PM_{10} and $PM_{2.5}$, a mean $PM_{2.5}$:PM_{10} ratio of 0.57 was observed. This ratio is similar to that found for cape town (0.59).

Table 3.3: Summary of $PM_{2.5}$ estimates for Joburg Monitoring sites

Monitoring Station	$PM_{2.5}$ estimate at a mean $PM_{2.5}$:PM_{10} = 0.57)	Lower limit ($PM_{2.5}$:PM_{10} =0.5)	Upper Limit ($PM_{2.5}$:PM_{10} =0.65)
New Town	35.23 μg/m^3	30.90 μg/m^3	40.17 μg/m^3
Lapa	25.71 μg/m^3	22.55 μg/m^3	29.32 μg/m^3
Jabavu	28.51 μg/m^3	25.01 μg/m^3	32.51 μg/m^3
Alexandra	35.85 μg/m^3	31.45 μg/m^3	40.89 μg/m^3
Buccleuch	31.49 μg/m^3	27.63 μg/m^3	35.91 μg/m^3
Mintek	26.22 μg/m^3	23.00 μg/m^3	29.90 μg/m^3
Ester park	24.78 μg/m^3	21.00 μg/m^3	27.30 μg/m^3

4. Ethekwini and Surrounding Areas

4.1 Monitoring Status in Ethekwini

The Ethekwini Municipality established a modern air quality monitoring network in the South Durban Basin in December 2003. The basin is located on the eastern seaboard of South Africa and has a mix of heavy industrial activity and residential settlements in close proximity. In response to many decades of struggle for cleaner air, an inter-governmental process established the air quality monitoring network as one of many strategic projects within the Multi-point Plan for the basin. The plan is aimed at improving air quality to meet health based standards. The main objective of the network is to provide a quantitative measure of air quality, measure compliance with air quality standards and provide a means of verification for dispersion models. The network was designed by an expert team from the Ethekwini Health Department under the technical guidance of NILU, the Norwegian Institute for Air Research.

The air quality monitoring network, whilst primarily focused in the South Durban basin, also extends into the city centre and three background sites. Each of the stations measures a range of pollutant and meteorological parameters in five minute averages. The two main sources of air pollution that the network aims to target are industrial and traffic pollution. The pollutants measured include sulphur dioxide, total reduced sulphur, oxides of nitrogen, particulate matter (PM_{10}), ozone and carbon monoxide. The network incorporates the latest technology in continuous air quality monitoring. The network currently consists of twelve air monitoring stations and six meteorological stations. The three background stations are located at Alverstone, Congella and Prospecton. The network is dynamic in nature as new stations could be added and obsolete stations removed.

4.1.1 Ganges Monitoring Station

The Ganges station is located in the grounds of the Ganges Secondary School, Jammu Road, Merebank, along the Southern Freeway, northbound. The elevation of the station is 20 m above sea level. The station is representative of a suburban traffic zone. The station location was selected to obtain information on the levels of NO_2 and PM_{10} from traffic and SO_2 from the medium and small scale industries in the Merebank, Mobeni and Jacobs areas.

4.1.2 King Edward Monitoring Station

The station is located at the King Edward Hospital, Sydney Road, Congella, adjacent to the Medical Centre, at an elevation of 23 m above sea level. It is representative of an urban background and the measurements recorded here would indicate the type and levels of pollutants that could enter the valley. The pollutant parameters measured here are $NO/NO_2/NO_x$ and PM_{10}. A bubbler was recently installed to measure SO_2 over 3 to 4 day averaging periods.

4.1.3 City Hall Monitoring Station

The station is located in the City Hall parking area at an elevation of 5m above sea level. It represents urban traffic and was selected to quantify traffic pollutants in the CBD. The pollutants measured at the station are $NO/NO_2/NO_x$ and PM_{10}. The measurement of SO_2 at the station was terminated after it was found that SO_2 levels were relatively low and there was a greater need to measure TRS at Southern Works with the analyser.

4.1.4 Settlers Monitoring Station

This station is located Settlers School, 98 Lakhimpur Road, Merebank, on the valley floor and represents an urban industrial environment. The elevation of the stations is 23 m above sea level. It was selected to record concentrations from stack emissions and ground level emissions from Engen and Mondi. It also represents concentrations within immediate residential area of Merebank. The pollutant parameters measured at the station are SO_2 and TRS.

4.1.5 Wentworth Monitoring Station

The Wentworth station is located at the Wentworth Reservoir, Boston Road, near the Wentworth Hospital. Its elevation above sea level is 78 m and it is representative of a residential environment. The major impacts that the stations quantifies are those related to industrial pollution from Merbank, Jacobs, Mobeni and Clairwood. This is an existing site from the old network that has been upgraded with new equipment and a new meteorological tower. The parameters measured at the station are SO_2, $NO/NO_2/NO_x$, PM_{10}, O_3, wind speed, wind direction, ambient temperature, delta temperature and barometric pressure.

4.1.6 Ferndale Monitoring Station

Ferndale is located in the north of Durban. It is situated in and around a residential area as well as a commercial area. The site is very close to the N3 (National road) which has a high vehicle density. Therefore, it can be safely assumed that the major contributors to PM_{10} levels in the vicinity of this site are the mobile sources.

4.2 Data Analysis for Ethekwini

PM_{10} data received from the Ethekwini Municipality was only available for the 2004 year period. In the past there has been monitoring in Ethekwini and surrounding areas, however monitoring was not performed on continuous basis, therefore no data could be retrieved for the years prior to 2004. Also comparisons have not been made with previous years' data as the quality control systems and procedures utilised in the management of data and equipment of the older networks do not meet current standard

Once again, due to one data point observed in all the monitoring stations, back-projection to the year 2000 based on assumption that there is little or no change in the annual average concentration of PM_{10} in all the stations for the past four years had to be done. As more data is available, more meaningful approximation of PM_{10} annual average concentrations for this station would be possible.

Table 4.1: A summary table of PM_{10} estimates for Ethekwini

Station	Annual Average ($\mu g/m^3$)	24-Hour MAX. ($\mu g/m^3$)	24-Hour Exceedances
Wentworth	39.1	143.1	27
Ganges	46.4	179.3	36
City Hall	38.1	159.7	21
King Edward	37.6	162.2	21
Ferndale	39.7	145.9	18
Settlers school	40.0	NA	NA

Notes; NA: Not Available

4.3 Estimating $PM_{2.5}$ from PM_{10} for Ethekwini stations

No data could be obtained on $PM_{2.5}$ for all the stations in Ethekwini. In fact, the 2004 annual report released this year, described all the monitoring stations as well as all the air pollutants that are measured in each stations. No single station could be identified that measures $PM_{2.5}$. In an attempt to estimate PM2.5 from PM10, Ethekwini is analysed to make sound assumptions concerning its sources as well its comparison against other industrialised cities in the country. Ethekwini consist of many air pollution sources such as those described for each monitoring station and are industry intensive. Looking at the sources of air pollutants as well as the data from the monitoring sites, Ethekwini can be reasonable compared to Cape Town. This implies that we may observe a similar range of $PM_{2.5}$:PM_{10} ratios in Ethekwini as that we observe in Cape Town. Therefore a mean $PM_{2.5}$:PM_{10} ratio of 0.59 is chosen and a range of 0.5 to 0.65 is selected on the basis that Ethekwini is an industrialised city. The analysis of $PM_{2.5}$ estimates from PM_{10} data are presented in the table below.

Table 4.2: Summary of $PM_{2.5}$ estimates for Ethekwini stations

Monitoring Station	$PM_{2.5}$ estimate at a mean $PM_{2.5}$:PM_{10} = 0.59)	Lower limit ($PM_{2.5}$:PM_{10} =0.5)	Upper Limit ($PM_{2.5}$:PM_{10} =0.65)
Ganges	27.38μg/m^3	23.20μg/m^3	30.16μg/m^3
Wentworth	23.07μg/m^3	19.55μg/m^3	25.42μg/m^3
City Hall	22.48μg/m^3	19.05μg/m^3	24.77μg/m^3
King Edward	22.18μg/m^3	18.8μg/m^3	24.44μg/m^3
Settlers	23.60μg/m^3	20μg/m^3	26.00μg/m^3
Ferndale	23.42μg/m^3	. 19.85μg/m^3	. 25.81μg/m^3

5. Vaal Triangle

5.1 Air Pollution Situation in the Vaal

Elevate levels of airborne particulates are known to occur over the Vaal Triangle. The quantification of particulates, particularly within the inhalable fractions, has formed the focus of various past campaigns and is currently the aim of certain on-going monitoring efforts.

5.2 Identified Monitoring Stations

5.2.1 Sasolburg Industrial Monitoring Station

Industrial activity in Sasolburg consists of metallurgical, petrochemical (Sasol and Natref), chemical (Sasol, Karbochem and Sasol Polymers), and power generation (Letabo Power Station, southeast of Sasolburg). Although attempts have been made by some industries to quantify their air pollution emission rates, these remain focussed around criteria pollutants only, i.e. sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and particulate matter (PM). Individual industry-wide estimates of volatile organic compounds (VOCs) have also been made, but lack

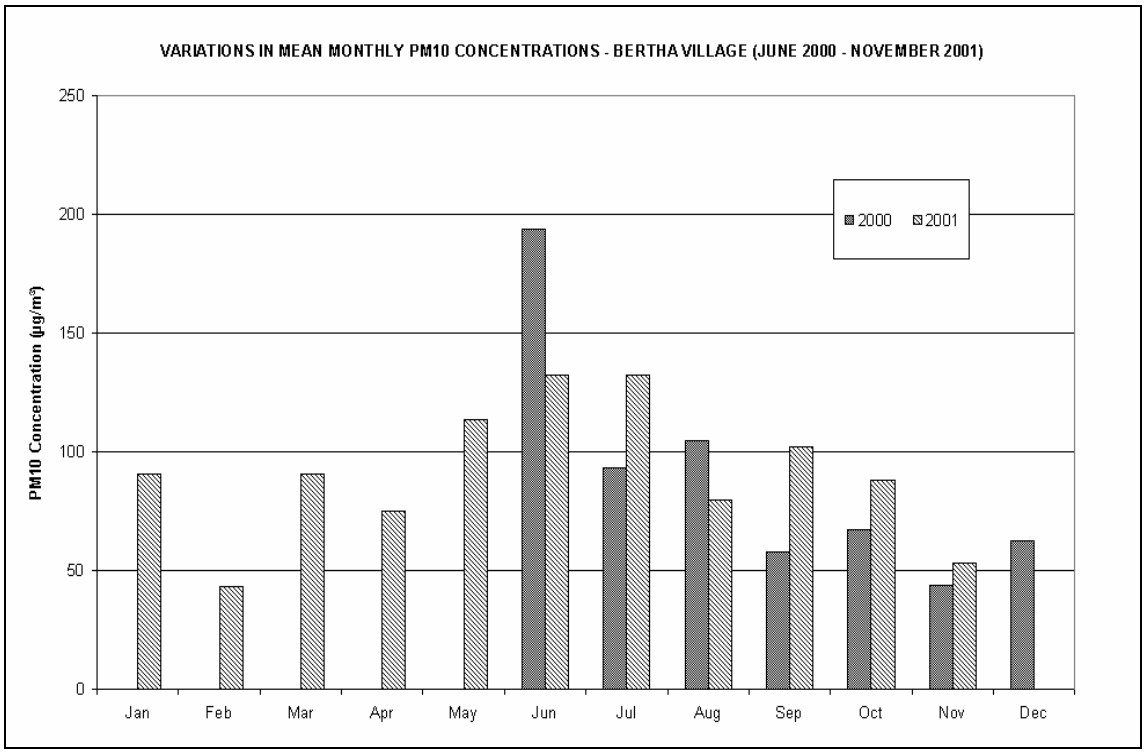
the exact make-up of this group of pollutants. Iscor Vanderbijlpark Works represents the largest single source of particulate and sulphur dioxide and hydrogen sulphide emissions within the Vanderbijlpark area due to emissions from the coking ovens. Within the Sasolburg area, the largest sulphur (sulphur dioxide and hydrogen sulphide) emissions are from Sasol, followed by Natref (sulphur dioxide). Volatile organic emissions are also predominantly from these two sources.

Yvonne Scorgie observed an annual average PM_{10} concentration of 57 g/m^3 for the year 2002. Using similar arguments as those applied in other monitoring stations with one data point, this data point was projected back to the year 2000.

5.2.1 Bertha Village Monitoring Station

Particulate concentrations are recorded using a two stage stacked filter unit at Bertha Village this allows for the coincident measurement of coarse mode (i.e. 2.5 - 10 µm) and fine mode (i.e. <2.5 µm) particles. By summing the coarse and fine modes, total concentrations of PM10 are obtained. Bertha Village is a mining residential area located just west of the Lethabo Power Station and immediately SSW of the New Vaal Colliery. Exceedances of the current SA PM10 guideline occurred on 7.5% of days at Bertha Village. PM10 concentrations were in the "high" to "very high" range for 51% of days. A clear increase in particulate loadings occurred during winter months with maximum concentrations being recorded in June and July.

Figure 5.1: Monthly average PM10 concentrations recorded by New Vaal Colliery using a stacked filter unit during the period June 2000 to November 2001.



An annual average PM_{10} concentration of 86.33µg/m^3 was computed from this mean monthly PM_{10} concentration data with a standard deviation of 28.59µg/m^3.

5.2.2 Steam Station 2 Monitoring Station

The Steam Station 2 site is located between the Sasol Chemical Industrial complex and the Zamdela residential area. Highest hourly, highest daily and monthly average PM_{10} concentrations recorded at this site, as obtained for use by Sasol, are presented in table 5.1. Exceedances of the current SA daily PM_{10} guideline were observed to occur, with highest daily average concentrations being in the "high" to "very high" range for all months except November and December 2001.

Table 5.1: Highest hourly, highest daily and monthly average PM_{10} concentrations recorded at the Steam Station 2 site during the July 2001 to July 2002 period. (Exceedances of the EC daily average limit value of 50µg/m³ given in bold.

Date	Highest Hourly (µg/m^3)	Highest Daily (µg/m^3)	Monthly Average (µg/m^3)
July-01	347	**59**	28
August-01	370	**88**	61
September-01	477	**222**	45
October-01	383	**94**	46
November-01	208	**70**	34
December-01	262	**72**	30
January-02	351	**54**	26
February-02	353	**120**	49
March-02	783	**213**	102
April-02	510	**147**	90
May-02	700	**201**	105
June-02	570	**162**	87
July-02	870	**200**	121

Based on the available monitoring data it may be concluded that high ambient particulate concentrations occur across much of the Vaal Triangle. A mean PM_{10} concentration of 63.38µg/m^3 with a standard deviation of 33.28µg/m^3 was observed for this data period. Since only one data point could be obtained for this monitoring station, this PM10 estimate was used for back projection of PM10 annual concentration to the year 2000. Similar arguments as those provided for monitors with one data point hold.

5.2.3 Orange farm Monitoring Station

Orange farm monitoring station is situated in a residential area that is close to the national road (N1). Sources contributing to observed PM10 levels in this site include combustion products from vehicle emissions from high vehicle density observed in the national road. This residential area is populated by middle to low income earners who use coal and wood for cooking and heat generation to keep warm.

PM_{10} data received from Yvonne Scorgie was only for the year 2004. From this data, the annual average concentration of PM10 for Orange Farm was already computed to be 64.55µg/m^3 for the complete 2004 period.

This data point was projected back to the year 2000 annual PM_{10} concentration by assuming that there is little or no change in the annual average concentration of PM_{10} in Orange Farm for the past four years. This back-projection had to be done in this way, since only one data point was observed for the Orange farm station. As more data is available, more meaningful approximation of PM_{10} annual average concentrations for this station would be possible. Therefore the annual average concentration of PM_{10} for the year 2000 at the Orange Farm station was assumed to be 50.02$\mu g/m^3$.

Table 5.2: A summary table of PM_{10} estimates for the Vaal Triangle region

Station	Annual Average ($\mu g/m^3$)
Sasolburg	57.00
Bertha Village	86.33
Steam Station	63.38
Orange farm	64.55

5.3 Estimating $PM_{2.5}$ from PM_{10} for Vaal Triangle stations

There have been no attempts whatsoever from ambient studies or monitoring undertakings to monitor $PM_{2.5}$ despite having instruments that can measure both $PM_{2.5}$ and PM_{10}. Having performed data analysis on $PM_{2.5}$:PM_{10} ratio estimates for both Cape Town and Johannesburg, it was observed that their means are almost equal (0.59 for Cape Town and 0.57 for Johannesburg). It was then assumed that the mean $PM_{2.5}$:PM_{10} ratio for Vaal Triangle is similar to that observed in these areas and also floating around the lower limit and upper limit range of ($0.5<PM_{2.5}:PM_{10}<0.65$) since Vaal Triangle is an intense industrial area. Therefore a mean $PM_{2.5}$:PM_{10} ratio of 0.59 was chosen for Vaal Triangle)

Table 5.3: Summary of $PM_{2.5}$ estimates for Vaal Triangle Monitoring sites

Monitoring Station	$PM_{2.5}$ estimate at a mean $PM_{2.5}$:PM_{10} = 0.59)	Lower limit ($PM_{2.5}$:PM_{10} =0.5)	Upper Limit ($PM_{2.5}$:PM_{10} =0.65)
Sasolburg	33.63 $\mu g/m^3$	28.50 $\mu g/m^3$	37.05 $\mu g/m^3$
Bertha village	50.93 $\mu g/m^3$	43.17 $\mu g/m^3$	56.11 $\mu g/m^3$
Steam Station 2	37.39 $\mu g/m^3$	31.69 $\mu g/m^3$	41.20 $\mu g/m^3$
Orange Farm	29.51 $\mu g/m^3$	32.28 $\mu g/m^3$	41.96 $\mu g/m^3$

6. North West

6.1 Rustenburg

Rustenburg lies on the edge of the bushveld igneous complex, one of the most heavily mineralised districts in the world. Mines in the region produce granite, platinum, chrome, lead and slate. On mines, dust is generated by the movement of material, gravel roads and wind blown from stockpiles, tailings dams and other disturbed areas. The exact location of the monitoring site could not be located, therefore the site was assumed to exist in the middle of Rustenburg. An annual average of 57$\mu g/m^3$ was obtained for Rustenburg from Yvonne Scorgie data sources for the year 2003. Similar arguments as those used to estimate annual average concentrations were used to project this figure to the year 2000. In this way, an annual average annual concentration of 57$\mu g/m^3$ was assumed.

6.2 Estimating $PM_{2.5}$ from PM_{10} for Rustenburg station

According to a report by Yvonne Scorgie, no $PM_{2.5}$ monitoring was observed in Rustenburg. This shift the emphasis to assuming the $PM_{2.5}$:PM_{10} ratio by accessing the nature of the city as well analysing the sources of pollution. We begin by recognising that Rustenburg is intense in mining. In a mining environment, dust emissions are expected to be very high. This means that

more pollutants would be concentrated in the coarse fraction (PM_{10}-$PM_{2.5}$) of PM_{10}, thus the $PM_{2.5}$:PM10 ratio is expected to be lower than in other regions of the country. Cohen et al suggested that in areas with highly pronounced fugitive dust emissions, an assumed mean $PM_{2.5}$:PM_{10} ratio of 0.35 is used. Cohen at al further suggests that an expected range of is $0.24 < PM_{2.5}:PM_{10} < 0.50$. The table below summarizes the analysis of $PM_{2.5}$ estimation from PM_{10}.

Table 6.1: Summary of $PM_{2.5}$ estimates for Rustenburg Monitoring site

Monitoring Station	**$PM_{2.5}$ estimate at a mean $PM_{2.5}:PM_{10}$ = 0.35)**	**Lower limit ($PM_{2.5}:PM_{10}$ =0.24)**	**Upper Limit ($PM_{2.5}:PM_{10}$ =0.50)**
Rustenburg	19.95 $\mu g/m^3$	13.68 $\mu g/m^3$	28.50$\mu g/m^3$

Appendices

Appendix A: Summary of all PM_{10} and $PM_{2.5}$ estimates for all monitoring stations.

Exposure Metric	PM_{10} ($\mu g/m^3$)	Mean $PM_{2.5}$ ($\mu g/m^3$)	$PM_{2.5}$ (LL) ($\mu g/m^3$)	$PM_{2.5}$ (UL) ($\mu g/m^3$)
Station	**Cape Town**			
Khayelitsha	56.76	33.49	28.38	36.89
City Centre	23.10	13.63	11.50	15.02
Table view	22.90	13.51	11.45	14.89
Goodwood	34.69	20.47	17.35	22.55
Bellville South	33.02	19.48	16.51	21.46
Station	**Joburg and Surrounding Areas**			
Newtown	61.10	35.23	30.90	40.17
Lapa	45.00	25.71	22.55	29.32
Jabavu	50.02	28.51	25.01	32.51
Alexandra	44.00	35.85	31.45	40.89
Buccleuch	55.25	31.49	27.63	35.91
Mintek	46	26.22	23.00	29.90
Ester park	42	24.78	21.00	27.30
Station	**Ethekwini**			
Wentworth	39.1	27.38	23.20	30.16
Ganges	46.4	23.07	19.55	25.42
City Hall	38.1	22.48	19.05	24.77
King Edward	37.6	22.18	18.8	24.44
Ferndale	39.7	23.60	20	26.00
Settlers school	40.0	23.42	19.85	25.81

Exposure Metric	PM_{10} ($\mu g/m^3$)	Mean $PM_{2.5}$ ($\mu g/m^3$)	$PM_{2.5}$ (LL) ($\mu g/m^3$)	$PM_{2.5}$ (UL) ($\mu g/m^3$)
Station	**Vaal triangle**			
Sasolburg	57.00	33.63	28.50	37.05
Bertha Village	86.33	50.93	43.17	56.11
Steam Station	63.38	37.39	31.69	41.20
Orange farm	64.55	29.51	32.28	41.96
Station	**North West**			
Rustenburg	57	19.95	13.68	28.50

Appendix B: Coordinates for all the identified monitoring stations

Station	Latitude (East)	Longitude (North)	Coordinate Units
Cape Town			
City Centre	- 33°55'30"	18°25'24"	DD MM SS
Goodwood	- 33°54'04"	18°33'59"	DD MM SS
Tableview	- 33°49'01"	18°30'44"	DD MM SS
Khayelitsha	- 34°02'53"	18°42'39"	DD MM SS
Bellville South	- 33°55'30"	18°25'24"	DD MM SS

Station	Latitude (East)	Longitude (North)	Coordinate Units
Joburg and Surrounding areas			
New Town	(-) 103154.004	(-) 2899968.137	Meters
Lapa Station	(-) 25°45'39"	28°10'43"	DD MM SS
Jabavu (Soweto)	(-) 87141.114	(-) 2905121.523	Meters
Alexandria	(-) 26°07'53"	28°17'40"	Meters
Buccleuch	(-) 109992.601	(-)2882306.425	Meters
Esterpark (Kempton Park)	(-) 26.100	28.250	DD MM SS
Mintek (Randburg)	(-) 26°06'11"	27°59'21"	DD MM SS

Station	Latitude (East)	Longitude (North)	Coordinate Units
Ethekwini			
City Hall	(-) 2663	(-) 3304110	Meters
King Edward	(-) 1052	(-) 3306633	Meters
Wentworth	(-) 1074	(-) 3312509	Meters
Ganges	(-) 3397	(-) 3314113	Meters
Ferndale	(-) 29°49’31”	31°00’32”	DD MM SS
Settlers	(-) 2027	(-) 3315243	Meters

Station	Latitude (East)	Longitude (North)	Coordinate Units
Vaal Triangle			
Orange farm	(-) 86459.369	2930265.171	Meters
Sasolburg Industria	(-) 26.833	27.850	DD
Bertha Village	(-) 26°46’46”	27°51’11”	DD MM SS
Steam Station 2	(-) 26°50’06”	27°50’50”	DD MM SS
North West			
Rustenburg	(-) 25°39’28”	27°13’45”	DD MM SS

Appendix C: PM_{10} Estimates from GMAPS model

City	PM10 ($\mu g/m^3$)	latitude	longitude
Cape Town	**12**	**-33.933**	**18.467**
Johannesburg	**28**	**-26.167**	**28.033**
East Rand	26	-26.250	28.333
PRETORIA	28	-25.750	28.200
Durban	**29**	**-29.883**	**31.000**
West Rand	25	-26.117	27.750
Port Elizabeth	**15**	**-33.967**	**25.600**
Sasolburg	**21**	**-26.833**	**27.850**
Soweto	**29**	**-26.283**	**27.833**
Umlazi	22	-29.967	30.883
Ibhayi	20	-30.817	29.150
Dlepmealow	28	-26.100	28.000
Lekoa	18	-26.800	27.950
Tembisa	23	-25.967	28.233
Kathlehong	27	-26.333	28.150
Evaton	25	-26.533	27.883
Khayelitsha	**10**	**-34.050**	**18.667**
Botshabelo	23	-25.700	29.400
Roodepoort	28	-26.167	27.883
Kwamashu	21	-29.750	30.983
Pietermaritzburg	25	-29.600	30.400
Mamelodi	25	-25.667	28.333
Daveyton	24	-26.150	28.417
Germiston	27	-26.250	28.167
Bloemfontein	22	-29.117	26.233
Mangaung	18	-29.100	26.300
Alexandra	**29**	**-26.117**	**28.100**
Boksburg	27	-26.217	28.250
Benoni	28	-26.200	28.300
Kempton Park	**24**	**-26.100**	**28.250**
East London	18	-32.972	27.872
Ntuzuma	19	-30.450	30.083
Sandton	**29**	**-26.100**	**28.067**
Springs	27	-26.267	28.433
Vereeniging	26	-26.683	27.933

Areas in bold are those with monitoring stations

Appendix D: Comparison of estimates from monitoring data and GMAPS model

Urban City / Region	**Monitoring Data PM_{10} estimates Units: $\mu g/m^3$**	**GMAPS PM_{10} Estimates Units: $\mu g/m^3$**
Cape Town	23	12
Khayelitsha	57	10
Johannesburg	61	28
Durban	38	29
Sasolburg	57	21
Soweto	50	29
Alexandra	44	29
Kempton Park	42	24
Sandton (close to Randburg)	46	29