SULPHUR DIOXIDE MEASUREMENTS IN SOUTH DURBAN: THE CULMINATION OF 8 YEARS OF MONITORING

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ABSTRACT

The South Durban industrial basin comprises residential areas in close proximity to industry. The South Durban Sulphur Dioxide Management System was formed in 1994 in response to concerns regarding SO2 concentrations in the area. A Steering Committee, consisting of representatives from the national and local authorities, industry and the local community, was formed to monitor ambient SO2 concentrations to thereby facilitate informed decision-making on management strategies for industrial pollution control in the South Durban region. ECOSERV (Pty) Ltd were appointed as project managers in November 1995 to oversee:

- the effective storage of the data collected by the system;
- day-to-day maintenance of the extensive and varied equipment comprising the system; and
- regular reporting and analysis of the data.

The monitoring network consisted of an array of continuous SO_2 analysers, an O_3 analyser, a NO_x analyser and weather stations. Data was relayed regularly via radio telemetry to a database server computer, which was in turn linked to a pollution dispersion model to enable real-time modeling of conditions. During the eight-year lifetime of the network, permanent monitoring stations were established at Wentworth, Southern Works, AECI and Athlone Park, while a mobile trailer containing a SO_2 analyser was also deployed at various localities of concern within the region. Results obtained from the mobile station when at Settlers School suggested the need for further investigation and a semi-permanent caravan was established by the Ethekwini (Durban) Municipality in 2000. The monitoring system was accredited by the South African National Accreditation System (SANAS) for SO_2 monitoring in March 1999, which together with the monitoring system run by Ecoserv in Richards Bay, were the first to meet this quality standard in South Africa.

While the monitoring system latterly underwent various name changes, eventually being called the Durban Air Quality Forum, the functions and personnel essentially remained the same. The functions of the Steering Committee and monitoring network terminated at the end of 2003 as the Ethekwini Municipality embarked on a new and expanded monitoring network in terms of the South Durban Basin Multi-Point Plan.

Results of continuous SO_2 data collected at the Steering Committee monitoring stations from July 1996 to December 2003 are presented. A general improvement has been noted in the air quality in South Durban in terms of SO_2 since the monitoring program was operational, which, while encouraging for air pollution managers, still indicates local areas of concern and the persistent problem of the high loading of SO_2 in South Durban. The Municipality's expanded network of 16 monitoring stations, which includes the monitoring of PM_{10} and oxides of nitrogen, in addition to SO_2, will provide a more detailed insight into pollution levels in the Durban area.

1 1INTRODUCTION

This paper summarises the results obtained from continuous SO_2 monitoring in South Durban from July 1996 to December 2003. The South Durban industrial basin has long been an area of concern with regard to air quality. Industrial development has occurred, with little or no consideration for atmospheric pollution or the cumulative effects on air quality (South Durban Basin Multi-point Plan, 2003). Poor atmospheric dispersion conditions, during winter and topographic channelling of pollution (Diab & Preston-Whyte, 1980) contribute to elevated pollution concentrations. The close proximity of residential areas to industry and major traffic routes has exacerbated the problem. There is a history of conflict between local communities and industry, which has intensified over time (D'Abreton, et. al.) and there is increasing concern over the impacts of air pollution on human health.

Sulphur dioxide (SO_2) is recognised as a key pollutant when considering the impact of fuel-burning sources. Smoke and 48 to 72 hourly average SO_2 data from various stations in Durban has been measured by soiling index and bubbler instruments, respectively, since the 1960's (Bissett, 1995). The need for more accurate and continuous SO_2 data collection in South Durban was identified and to this end the South Durban Sulphur Dioxide Management System Steering Committee was formed in 1994. The Committee included representatives from industry, local authorities, national authorities and the local community. This body's function was to monitor ambient SO_2 concentrations with a

view to facilitate management strategies for industrial pollution control in the South Durban region.

ECOSERV were appointed as project managers in November 1995 to oversee:
- the effective storage of data
- day-to-day maintenance of equipment, and
- regular reporting and analysis of the data.

Validated SO_2 data is available from 1 July 1996. The South Durban monitoring system experienced various name changes since inception, ultimately being named the Durban Air Quality Forum. The functions and personnel, however, remained essentially the same. The Association was terminated at the end of 2003, when the Ethekwini Municipality implemented a new and expanded monitoring network, in terms of the South Durban Multi-Point Plan.

2 EQUIPMENT

The monitoring network (refer Fig. 1) comprised:

- Three permanent SO_2 analysers, situated at Wentworth, Southern Works and AECI (and initially a permanent station at Athlone Park, discontinued at the end of 1999).

- A mobile SO_2 monitoring trailer (deployed over various periods since 1999 at different locations of concern in South Durban).

- Settlers School, originally a mobile location from June to October 2000, was established as a semi-permanent monitoring station by the Ethekwini Municipality at the end of October 2000, including SO_2, CO, NO_x and particulate monitoring.

- Weather stations were established at Wentworth, Southern Wastewater Treatment Works (abbreviated to Southern Works), AECI, Sapref, Bluff and Island View. Measurements included wind speed, wind direction, temperature, solar radiation, rainfall, pressure and humidity.

- Ozone and NO_x analysers at the Wentworth station.

- The HAWK pollution dispersion model, situated at the Wentworth base station.

- A radio telemetry network relaying data from the remote stations to a base station at Wentworth.

- A structured query language database, collecting and processing all data, acting as the core of the wireless network and dial-in network facilities for data users.

The meteorological and air quality data were initially recorded as 3-minute averages, however the averaging time was changed to 5 minutes from January 2002 to facilitate comparison with the revised National 10-minute average guideline for SO_2. (December 2001).

2.1 Quality Assurance

Sulphur dioxide was measured by means of continuous ultraviolet fluorescence analysers, which were regularly maintained and calibrated. The SO_2 analysers are designated as equivalent methods in terms of the United States Code of Federal Regulations Volume 40 Part 53. Equivalent method numbers assigned to the various analysers used are: Dasibi 4108 (EQSA-1086-061), TECO 43A (EQSA-0486-060) and API 100A (EQSA-0495-100). The results relate only to the air sampled and care should be taken in extrapolating the results to surrounding areas. In terms of quality assurance all measurements allow for a maximum precision error of 15% and a zero tolerance of plus or minus 10 ppb. The South Durban monitoring system was accredited by the South African National Accreditation System (SANAS) for SO2 monitoring in March 1999, which together with the monitoring system run by Ecoserv in Richards Bay, were the first to meet this quality standard in South Africa. Accreditation is ongoing and is re-evaluated annually.

3 LOCATION AND PREVAILING WEATHER CONDITIONS

The study area and monitoring stations in relation to industry (black font) and main residential areas (blue font) are indicated in Figure 1. The South Durban basin is separated from the sea by a Holocene dune cordon 80 to 100 m in height. This topography effectively prevents air exchange between the basin and sea at lower levels, particularly during stable atmospheric conditions. Winds blow predominantly from the NNE and SSW to SW (refer Fig. 2). Light nocturnal land breezes blow mainly from the NNW to west. Land breezes are more prevalent during winter, during which surface air temperature inversions are common.

The Wentworth measurement station is located approximately 70 m above msl (the level at which the temperature inversion often occurs during winter). The industrial areas of Jacobs and Mobeni are to the west; while the Engen refinery is to the south and the Sapref refinery and Mondi Plant are to the SSW and south-west of the station, respectively. The Southern Works and Settlers School stations are situated at 15 to 17 m above msl and between the Engen refinery (to the north-east and NNE) and the Sapref refinery and Mondi (south-west to SSW of the stations). The Southern Works station was moved some 800 m northwards during April 1998 and the demarcation on Figure 1 shows the station location from May 1998 to the end of December 2003. The AECI station was located near the Umbogintwini industrial complex, including the Tioxide and AECI industries to the west to WNW. The Athlone Park station was located approximately 100 m above msl on the seaward side of the Holocene dune cordon. The station was discontinued at the end of 1999.

Figure 1 : Location of SO2 monitoring stations in South Durban. Red font indicates permanent stations, green font indicates temporary stations (mobile trailer), blue font indicates residential areas and black indicates industry.

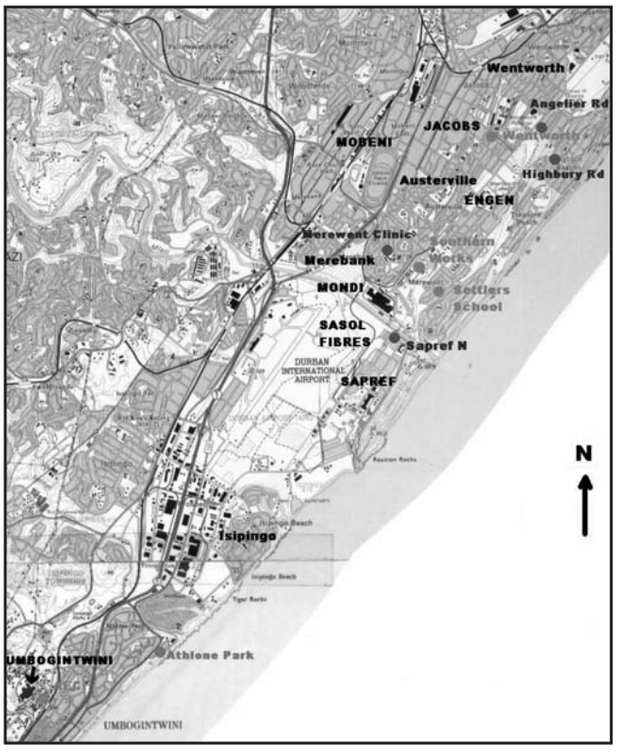
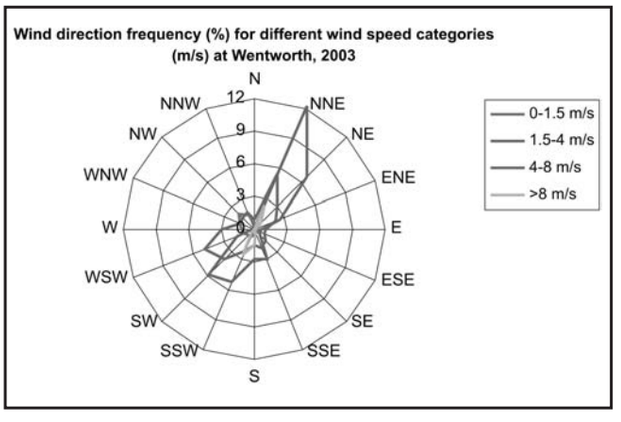


Figure 2: Annual wind frequency at Wentworth



4 GUIDELINES

The revised National Department of Environment and Tourism (DEAT) guidelines for SO_2 (Government Notice No. 1387 of Government Gazette 22491, 21 December 2002), and which are equivalent to the World Health Organisation (WHO) guidelines, are given in Table 1. Unfortunately the data averaging time of 3 minutes prior to 2002 does not allow direct comparison of historic data to the

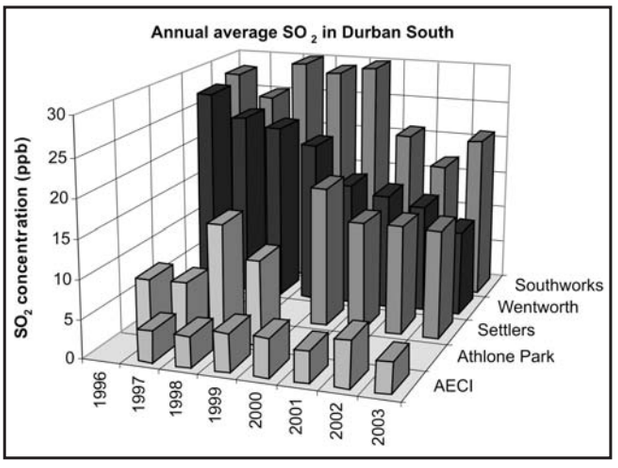
Table 1: Recommended DEAT guidelines for SO2 (21/12/2002)

Variable	10-minute average	Daily (24-hr) average	Annual average
SO_2	191 ppb	48 ppb	19 ppb

5 ANNUAL & INTER-ANNUAL SO2 CONCENTRATIONS

Annual average SO_2 for each of the permanent analyser stations is presented in Figure 3.

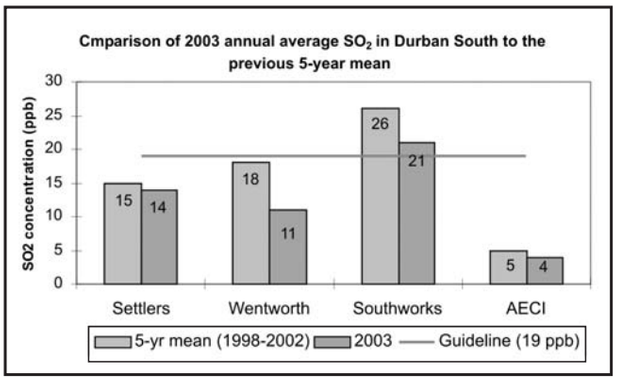
Figure 3: Annual average SO2 for each of the permanent analyser stations in South Durban, 1996 - 2003.



SO2 concentrations were highest at Southern Works, where the annual average SO_2 exceeded the DEAT National Guideline of 19 ppb for all years apart from 2002. The guideline was also exceeded at Wentworth during the first four years of measurement (i.e. 1996 to 1999). While concentrations at Wentworth and Southern Works were comparable during the earlier years, latterly there has been a steady decline at Wentworth. The decrease in SO_2 at Wentworth can be attributed to the switch by Frame Textiles to electric boilers during early 1998, ongoing reductions in emissions from the refineries and reduced HFO and coal burning by some smaller industries (converted to gas and electricity). Annual average SO_2 concentrations at Settlers and Wentworth are comparable, while the lowest annual average was measured at AECI. There has been little variation in the concentrations at AECI since 1996 and over the last three years at Settlers.

Figure 4 indicates the annual average SO_2 at the permanent monitoring stations for the most recent annual period (2003) compared to the previous 5-year mean for the period 1998 to 2002. The mean for Settlers School is applicable for the period June 2000 to December 2002 (data capture only commenced during June 2000). Even though the annual average SO_2 at Southern Works increased during 2003 compared to the previous year, comparison with the 5-year mean still shows an overall improvement in air quality at the station. At Wentworth a significant reduction in annual average SO_2 is evident for 2003 compared to the 5-year mean for 1998 to 2002, indicating good improvement in the air quality at the station. Annual average SO_2 at the AECI station was slightly lower than the 5-year mean, while the annual average at Settlers School was consistent with the previous two years.

Figure 4: 2003 annual average SO2 concentrations at South Durban monitoring stations compared to previous 5-year mean

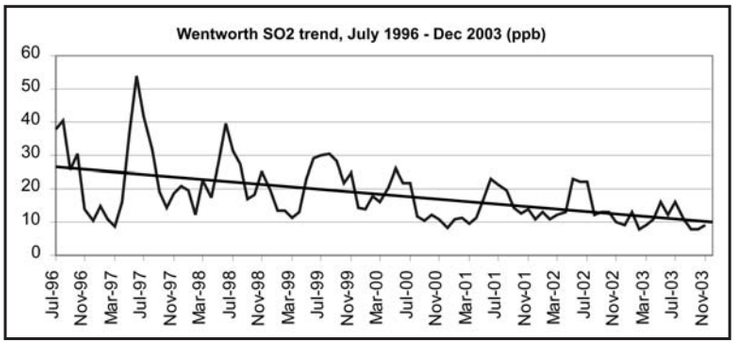


6 LONG-TERM TRENDS IN MONTHLY AVERAGE SO_2

The long-term trends in monthly average SO_2 for the major stations are provided in Figures 5 to 7. The black line indicates the regression line.

6.1 Wentworth

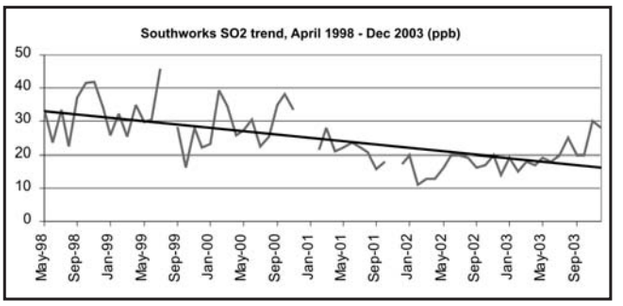
Figure 5 : Long-term trend in monthly average SO2 at Wentworth



At Wentworth, distinct seasonal fluctuations are indicated in the long-term trend of monthly average SO_2, with higher monthly average concentrations measured during winter compared to the summer months. The regression analysis indicates a general decrease in SO_2 concentrations since 1996. Mainly related to a decrease in SO_2 concentrations during winter, as the summer averages have remained fairly constant. Reasons for the overall reduction in winter concentrations compared to previous years include the switch by Frame Textiles to electricity during early 1998, ongoing reductions in emissions from the refineries and reduced HFO and coal burning by some smaller industries, which have converted to gas and electricity.

6.2 Southern Works

Figure 6 : Long-term trend in monthly average SO2 at Southern Works



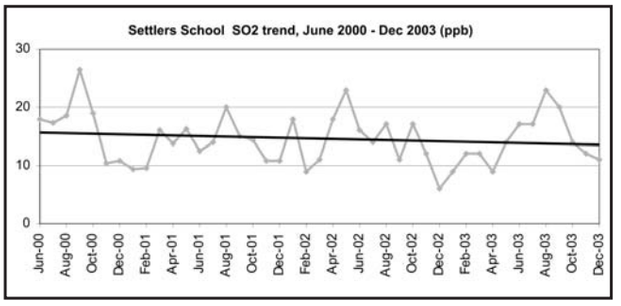
Notes: *Trend reflected since station move during April 1998*

The trend in monthly average SO2 at the Southern Works admin building site since May 1998 (Fig. 6) is fairly variable, depending on SO2 emissions and the frequency of SSW winds, which transport SO2 from the direction of the major sources of Mondi and Sapref. The regression line indicates a general decrease in monthly average SO_2 since 1998, although an increase was evident towards the end of 2003.

6.2 Settlers School

The trend in SO_2 at Settlers (Fig. 7) extends over a shorter time period to that of the other stations owing to the fact that data capture only commenced in June 2000. The long-term trend is fairly variable, depending mainly on the frequency of NNE winds, which transport SO_2 from the major source of Engen. The regression line indicates a slight decrease in concentrations since June 2000. Monthly average SO2 dropped to a minimum during December 2002 and concentrations were relatively low from January to April 2003, however an increase in monthly average SO_2 was evident from June to September 2003.

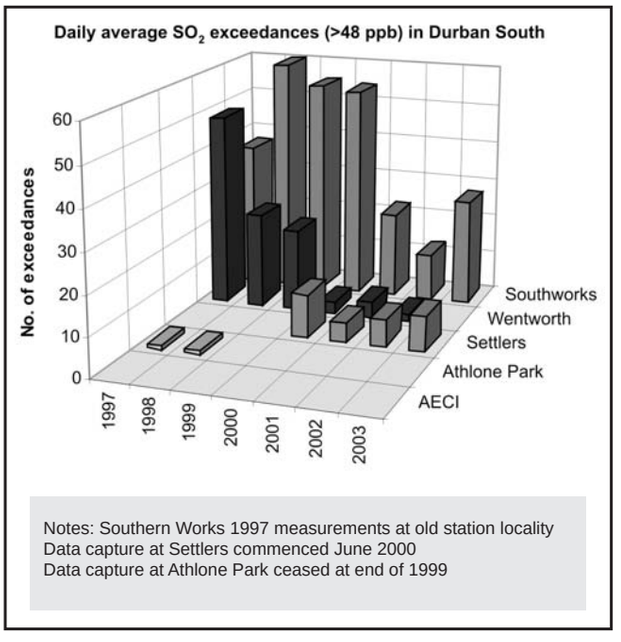
Figure 7 : Long-term trend in monthly average SO2 at Settlers School



7 DAILY AVERAGE SO2 GUIDELINE EXCEEDANCES

Unfortunately the data averaging time of three minutes prior to 2002 does not allow for comparison of historic data to the new 10-minute average guideline, therefore only the coarser resolution daily averaging period can be applied to make comparison of compliance over the longer term. The number of exceedances of the revised DEAT/WHO daily average guideline of 48 ppb is presented in Figure 8. The initial year of data capture (1996) is not reflected as data was only valid for half of the year (July 1996 onwards).

Figure 8: Number of exceedances of the revised DEAT/ WHO daily average guideline since 1997.



There has been a significant reduction in the number of daily average exceedances at Wentworth since 1999, so much so that no exceedances were recorded during the most recent reporting period of 2003. Although there has been a significant reduction in the number of daily average exceedances at Southern Works since 2000, the number of exceedances remained unacceptably high up to 2003, indicating a region of high loading of pollutants. There has been no significant change in the number of daily average exceedances at Settlers School. There have been no daily average guideline exceedances recorded at the AECI station.

8 10-MINUTE AVERAGE GUIDELINE EXCEEDANCES AND FREQUENCY DISTRIBUTION

The 3-minute average data prior to 2002 is not directly comparable to the 10-minute average guideline, thus only the number of 10-minute average SO2 exceedances recorded over the two most recent reporting periods (i.e. 2002 and 2003) are provided (Table 2).

Table 2: Number of 10-minute average guideline exceedances (191 ppb) recorded at four monitoring stations in South Durban during 2002 and 2003.

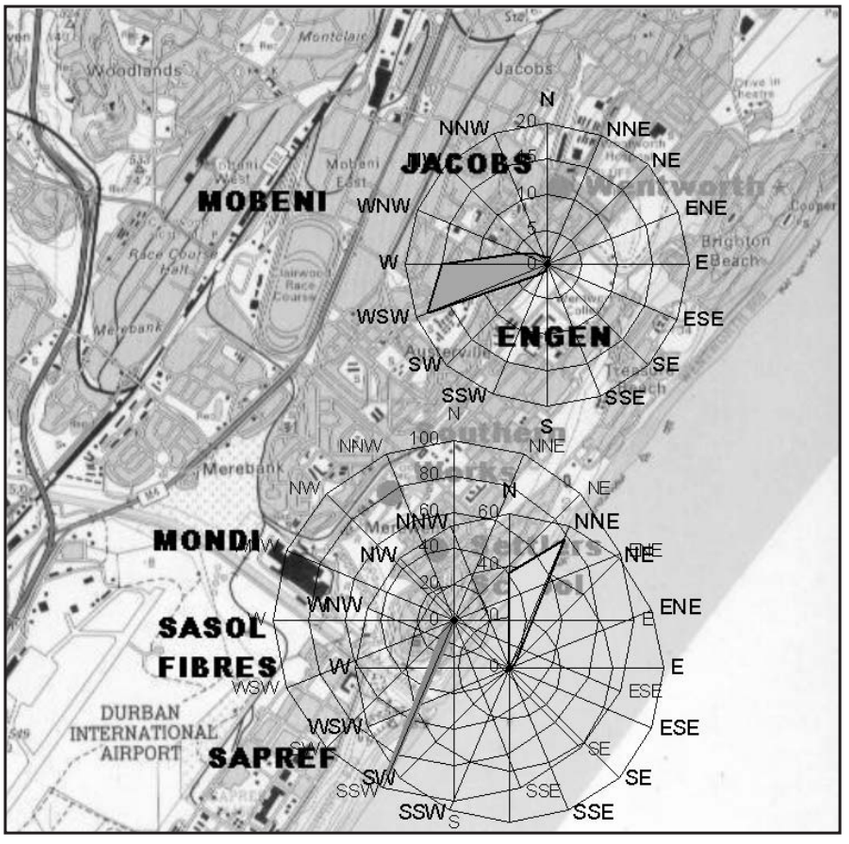
Year	Wen-tworth	South-work	Settlers Schoo	AECI
2002	37	37	119	1
2003	9	440	118	1

The number of 10-minute average guideline exceedances recorded at Wentworth during 2003 decreased compared to the previous year, while that at AECI was consistently low. The number recorded at Settlers was consistent, however still unacceptably high, while there was a significant increase at Southern Works, following a particularly low number of exceedances during 2002. The source directions of the 10-minute average exceedances at Wentworth, Southern Works and Settlers School are provided in the frequency roses in Figure 9. The scale represents percentage of total exceedances per station. Note the variation in scale between stations and cognisance must be taken of the wind frequency pattern for the area (Fig. 2).

Figure 9 shows the differences in the locations of the monitoring stations relative to sources and the predominant winds. At Wentworth, most exceedances were related to light westerly to WSW winds, the most likely source of which corresponds to industry in the Jacobs and Mobeni areas. The majority of these exceedances were recorded during the early morning and were correlated with

atmospheric stability and poor dispersion conditions. At Southern Works, 91% of 10-minute average exceedances were measured during moderate to fresh winds from the SSW. The most likely sources are Sapref and Mondi (Sasol Fibres was shut down in 2001). This situation is in striking contrast to that at the Settlers School, less than a kilometre to the east. The Settlers School station typically measured elevated SO_2 during moderate to fresh northerly to NNE winds, which correspond to the direction of the Engen refinery. In the case of both Southern Works and Settlers, the elevated ground level concentrations are most likely a result of stack down-drafting. In isolated cases light wind events in the morning have suggested downward fumigation of accumulated pollutants with the diurnal break-up of the temperature inversion. A great deal of work has been done understanding the causes of these effects and is reported separately.

Figure 9: Source directions of 10-minute average exceedances



9 THE WAY FORWARD

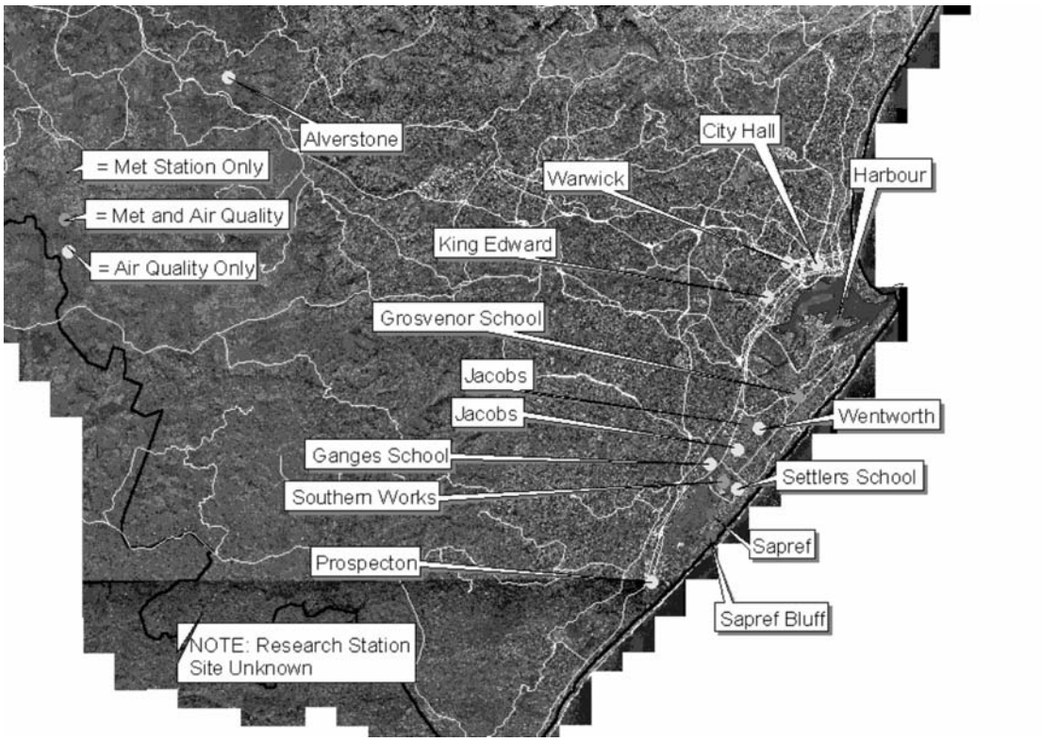
The Ethekwini Municipality has adopted the South Durban Multi-point Plan, as initiated by the national Minister of Environmental Affairs and Tourism. The goals of this plan (South Durban Basin Multi-point Plan, 2003) are :

- To provide an improved and integrated decision making framework for air pollution management
- Reduce air pollution to meet health based air quality standards
- Achieve improved quality of life for the local community.

To this end the Municipality has established a network of 16 monitoring stations, which includes the monitoring of PM10, oxides of nitrogen, ozone and carbon monoxide, in addition to SO2. This will provide a more detailed insight into pollution levels in the Durban area. The Wentworth, Southern Works and Settlers School stations have been integrated into the new monitoring system, which was

initiated at the end of 2003. The new monitoring site locations are indicated in Figure 11.

Figure 11: South Durban Multi-point Plan monitoring station locations



10 CONCLUSION

Data from the monitoring stations in South Durban has indicated an overall decrease in SO2 concentrations and guideline exceedances, due mainly to reduce emissions from industry over the last few years. However, there are still certain hot-spots, or areas of concern where consistently high concentrations of SO2 are measured and the SO2 guidelines are exceeded. The Municipality's expanded network of 16 monitoring stations will provide a more detailed insight into air pollution levels in the Durban area, the results of which can be applied to further reducing pollution and ultimately improving the quality of life for all.

11 REFERENCES

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12 ACKNOWLEDGEMENTS

The Steering Committee of the former Durban Air Quality Forum is acknowledged for the SO_2 and meteorological data reported from their monitoring stations. The Ethekwini Municipality Environmental Health Department is acknowledged for the SO_2 and meteorological data from Settlers School.