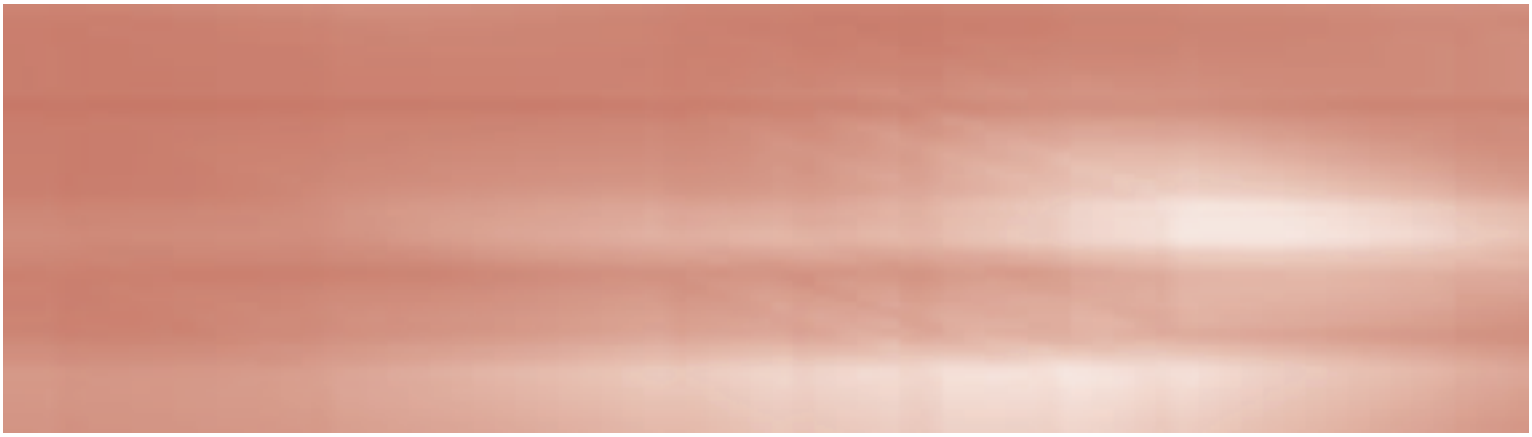
Air Quality Monitoring Report

HOT SPOT REPORT NO 2

AUGUST 2001

PARTICULATE AIR QUALITY AT WHYALLA



South Australia

DEPARTMENT FOR environment and heritage

Government of South Australia

Particulate Air Quality at Whyalla, South Australia

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ISBN 1 876562 29 3
August 2001

Printed on recycled paper

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GLOSSARY

NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medicla Research Council
NPI	National Pollutant Inventory
TSP	total suspended particulates
UNEP	United Nations Environment Program
WHO	World Health Organisation

SUMMARY

Whyalla, South Australia's largest regional city, is located on the western shores of the upper Spencer Gulf. Whyalla is home to 24,000 residents and a steel works that produces structural steel, rails and semi-finished slabs, blooms and billets. The steel works trades as OneSteel Manufacturing Pty Ltd. The term 'steel works' is used throughout this document to generically describe all OneSteel activities at Whyalla. Other major industries in the area include crude oil and LPG production, industrial fabrication, commercial salt production, and industrial services and transport. All are sources of air pollution.

Air pollution from industrial activities is a problem in Whyalla. The Environment Protection Agency (EPA) has monitored particulate air quality from two sites (Hummock Hill and Civic Park) in Whyalla since 1989. The site at Hummock Hill was selected to monitor particulate emissions from the pellet plant, which has had the potential to impact on a significant portion of the city. At Civic Park a residential background site was installed to compare with Hummock Hill. A third site at Whitehead Street was established at the beginning of 2000 to monitor levels of particulates in residential areas close to the steel works.

The National Pollutant Inventory determined that the steel works emitted each year 1500 tonnes of particulate matter (as PM_{10}). The steel works also emitted significant quantities of carbon monoxide, oxides of nitrogen and sulfur dioxide (Environment Australia 2000). The steel works is licensed under the *Environment Protection Act 1993* (the Act), which authorises OneSteel to operate its activities under conditions governing the levels of permissible emissions to air and the operation and maintenance of plant and equipment.

This report investigates levels of particulate matter since 1990 at each site in Whyalla compared with the Australian air quality standard and other guidelines. Particulate matter was measured as total suspended particulates (TSP) at all sites and as PM_{10} at Hummock Hill. Meteorological information (wind speed and direction) provided data to determine the source of particles transported to residential areas. Two heavy metals associated with steel works activities, iron and manganese, were monitored to determine concentrations associated with airborne particles.

At Civic Park, the monitoring site furthest away from the steel works, particle levels were always well below the World Health Organisation's (WHO) air quality guideline for TSP. At Whitehead Street, a residential area near the steel works, the air quality during 2000 exceeded the WHO guideline for TSP on four occasions. (These sites only measured TSP for which there is no NEPM standard.) At Hummock Hill, the monitoring site closest to the steel works, the air quality during 1999 and 2000 frequently exceeded the WHO guideline for TSP and the NEPM standard for PM_{10}. During these two years the National Health and Medical Research Council (NHMRC) annual average guideline for TSP was also exceeded at the Hummock Hill site.

Analysis of wind direction and speed clearly demonstrated that airborne particles, on days when air quality guidelines were exceeded, were transported from the direction of OneSteel's operations. When compared with background levels measured at Civic Park, it is clear that particles sourced from the steel works contributed up to 95% of airborne particulate matter, directly causing the exceedences of the air quality NEPM standard for PM_{10} at Hummock Hill. Particulate matter originating from the steel works will contain iron and manganese. High concentrations of both metals were measured at Hummock Hill and at Whitehead Street.

The EPA is working closely with OneSteel to develop a more thorough site management program to reduce particle levels.

INTRODUCTION

What is particulate matter?

Particles of various sizes are suspended in the air and can give it a hazy appearance. Particles are monitored and reported in size-related categories. Total suspended particulates (TSP) include all particles up to 50 micrometres (μm) in diameter. Particulate matter less than 10 μm in diameter is known as PM_{10}.

Health effects

Particulate air pollution is responsible for a range of health effects including respiratory and cardiovascular problems and asthma. Some people are more sensitive than others—for example, the elderly and those suffering from pre-existing heart or lung disease. The young are also sensitive, with evidence of increased frequency of respiratory tract infections, coughing and wheezing following exposure to some airborne particulates (NEPC 1998).

Australian Air Quality Standards and other air quality guidelines

It is PM_{10} and finer particles like $PM_{2.5}$ that are of most concern to human health. Particles up to 10 μm in size are inhalable, and those up to 2.5 μm can travel deep into the lungs and become lodged there. The PM_{10} National Environment Protection Measure (NEPM) air quality standard is measured over 24 hours as this daily average figure can be linked to health effects. The NEPM air quality standard is 50 micrograms per cubic metre ($\mu g/m^3$) as a 24-hour average. Five daily exceedences are allowed in one year (NEPC 1998).

There are no NEPM air quality standards for total suspended particulates. However, the NHMRC (1996) has recommended an ambient air quality guideline of 90 $\mu g/m^3$ measured as an annual average (this guideline, however, is used in conjunction with an annual SO_2 guideline). A WHO guideline has been set at 120 $\mu g/m^3$ as a 24-hour average (WHO 1999, WHO and UNEP 1992) and has been used in the assessment of TSP data in other studies (Environment Canada 1998) and in this report.

The air quality standards and guidelines are summarised in table 1 below.

Table 1. Particulate matter standards and guidelines

	NEPM (1998) Standard	NEPM (1998) Goal	WHO (1999) Guideline	NHMRC (1996) Guideline
Particles as PM_{10}	50 $\mu g/m^3$ (24-hour average)	No more than 5 days/year		
Total Suspended Particulates (TSP)			120 $\mu g/m^3$ (24-hour average)	90 $\mu g/m^3$ (annual average)*

* For relevance, the TSP guideline needs to be read in conjunction with the annual NHMRC (1996) guideline for SO_2 (60 $\mu g/m^3$ as an annual average). Although SO_2 was not measured in this study, comparison against the guideline is still useful.
The standard and guidelines referred to in this report are used for evaluating long-term trends to assess the effectiveness of control strategies and the progress towards achieving the NEPM goal.

Ambient Air Quality and the National Environment Protection Measure

The NEPM for Ambient Air Quality requires that PM_{10} particulate levels (those particles smaller than 10 micrometres in size) in major urban areas meet a standard of 50 µg/m^3 by June 2008, with a goal of not more than five daily values greater than the standard in one year. The NEPM requires the installation of performance monitoring stations in urban centres with a population greater than 25,000 people. It includes provision for additional monitoring stations where pollutant levels are influenced by local characteristics such as emission sources. OneSteel has been shown to be a significant emission source for particulates, hence the monitoring in this area. It is the EPA's responsibility to ensure that OneSteel works towards meeting the targeted fine particulate level in Whyalla.

What is an exceedence of the NEPM?

Clause 17 of the Ambient Air Quality NEPM (NEPC 1998) requires that for each pollutant and applicable averaging time, the number of stations in each region that meet or do not meet the NEPM standard, and the number for which compliance is not demonstrated, should be stated.

A site-by-site assessment is to be made for regional compliance. For PM_{10} at each site the standard should not be exceeded more than five times per year. If any site in a region exceeds the standard more than five times (for PM_{10}), then non-compliance of the NEPM goal is reported.

Sources of particulate matter

Particles in the atmosphere are composed of a wide range of materials arising from a variety of sources. Coarse particles may come from, for example, suspended soils, dusts, sea-salt, construction work. Finer particles arise from combustion sources such as incineration, metallurgical processes, motor vehicles and domestic wood burning heaters, and some by chemical reactions in the atmosphere.

The relative contribution of each source type varies from day to day, depending on meteorological conditions and quantities of emissions from mobile and static sources. The fine particle fraction is composed predominantly of particles derived from combustion and chemical and manufacturing processes. The photograph below shows a major source of particulate matter, the OneSteel pellet plant, at Whyalla from Hummock Hill.

Figure 1. The pellet plant at the OneSteel steel works from Hummock Hill (photograph: EPA, August 2001)

Major air emission sources from the OneSteel steel works

Particulate matter at Hummock Hill is primarily sourced from the pellet plant, iron ore receiving hoppers, and ore crushing and stock-piling operations. Particle emissions from the pellet plant stack pass through a fine-particle and noxious gas cleaning system. Fugitive emissions from uncontrolled sources are a major concern in areas around the pellet plant, which is also near residences.

The topographic map below identifies the major emission sources from the steel works.

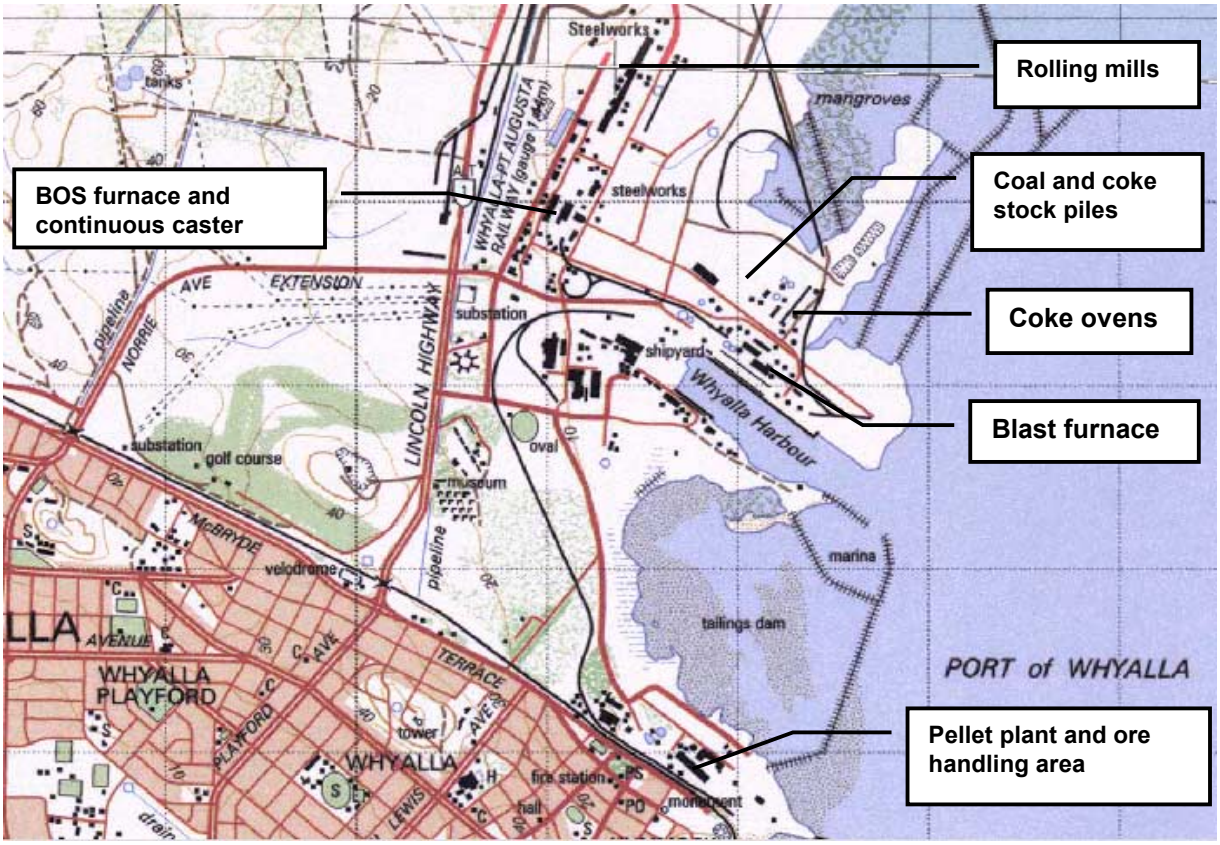


Figure 2. Whyalla and location of major air emission sources from the OneSteel steel works

SAMPLING METHODS

High volume sampling

Particulate matter as TSP and PM_{10} was measured using high volume samplers. The samplers draw air through a filter paper at a known constant rate for 24 hours. The resulting increase in the weight of the filter paper is expressed as the particulate concentration.

Total suspended particulates (TSP)

Total suspended particulates were collected on a glass fibre filter over a continuous 24-hour period at 6-day intervals (at the Whitehead Street site, sampling was conducted at 3-day intervals) and at a flow rate of approximately 1.4 m^3/minute. After each 24-hour period the filter was removed and weighed. A sub-sample of the collected particles on the filter was analysed for iron and manganese as described in Australian Standard AS 2800.

The high volume sampler conforms to Australian Standard AS 2724.3. For details of siting, operation and calibration of the sampler, refer to Australian Standards AS 2922 and AS 2724.3 and information given in the appendix.

Particulate matter (PM_{10})

For particulate matter less than 10 µm, 24-hour samples were collected in a PM_{10} high volume sampler and processed as for TSP. The airflow rate through the sampler is 1.13 m^3/minute. The equipment consists of a high volume sampler to which a 10-micrometre size-selective inlet (10 µm SSI) has been attached. The 10 µm SSI makes use of inertial separation of particles to ensure that only those with an equivalent aerodynamic diameter (EAD) less than 10 µm are collected.

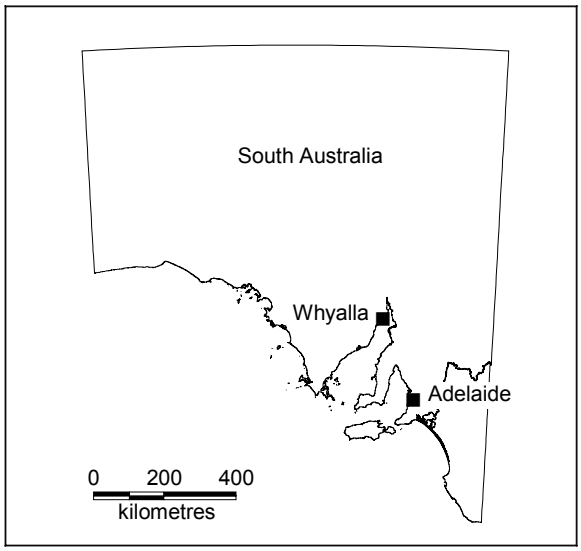
The PM_{10} sampler conforms to Australian Standard AS 3580.9.6. For details of siting, operation and calibration of the sampler, refer to Australian Standards AS 2922 and AS 3580.9.6 and information given in the appendix.

Meteorology

Meteorological data monitored at Whyalla includes wind speed and wind direction. Measurements for horizontal wind conform to Australian Standard AS 2923–1987.

MONITORING SITES

Whyalla is located on the western shores of the upper Spencer Gulf, South Australia (see State map). Monitoring at two sites (Hummock Hill and Civic Park) has been ongoing since March 1989. The Hummock Hill site is located directly adjacent to the pellet plant (300 metres), while Civic Park is situated 5000 metres from the pellet plant. A third site off Whitehead Street, situated 700 metres from the pellet plant, was established in March 2000 after complaints were received from nearby residents of air pollution emanating from the steel works.



The Hummock Hill site represents boundary conditions and may not represent residential exposure. The Whitehead Street site is considered to represent residential exposure.

TSPs were measured at all three sites. Particles as PM_{10} were monitored at Hummock Hill. Meteorology was measured within OneSteel's property. The following map shows each site's location and the location of OneSteel's pellet plant.

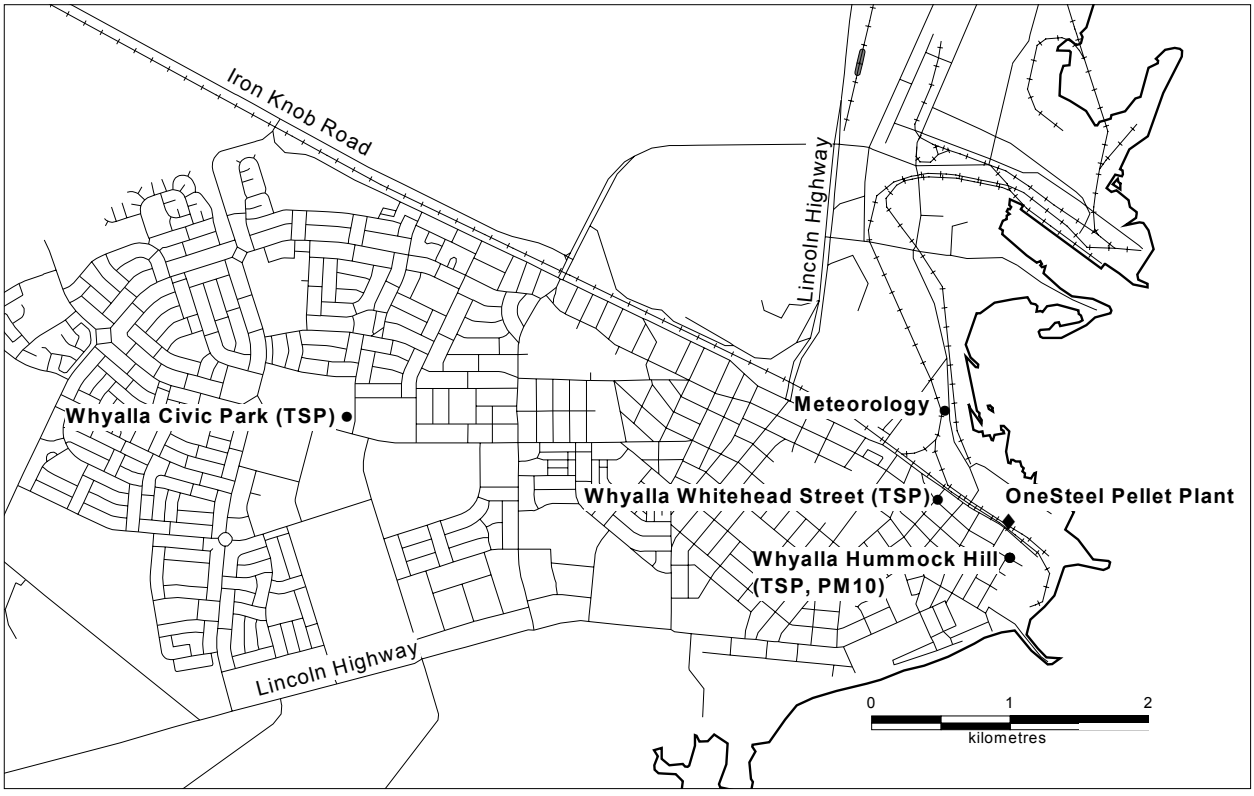


Figure 3. Whyalla and locations of EPA particulate matter monitoring stations

THE USE OF STATISTICS

Monitoring frequency

The purpose of Whyalla's air quality monitoring program is to assess ambient particle levels throughout the city's airshed by taking representative samples one day in every six. There is a risk in taking measurements of particulates at this sampling rate, as it can under-represent the possible number of exceedences during the full year. This is compensated by many years of data so that a full range of operating and meteorological conditions is sampled.

Consider, for example, a sampling regime producing in one year daily PM_{10} concentrations for 15% of the days in the year, and one exceedence is found. In the absence of further information about the missing days of data, the statistical expectation of the number of exceedences for the full year would be 1/15% = 6.6. Under such a sampling regime, one measured exceedence has meant that the likely number of exceedences for the year is approximately six, which is above the NEPM standard.

Descriptive statistics

Some other relatively simple statistical procedures have been used to further assist our understanding of the air quality data. Tables listed in this report may quote the annual number of exceedences of the NEPM standard; the highest, second highest and, in the case of PM_{10}, sixth-highest daily concentration in a year; and the 90th percentile. The percentile is similar to the maximum in that it indicates the range. Annual averages and monthly maxima are reported for TSP and metals where appropriate.

Differences between sites

It is important to determine whether there are statistically significant differences between monitoring sites. The variation in some data can be substantial but may not be significant from a statistical viewpoint; that is, is the difference greater than what one might expect by chance?

TSP and metal data for 2000 was tested for normality and for homogeneity of variances. As there is only one background site (or control) there is no spatial replication. Data collected on days when all three sites were sampled was used. Data was not normal and so the non-parametric Wilcoxon's signed ranks test for two groups, arranged as paired observations, was used to test for differences between sites.

Linear regression analysis is also used to determine the relationship between different variables. For example, the correlation between TSP at different sites was used to determine whether TSP comes from the same source. The strength of the correlation is stated in terms of the coefficient of determination R^2. The value of R^2 indicates the proportion of variance of a dependent variable (x) that is explained by an independent variable (y).

Determining the source of particulate matter

Determining the transport of particles is reliant on both the meteorology and topography of the surrounding landscape. The following diagram shows the elevation of Whyalla with respect to monitoring stations and the steel works.

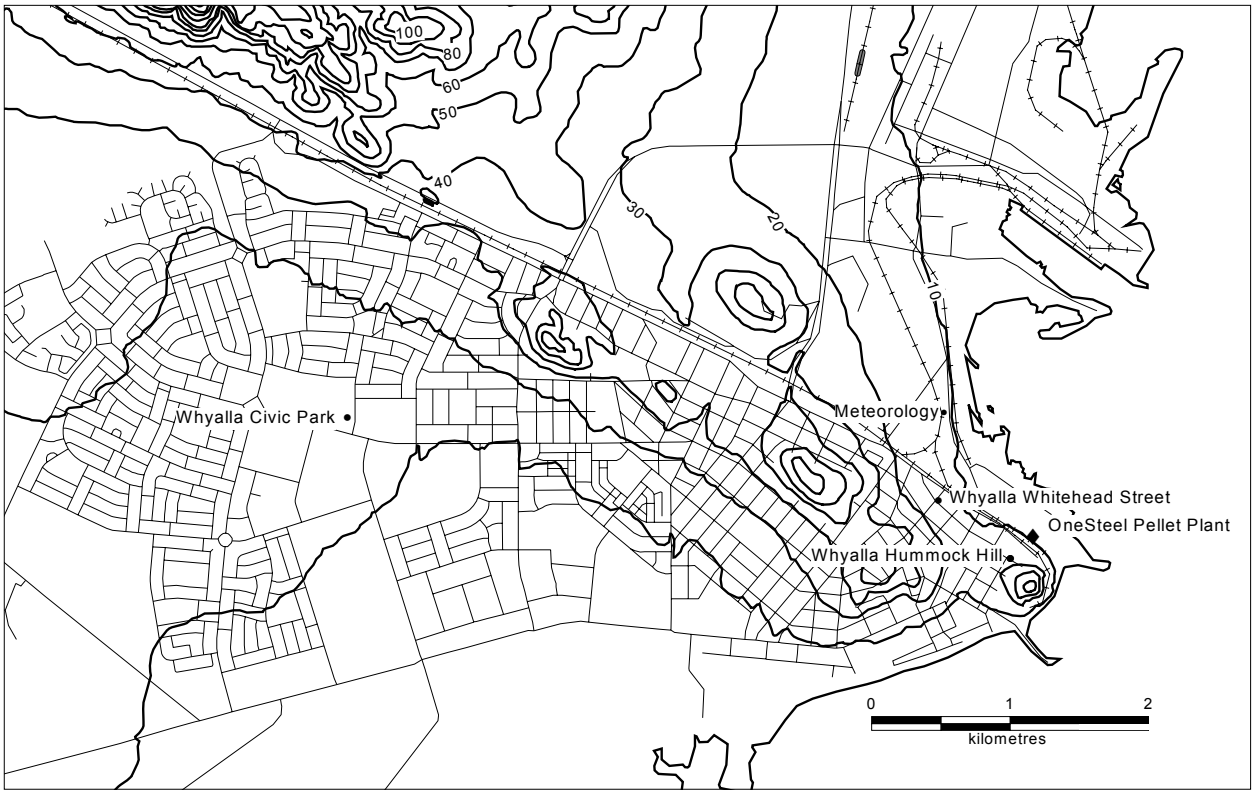


Figure 4. Map of Whyalla showing 10-metre contour intervals.

Graphs that describe wind direction, duration and velocity over a given period (wind roses) were used to determine the source of particles on days when total suspended particles exceeded the WHO guideline. As Whyalla has generally flat topography, it is crudely assumed that airborne particles are going to move generally in a straight line—especially over short distances such as to the Hummock Hill and Whitehead Street monitoring stations.

It is also assumed that wind will travel in a straight and uninterrupted line to Civic Park, a site located to determine background levels of particles. However, residential development may screen particulate matter, no matter its source, before reaching Civic Park. If this assumption is correct, then measurements are probably underestimating background concentrations of particles at this site.

OneSteel has begun investigating background levels of particulates by placing TSP and PM_{10} high volume samplers north of the steel works. In the future, the EPA will conduct comprehensive modelling of particulate matter using a non-steady state dispersion model that can take into account spatial variability of land surfaces and meteorological conditions. The model will eliminate the crude assumption that particles carried by wind will travel in a straight and uninterrupted line to their point of deposition. Modelling techniques, however, are limited in their ability to account for the many sources of fugitive particles.

RESULTS

Hummock Hill

Particulate matter (PM_{10})

In both 1999 and 2000, PM_{10} concentrations at Hummock Hill exceeded the NEPM standard on seven days. As more than five days exceeded the standard of 50 µg/m^3 in one year, 1999 and 2000 did not comply with the NEPM goal. Exceedences of the goal also occurred between 1990 and 1992. As particulate monitoring is conducted on one day in six, the actual number of exceedences would in reality be much higher. For example, in 2000 the NEPM standard was exceeded on 7 days over 45 days of sampling. The NEPM standard could have potentially been exceeded on 56 days if that sampling regime was extrapolated over the whole year. This is more than 11 times the allowable number of exceedences (NEPM goal).

Table 2. Annual NEPM standard exceedences of PM_{10} at Hummock Hill, Whyalla 1989–2000

Year	Number of NEPM Standard Exceedences (days)	Highest (µg/m^3)	2nd Highest (µg/m^3)	6th Highest (µg/m^3)	90th Percentile (µg/m^3)	Number of Samples
1990	10*	123	118	67	66	55
1991	7*	100	88	55	59	45
1992	10*	96	93	72	68	61
1993	3	141	87	39	38	61
1994	2	93	62	44	35	58
1995	5	123	91	48	48	54
1996	3	73	57	43	43	57
1997	2	92	79	43	43	47
1998	3	94	53	38	37	54
1999	7*	170	170	56	52	58
2000	7*	124	94	62	69	45

Note: 2000 data from January to September

*Not compliant with NEPM goal. The NEPM standard allows for five exceedences in a year. If more than five days exceeded the standard, then the site does not comply with the NEPM standard and goal for that year.
The standard and guidelines are used for evaluating long-term trends to assess the effectiveness of control strategies and the progress towards achieving the NEPM goal.

Figure 5 shows the number of exceedences as a bar graph. Poor ore handling and site management practices at the steel works are the most likely causes of the exceedences in 1999 and 2000. These problems are now being addressed (see page 24).

Annual NEPM standard exceedences and the NEPM goal

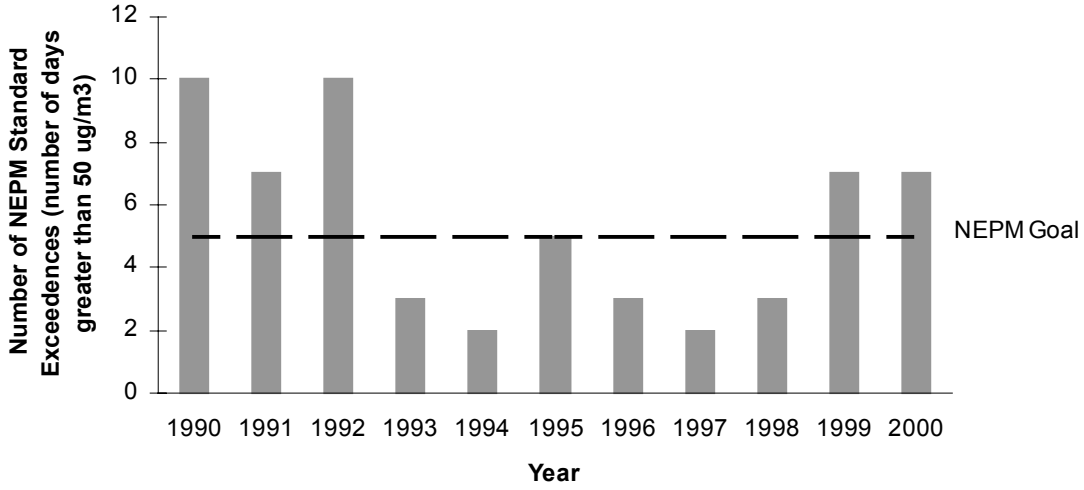


Figure 5. Annual number of NEPM standard exceedences of PM_{10} at Hummock Hill

The graph (figure 6) shows the variability of PM_{10} throughout the year. On each of the seven days when the PM_{10} NEPM standard (50 µg/m³) was exceeded, TSP also exceeded the WHO 24-hour air quality guideline (120 µg/m³) (figure 11).

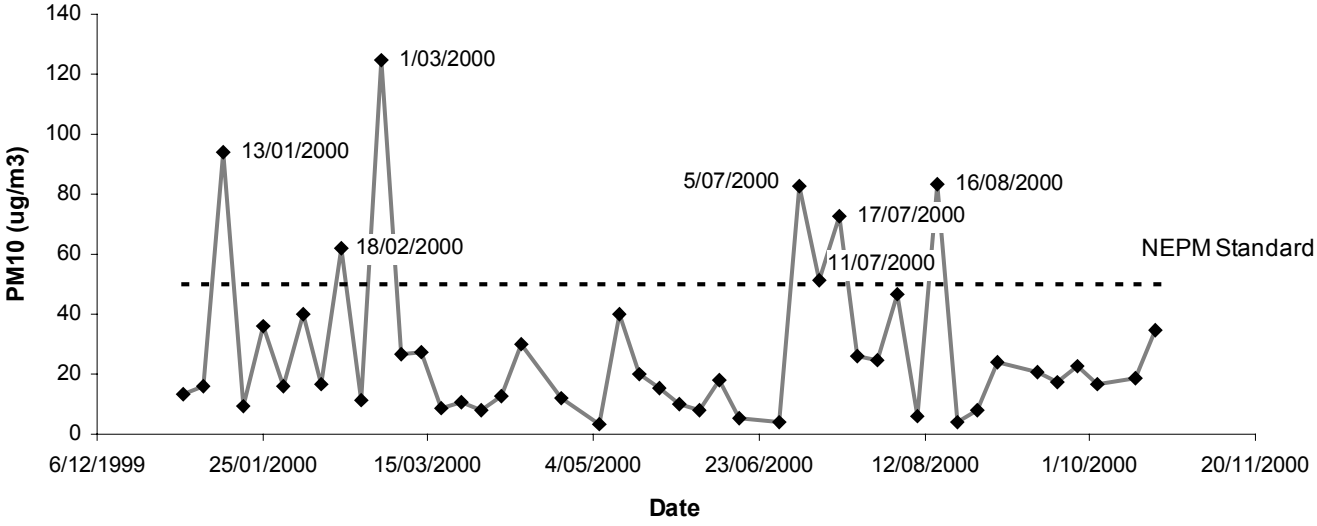


Figure 6. All PM_{10} samples at Hummock Hill in 2000 and the dates of individual exceedences of the NEPM standard

The graph (figure 7) shows the variability of PM_{10} since 1990 and the NEPM standard.

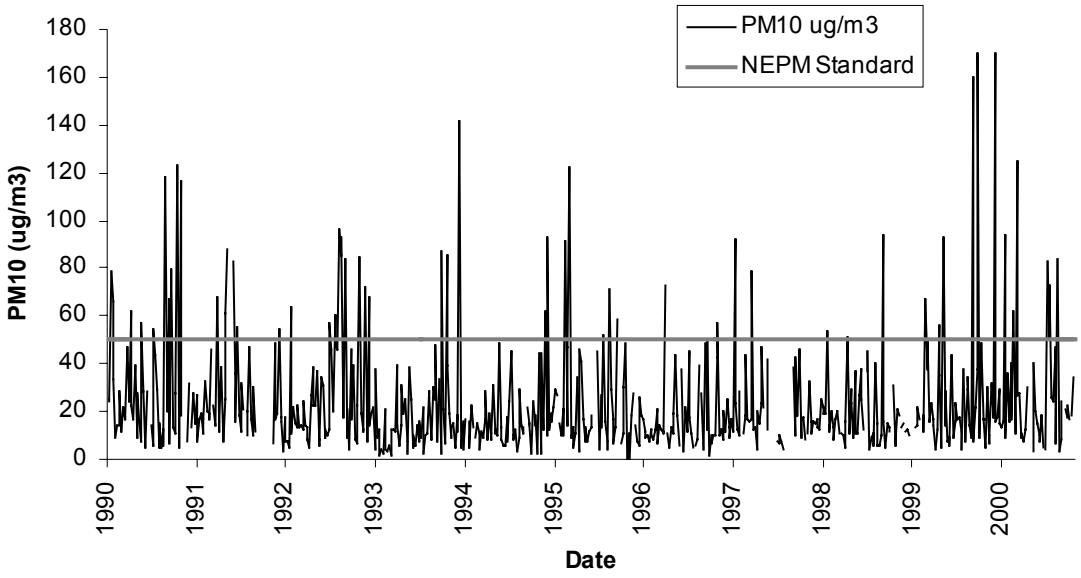


Figure 7. All PM_{10} samples at Hummock Hill since 1990 and the NEPM standard

Annual maximum PM_{10}

Annual maxima have exceeded the NEPM each year since monitoring commenced. However, between 1993 and 1998 PM_{10} values were less than the NEPM standard for 90% or more of the time (as shown by the 90th percentile line on figure 8).

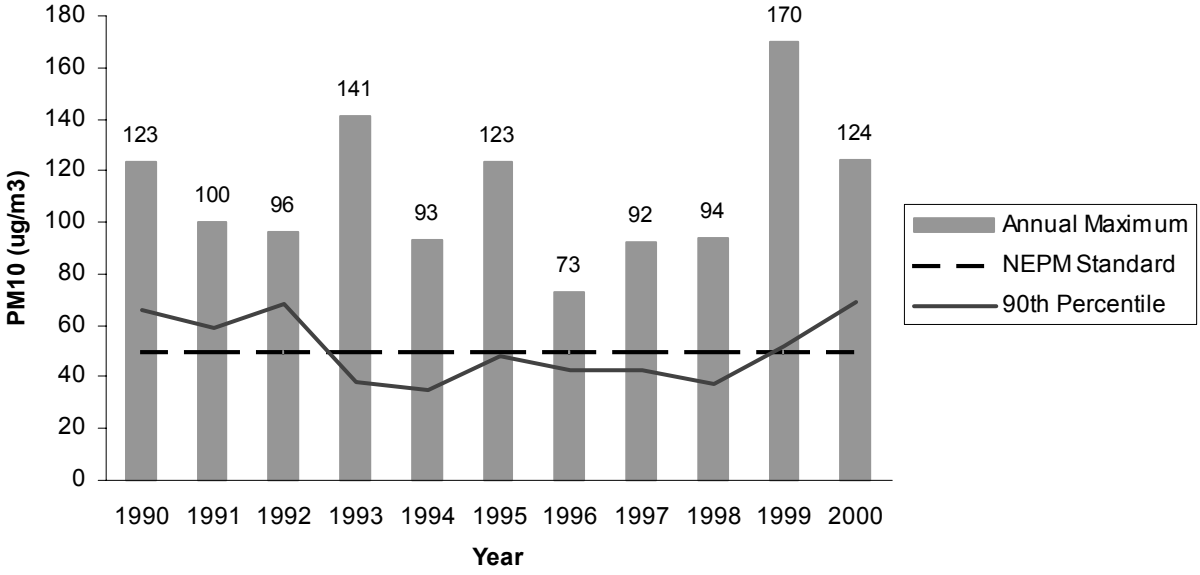


Figure 8. Annual maximum PM_{10} concentrations at Hummock Hill

Monthly maximum PM_{10} during 2000

In 2000 (excluding October, November and December) monthly maxima and 90th percentiles exceeded the NEPM standard on a number of occasions (figure 9).

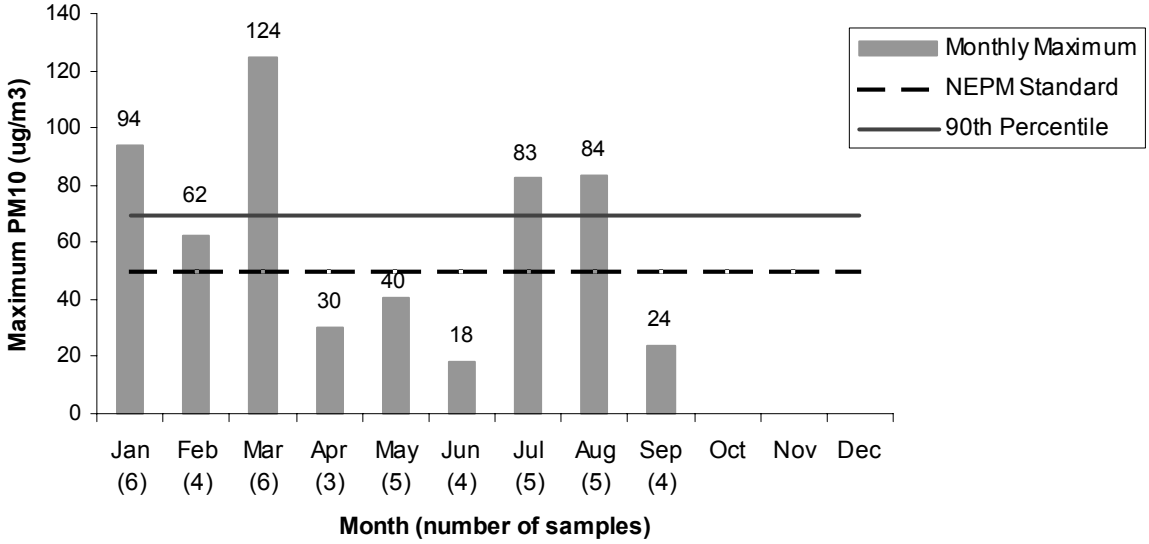


Figure 9. Monthly maximum PM_{10} concentrations at Hummock Hill in 2000

Total suspended particulates (TSP)

In 1999 and 2000 annual average TSP concentrations at Hummock Hill exceeded the NHMRC annual guideline (90 μg/m³). The 24-hour WHO guideline (120 μg/m³) was exceeded 25 times in the last two years, based on a sampling regime of one in six days.

Table 3. Annual exceedences of TSP at Hummock Hill, Whyalla 1989–2000

Year	WHO Guideline Exceedences	Annual Average (μg/m³)	Highest (μg/m³)	2nd Highest (μg/m³)	90th Percentile (μg/m³)	Number of Samples
1989	6	80	581	496	131	50
1990	9	74	309	286	158	60
1991	3	67	863	288	75	43
1992	12	77	567	241	168	59
1993	6	63	463	253	118	59
1994	2	46	248	129	97	59
1995	9	64	303	227	139	57
1996	8	57	185	159	141	57
1997	6	61	429	415	113	57
1998	6	60	360	161	128	56
1999	14	103*	823	630	203	57
2000	11	106*	451	432	232	46

Note: 2000 data from January to October

*Exceeds NHMRC annual average guideline of 90 μg/m³

WHO guideline exceedences

In 2000 the WHO guideline was exceeded 11 times based on a sampling regime of one in six days (figure 10).

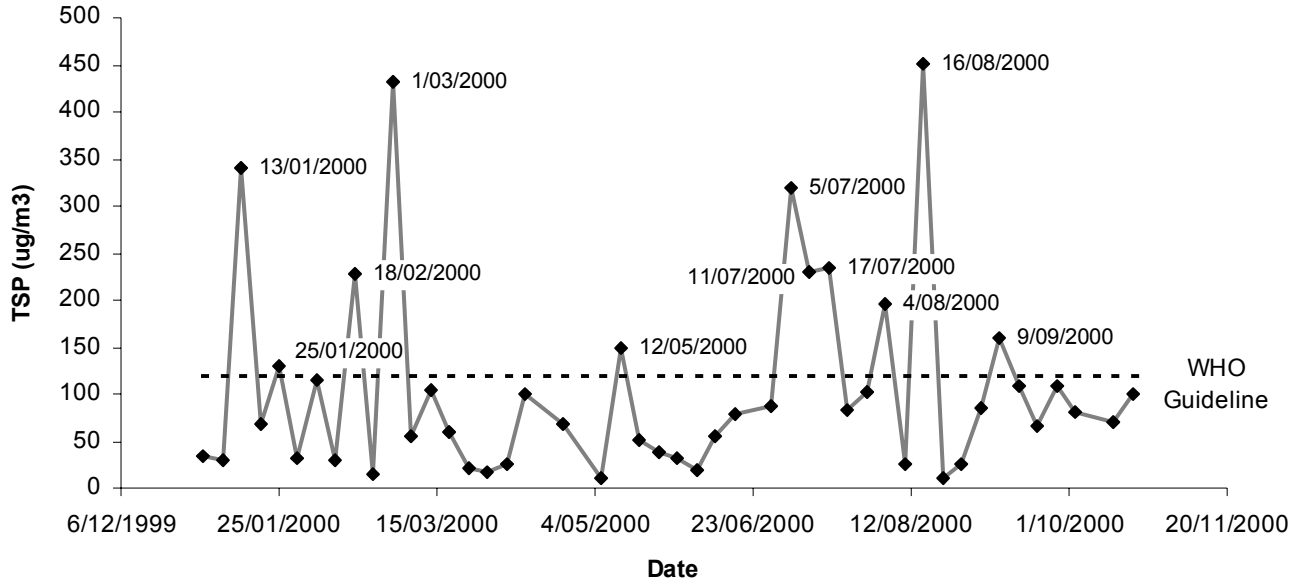


Figure 10. All TSP samples at Hummock Hill in 2000 and the dates of individual exceedences of the WHO guideline

The graph (figure 11) shows the variability of TSP since 1989 and the WHO guideline.

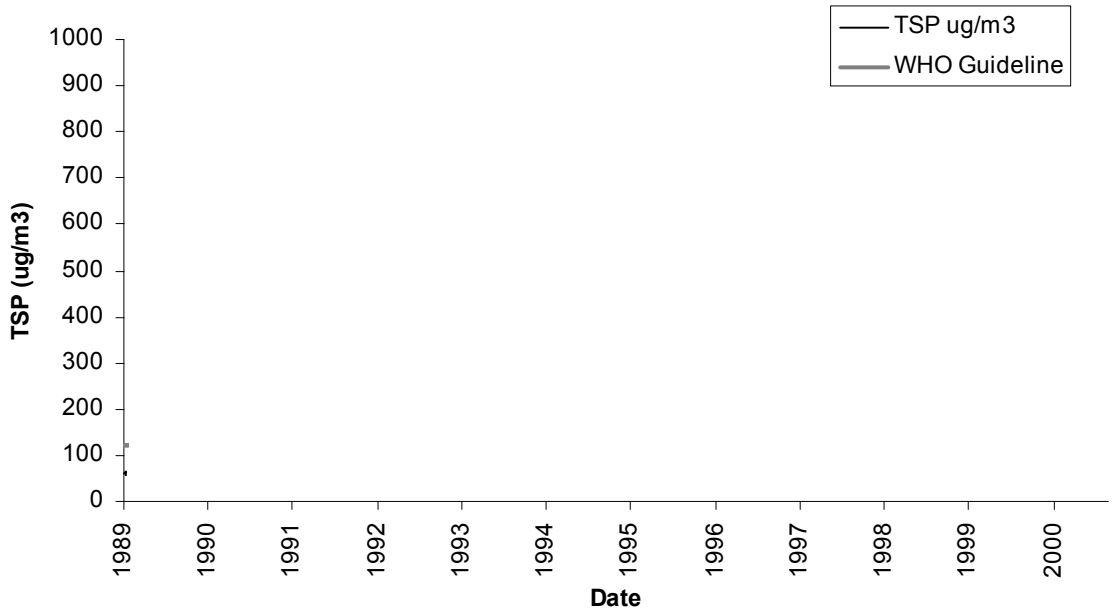


Figure 11. All TSP samples at Hummock Hill since 1989 and the WHO guideline

Annual average and maximum TSP

Annual average TSP values exceeded the NHMRC guideline in 1999 and 2000. The 90th percentile TSP values are at their highest levels in 1999 and 2000 (figure 12).

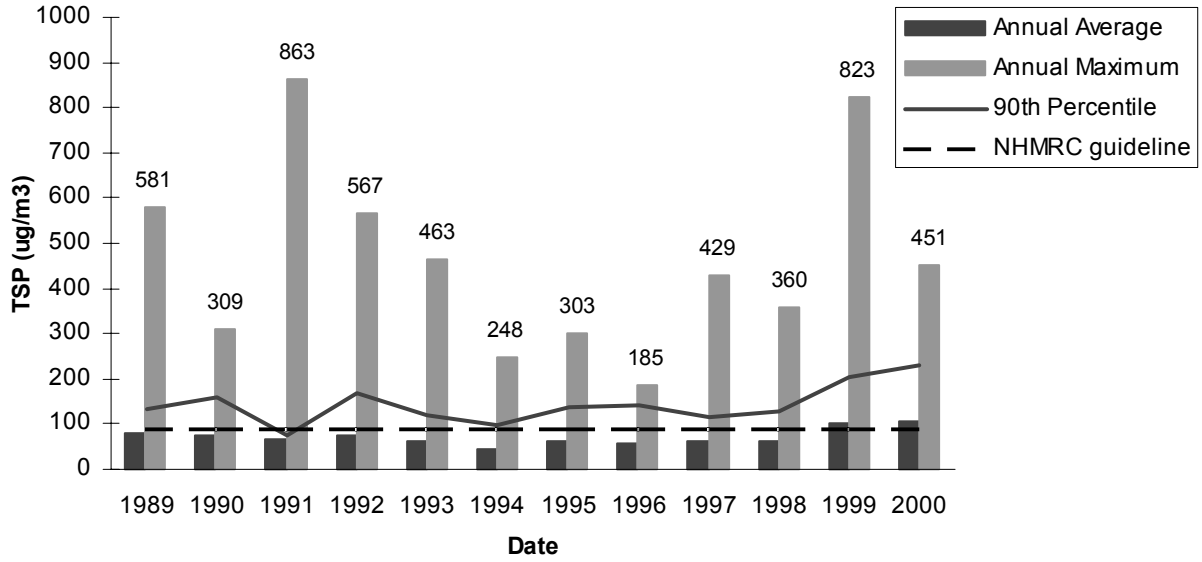


Figure 12. Annual average and maximum TSP at Hummock Hill

Civic Park

Total suspended particulates (TSP)

At Civic Park, particulate levels in all years were below the annual average NHMRC guideline of 90 µg/m^3. No 24-hour samples exceeded the WHO guideline in 2000.

Table 4. Annual exceedences of TSP at Civic Park, Whyalla 1989–2000

Year	WHO Guideline Exceedences	Annual Average (µg/m^3)	Highest (µg/m^3)	2nd Highest (µg/m^3)	90th Percentile (µg/m^3)	Number of Samples
1989	0	30	88	83	51	49
1990	0	31	111	88	53	60
1991	0	31	98	88	56	45
1992	0	31	96	80	53	59
1993	0	40	105	103	75	61
1994	1	45	120	91	82	60
1995	0	34	91	79	65	57
1996	2	52	142	123	98	58
1997	1	47	203	119	82	57
1998	2	40	184	143	75	54
1999	2	38	147	124	73	54
2000	0	31	92	90	58	47

Note: 2000 data from January to October

WHO guideline exceedences

The WHO guideline was not exceeded in 2000 (figure 13).

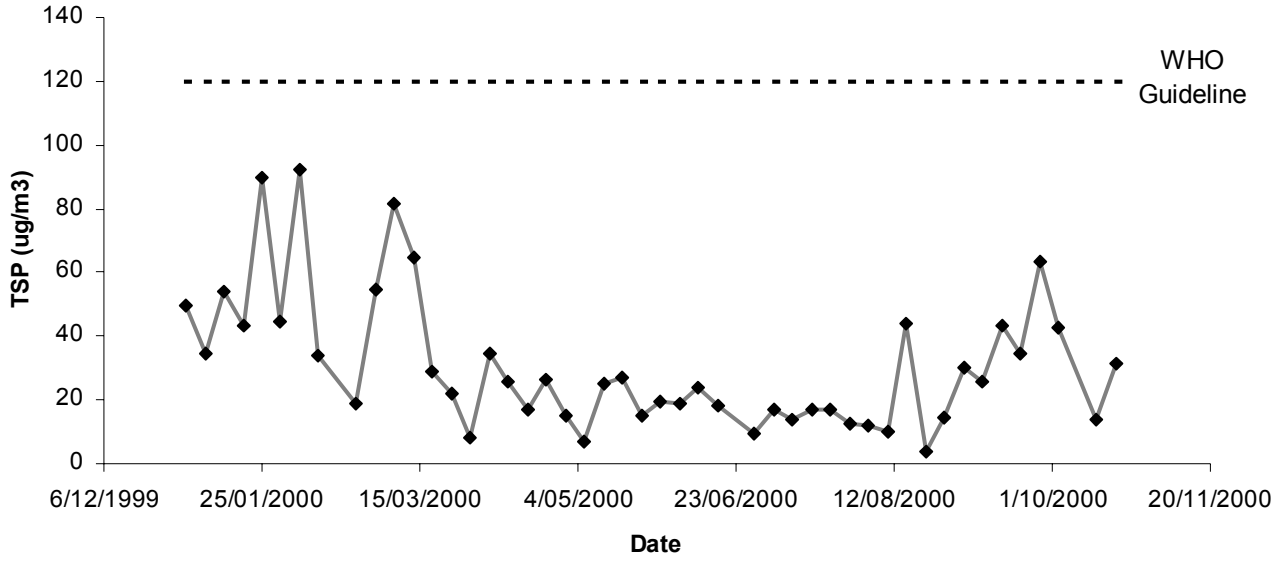


Figure 13. All TSP samples at Civic Park in 2000 and the WHO guideline

The graph (figure 14) shows the variability of TSP since 1989 and the WHO guideline.

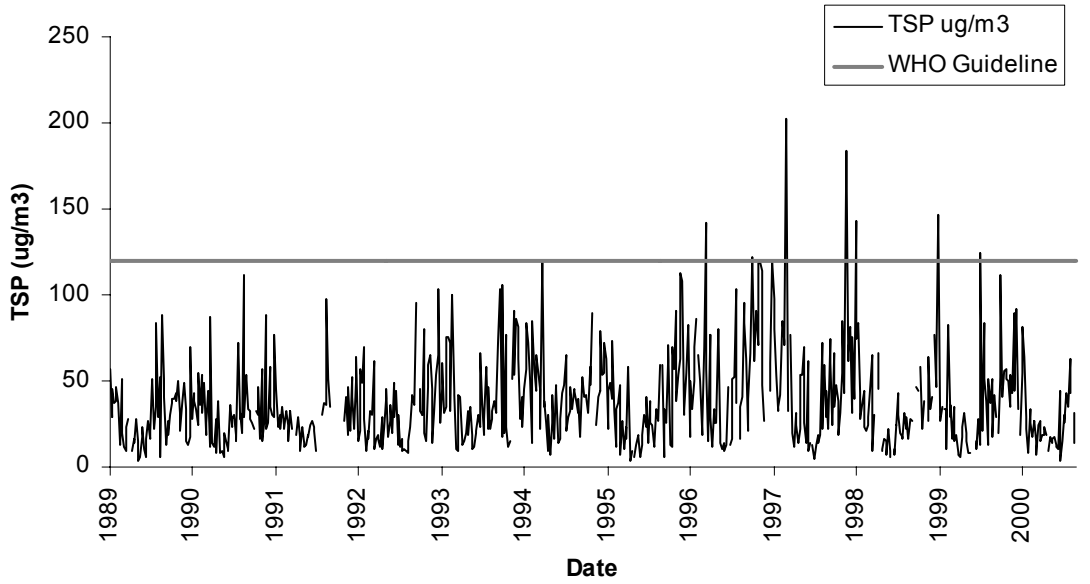


Figure 14. All TSP samples at Civic Park since 1989 and the WHO guideline

Annual average and maximum TSP

Annual average TSP values were below the NHMRC guideline in all years. The 90th percentile TSP values are at their highest levels in 1996 (figure 15).

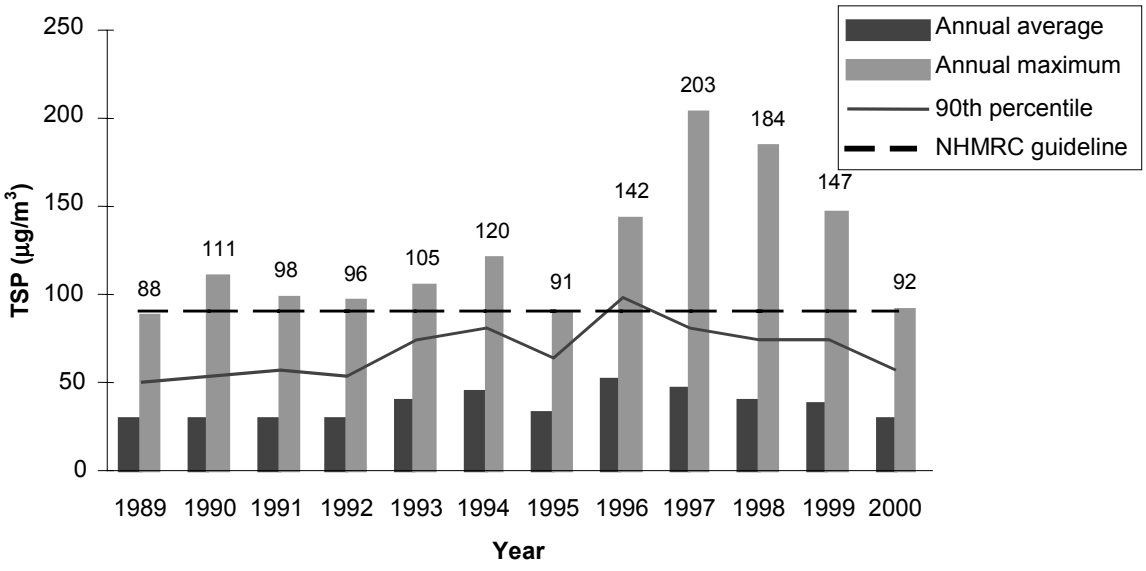


Figure 15. Annual average and maximum TSP at Civic Park

Whitehead Street

Total suspended particulates (TSP)

In 2000, TSP concentrations at Whitehead Street exceeded the 24-hour WHO guideline (120 µg/m³) on four days. The annual average complied with the NHMRC annual guideline (90 µg/m³); however, the data was only collected over 10 months.

Although the 90th percentile is below the WHO 24-hour guideline (figure 17), the guideline could have potentially been exceeded on 13 days if the data was extrapolated over the whole 10 months.

Unlike Hummock Hill, which is situated on the boundary of the pellet plant, the Whitehead Street site is considered to more accurately represent worst case residential exposure to particles.

Table 5. Annual exceedences of TSP at Whitehead Street, Whyalla 2000

Year	WHO Guideline Exceedences	Annual Average (µg/m³)	Highest (µg/m³)	2nd Highest (µg/m³)	90th Percentile (µg/m³)	Number of Samples
2000	4	46	202	153	86	90

Note: 2000 data from March to December

WHO guideline exceedences

The WHO guideline was exceeded four times, based on a sampling regime of one in six days in 2000 (figure 16).

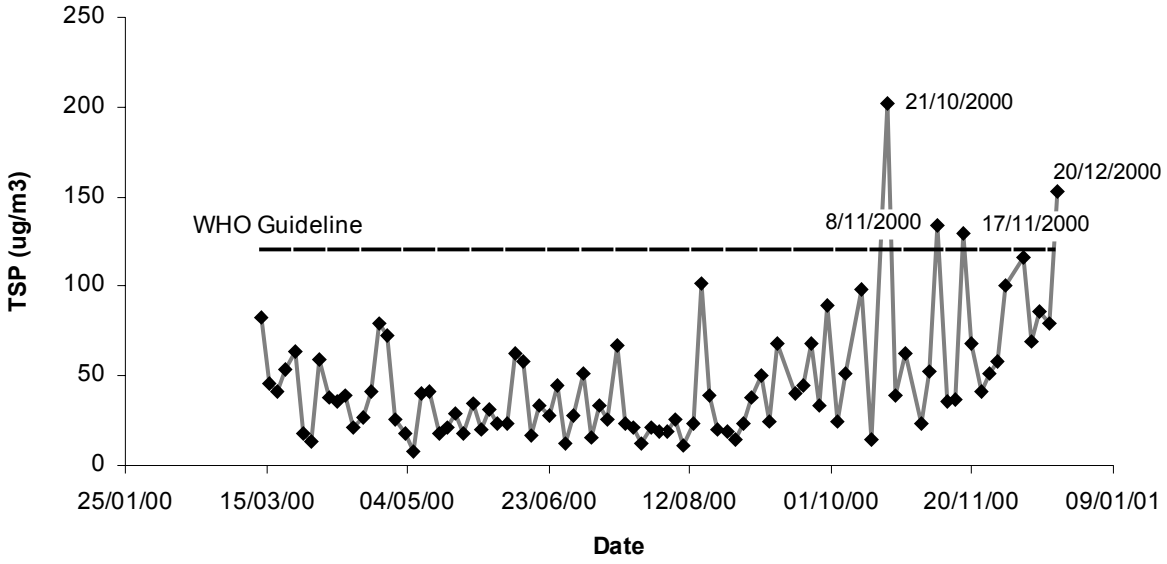


Figure 16. All TSP samples at Whitehead Street in 2000 and the dates of individual exceedences of the WHO guideline

Monthly maximum TSP

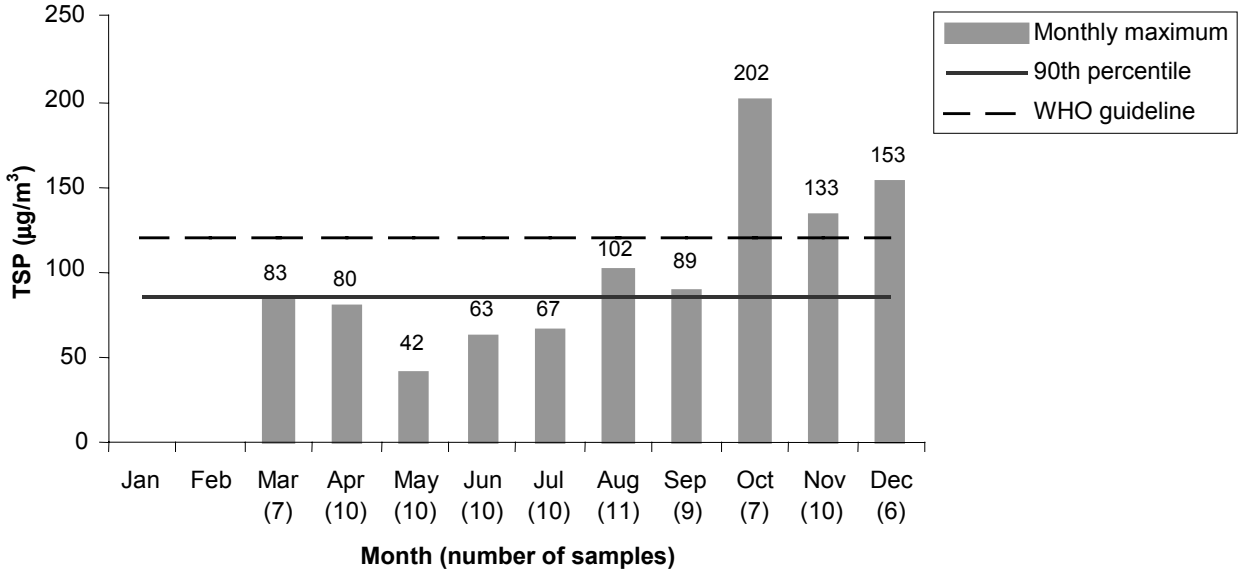


Figure 17. Monthly maximum TSP at Whitehead Street in 2000

Comparing TSP levels at the three Whyalla sites in 2000

It is important to determine whether there are statistically significant differences between monitoring sites. The variation in some data can be substantial but may not be significant from a statistical viewpoint.

Wilcoxon signed ranks test demonstrated that for TSP there is a significant difference between all three sites ($P<0.0005$).

TSP iron and manganese concentrations

Particulate matter originating from the steel works will contain iron and manganese. Both metals were measured as a proportion of total suspended particulates over each 24-hour sampling period. There was a significant association between TSP and iron at Hummock Hill ($R^2 = 0.853$, $P<0.0005$), an association at Civic Park ($R^2 = 0.720$, $P<0.0005$) and a poor association at Whitehead Street ($R^2 = 0.448$, $P<0.0005$). Similar results were observed between TSP and manganese: Hummock Hill ($R^2 = 0.853$, $P<0.0005$), Civic Park ($R^2 = 0.554$, $P<0.0005$), Whitehead Street ($R^2 = 0.425$, $P<0.0005$). The poor association at Whitehead Street may suggest that the site is impacted from another source of particles.

As the three sites are impacted by particles from the steel works from different wind directions, there is no association between sites for either TSP or metals.

The tables below summarise the heavy metal concentration in particles sampled from the three sites. There are no widely used health guidelines for either metal. The site closest to the steel works at Hummock Hill had the highest levels of metals, followed by Whitehead Street as the next closest, and Civic Park, which is situated furthermost from the pellet plant.

Wilcoxon signed ranks test demonstrated that for iron there was a significant difference between all sites ($P<0.0005$ between Civic Park and the other two sites; $P<0.005$ between Hummock Hill and Whitehead Street) on dates when all three sites were sampled. No conclusion is reached from this statistical difference. The difference between sites may simply be due to dilution but may also be due to other sources of particles.

Table 6. TSP iron in 2000

Monitoring Site	Annual Average ($\mu g/m^3$)	Maximum ($\mu g/m^3$)	10th Percentile ($\mu g/m^3$)	90th Percentile ($\mu g/m^3$)	Number of Samples
Hummock Hill	15.31	87.76	0.80	44.70	41
Whitehead Street	2.92	14.84	0.35	7.66	74
Civic Park	0.89	3.17	0.15	2.04	42

Note: 2000 data from March to December

Iron concentrations from the three sites in 2000 are shown in the graph below.

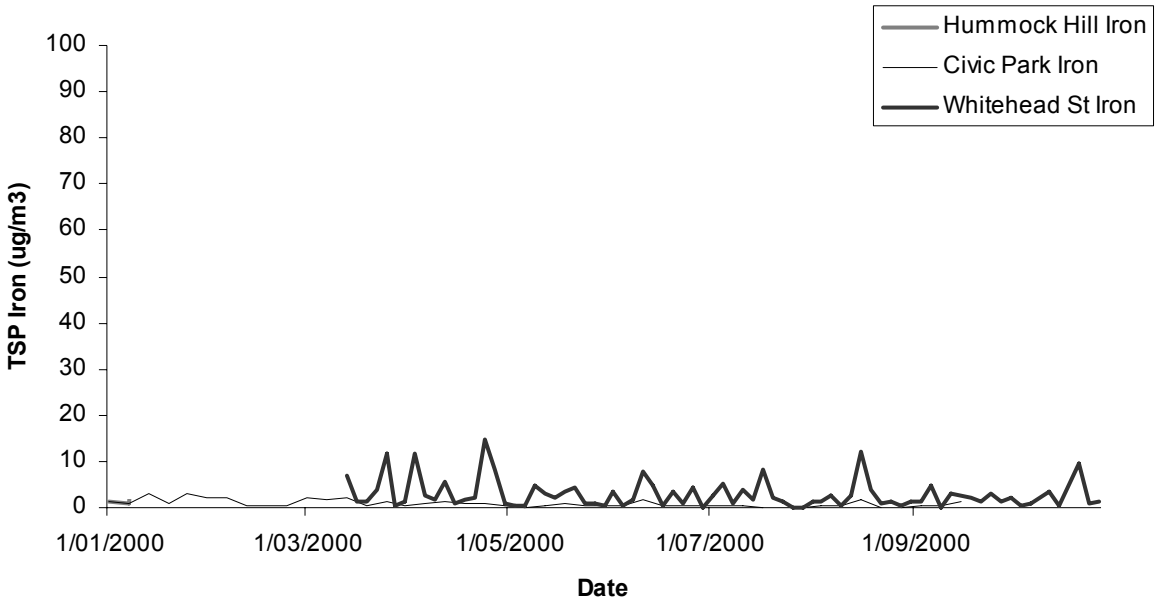


Figure 18. TSP iron concentrations at each site during 2000

Wilcoxon signed ranks test demonstrated that for manganese there was a significant difference between sites ($P<0.0005$ between Civic Park and the other two sites; $P<0.005$ between Hummock Hill and Whitehead Street) on dates when all three sites were sampled.

Table 7. TSP manganese in 2000

Monitoring Site	Annual Average ($\mu g/m^3$)	Maximum ($\mu g/m^3$)	10th Percentile ($\mu g/m^3$)	90th Percentile ($\mu g/m^3$)	Number of Samples
Hummock Hill	0.23	1.10	0.013	0.75	41
Whitehead Street	0.09	0.43	0.007	0.23	74
Civic Park	0.02	0.09	0.003	0.06	42

Note: 2000 data from March to December

Iron and manganese were also measured from the PM_{10} sampler. A summary of the results is given below.

Table 8. PM_{10} iron and manganese at Hummock Hill in 2000

Metal	Annual Average ($\mu g/m^3$)	Maximum ($\mu g/m^3$)	10th Percentile ($\mu g/m^3$)	90th Percentile ($\mu g/m^3$)	Number of Samples
Iron	4.51	33.61	0.172	15.71	40
Manganese	0.06	0.32	0.0001	0.24	40

There is no correlation for iron or manganese between sites ($R^2 <0.1$). The lack of correlation is most likely attributed to variable wind patterns throughout the day so that each site, over a 24-hour sampling period, is impacted by dust from a number of sources.

Where are the particles coming from?

The wind roses below summarise the occurrence of winds near Hummock Hill, showing the wind's strength, direction and frequency. The percentage of calms is represented in the lower left corner of each diagram. Each branch represents wind coming from that direction, with north to the top of the diagram. The branches are divided into segments of different thickness, which represent wind speed ranges from that direction. For example, the thinnest segment represents winds between one and three metres/second. The length of each branch segment is proportional to the percentage of winds in that speed range, blowing from that particular direction.

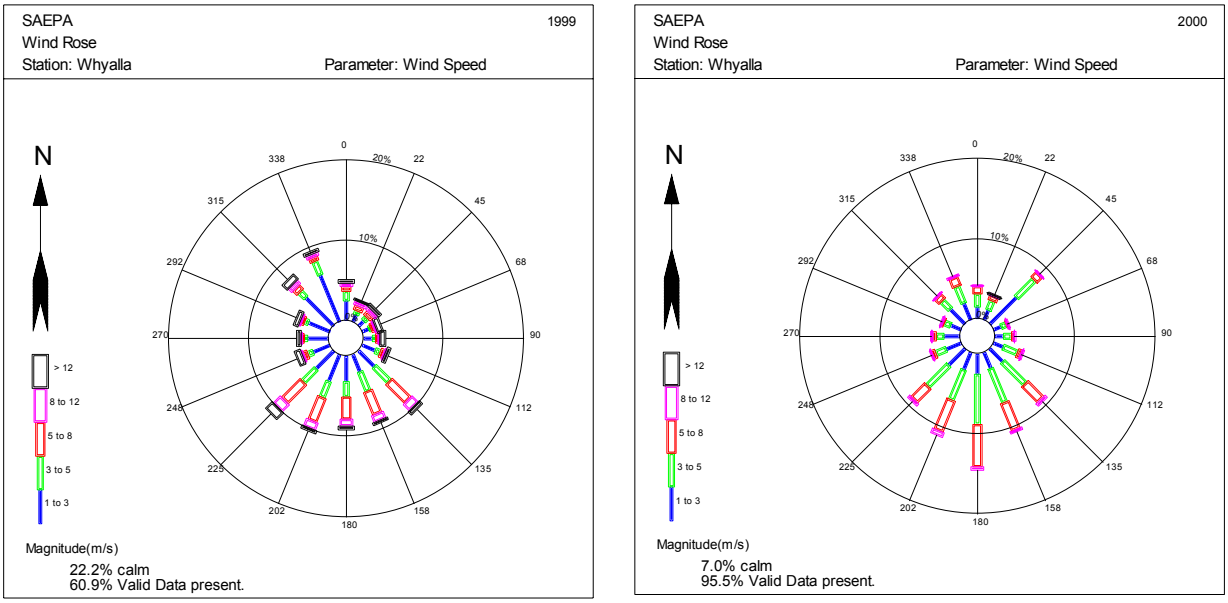


Figure 19. Wind roses for Whyalla near Hummock Hill in 1999 and 2000

The wind roses above (figure 19) show that the prevailing winds at Whyalla during 1999 and 2000 were from a southerly direction, meaning that dust from the steel works would mostly be transported north and in the opposite direction from Whyalla. There were, however, northerly and easterly winds of a velocity capable of transporting dust particles from the steel works towards Whyalla throughout 1999 and 2000.

Days of high TSP concentrations at Whitehead Street and Hummock Hill were assessed for wind direction and speed to determine the source of particles. High TSP days were defined as those exceeding the WHO guideline (120 µg/m^3). Wind speeds greater than 1.4 m/sec (5 km/hr) are considered strong enough to transport particles.

Table 9. High TSP levels at Whitehead Street in 2000 compared with daily wind direction and speed

Date	Daily TSP ($\mu g/m^3$)	Prevailing Wind Direction as a % of 24 hours	Average Daily Wind Speed m/sec {km/hr}
21/10/2000	201.5	ESE 55%, SE 10%, ENE 10%	2.5 {9.0}
08/11/2000	133.4	N 30%, NNE 20%, NNW 10%	5.2 {18.7}
17/11/2000	129.5	SSW 30%, S 30%, ESE 20%	3.8 {13.7}
20/12/2000	153.2	*Data not available*	3.0 {10.8}

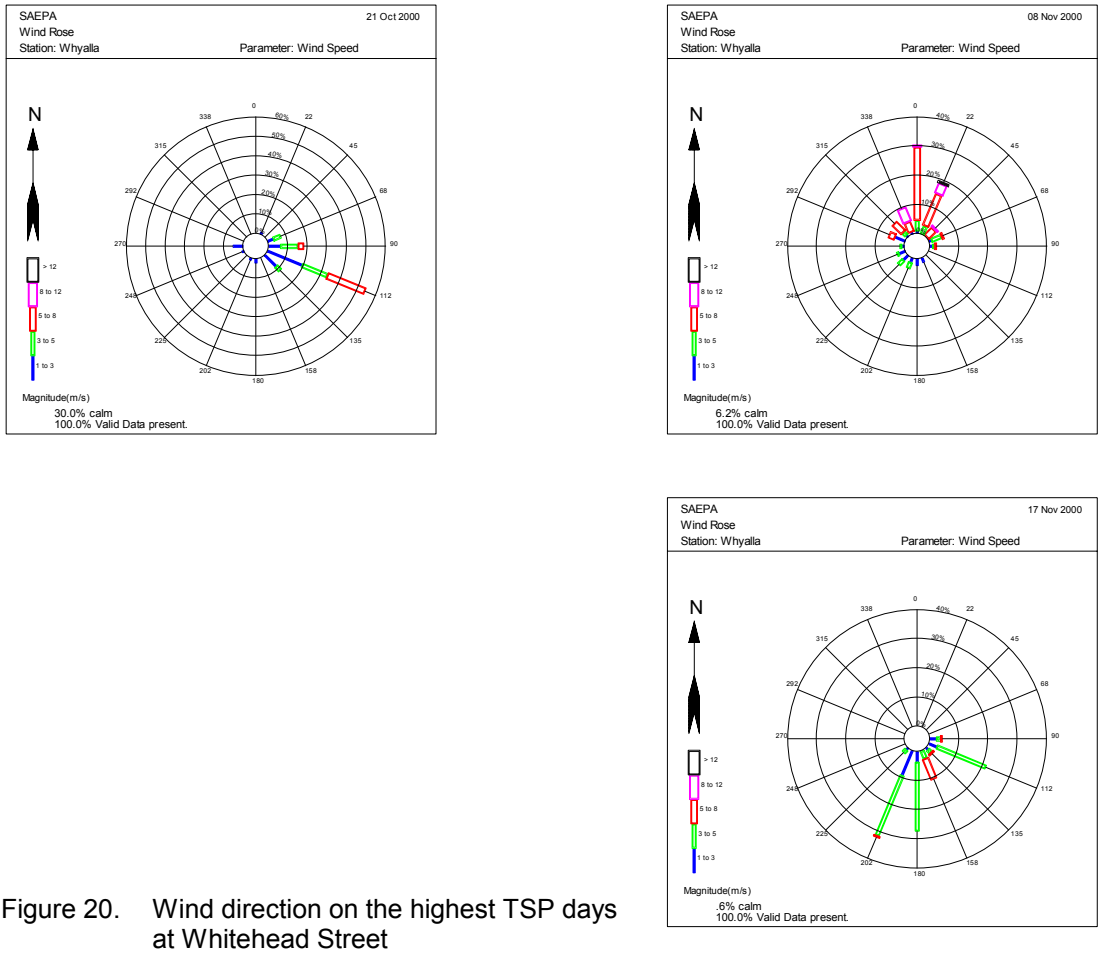


Figure 20. Wind direction on the highest TSP days at Whitehead Street

For the Whitehead Street site to be impacted by particles from the pellet plant, wind would need to be coming from approximately east-south-east (ESE) (112 degrees). The steel works' other operations—the continuous caster, rolling mill and blast furnace—are to the north of the Whitehead Street site. It is clear that particles on these high TSP days are from the direction of the pellet plant on two of the three days when meteorological data were available (table 9 and figure 20).

Table 10. High TSP levels at Hummock Hill in 2000 compared with daily wind direction and speed

Date	Daily TSP ($\mu g/m^3$)	Prevailing Wind Direction as a % of 24 hours	Average Daily Wind Speed m/sec {km/hr}
13/01/2000	341.2	NNE 10%, N 10%, NNW 10% NW 10%, NE 10%, SW 10%, ESE 10%, SE 10%	3.9 {14.0}
25/01/2000	129.0	S 15% SE 15% SW 15% SSE 15% SSW 15% NNW 5% NW 5%	2.7 {9.7}
18/02/2000	227.1	SW 25%, SE 20%, S 10%, SSE 10%, NNE 5%, N 5%	2.7 {9.7}
01/03/2000	432.0	NE 15%, NNE 10%, NW 10%, NNW 10%, SW 10%, N 5%, E 5%	3.2 {11.5}
12/05/2000	148.0	NE 25%, NNW 20%, NW 20%, NNE 20%, N15%	4.5 {16.2}
05/07/2000	318.2	NNE 30%, NE 20%, NW 15%, NNW 15%, N 15%	4.7 {16.9}
11/07/2000	229.6	NW 25%, N 20%, NNE 20%, NE 15%, NNW 15%	4.4 {15.8}
17/07/2000	235.0	N 60%, NNW 20%	2.1 {7.6}
04/08/2000	196.3	NE 30%, S 15%, SSW 10%, E 10%	2.7 {9.7}
16/08/2000	451.5	ENE 25%, NE 20%, E 20%, NNE 10%	3.9 {14.0}
09/09/2000	160.2	S 30%, W 20%, NW 15%, WNW 15%	3.2 {11.5}

Note: 2000 data only to October. On 21/10/2000, a corresponding high TSP day at Whitehead Street, TSP at Hummock Hill was 100.7 $\mu g/m^3$.

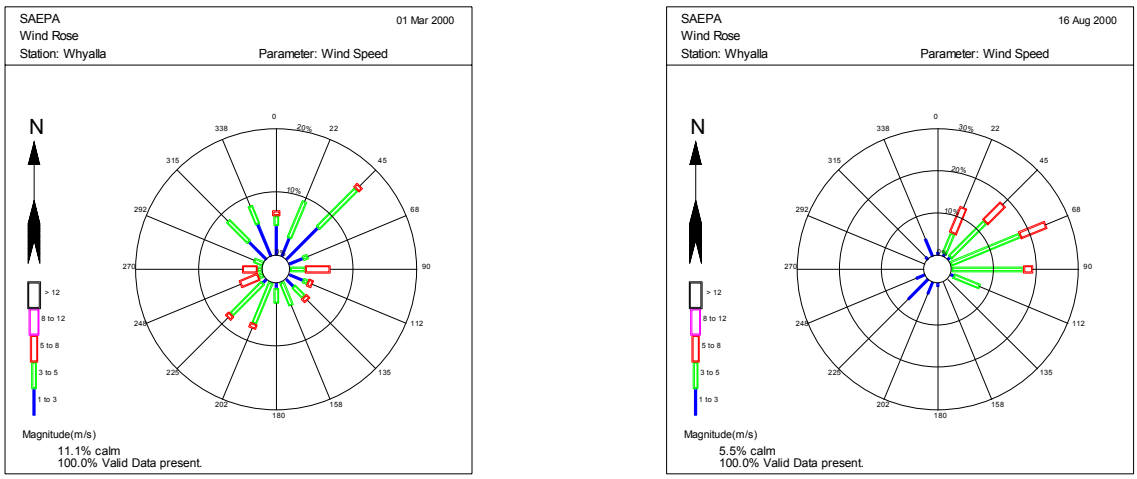


Figure 21. Wind direction on the two highest TSP days at Hummock Hill

For the Hummock Hill site to be impacted by particles from the pellet plant, wind would need to be coming from a north-easterly (NE) direction (45 degrees). On the two days exhibiting the highest levels of TSP, the prevailing wind was from the north-east. Other OneSteel operations are located to the north and north-west of Hummock Hill. On each occasion when TSP values exceeded the 24-hour guideline, the wind on that day, for a significant period of time, was from a northerly direction. On five days when TSP levels were lowest (less than 20 g/m^3), wind direction was principally from a southerly direction (table 10 and figure 21).

How much particulate matter comes from the steel works?

For TSP and metals, Civic Park is significantly different from Hummock Hill. Given the right wind conditions, it is therefore assumed that the Civic Park site represents background levels for particles in Whyalla without the influence of the steel works.

On those days when TSP exceeded the 24-hour guideline, it was demonstrated that northerly wind directions were transporting particles from the steel works to Hummock Hill. On the same days, TSP levels at Civic Park were very low. Wind on these days meant that particles from the direction of the pellet plant would not be carried to Civic Park.

On the four highest TSP days at Civic Park the prevailing wind direction was southerly. There were virtually no winds from the east (100 degrees)—the direction of the pellet plant.

On the 11 days when the TSP 24-hour WHO guideline was exceeded at Hummock Hill, the results of TSP were subtracted from background levels measured at Civic Park. The results indicate that nearly all the particles (and probably associated iron) originate from the steel works.

Table 11. Steel works contribution to particulate levels at Hummock Hill

Date	TSP at Hummock Hill ($\mu g/m^3$)	TSP at Civic Park (background) ($\mu g/m^3$)	Contribution of Steel Works to TSP at Hummock Hill ($\mu g/m^3$)	Contribution of Steel Works to TSP at Hummock Hill (%)
13/01/2000	341.2	53.9	287.3	84
25/01/2000	129.0	89.9	39.1	30*
18/02/2000	227.1	*No data*	*No data*	*No data*
01/03/2000	432.0	54.4	377.6	87
12/05/2000	148.0	24.8	123.2	83
05/07/2000	318.2	16.9	301.3	95
11/07/2000	229.6	13.8	215.7	94
17/07/2000	235.0	16.9	218.1	93
04/08/2000	196.3	11.9	184.4	94
16/08/2000	451.5	44.1	407.4	90
09/09/2000	160.2	25.8	134.4	84

* Only on 25/1/2000 did the steel works contribute a smaller fraction of TSP. On this day the wind was coming primarily from a southerly direction, which would have transported particles from the steel works away from Whyalla. The wind on this day came from a northerly direction for 10% of the time.

What is the EPA doing to reduce particulates?

To reduce the impact of the OneSteel operation on the residents of the eastern end of Whyalla, the Environment Protection Authority (the Authority) has required OneSteel to prepare an Environment Improvement Program (EIP) aimed at reducing the emission of dust from their site by 30% over the next two years. This EIP has been submitted to the Authority and the company is now undertaking works outlined in the program. Prior to compiling the EIP, OneSteel undertook a survey of significant dust sources from their operations and prioritised a number of projects aimed at addressing emissions from these sources. These projects are a combination of operating, maintenance and capital works, involving the expenditure of more than $4 million over three years. The EIP has been assessed by the Environment Protection Agency (EPA) for its content and suitability.

The EPA is currently auditing on a quarterly basis OneSteel's progress towards meeting the commitments of its EIP. This audit involves a site visit where works and initiatives undertaken in the previous quarter are presented, followed by a plant tour to verify works completed and housekeeping standards on site. These audits will continue and the EIP and dust emission reduction target will be reviewed regularly.

The current OneSteel EIP contains projects to be completed over a three-year time frame. It is impossible to quantify the exact impact of each project on Whyalla's east-end air quality, and whether in fact the projects listed in the works program will result in the air quality meeting the requirements of the Air NEPM. Hence the requirement for auditing and reviewing the progress and content of the EIP on a quarterly basis. The projects are anticipated, however, to result in an incremental improvement of air quality above that currently experienced.

OneSteel are currently working cooperatively with the Authority in attempting to reduce the impact of their dust emissions on the residents of the eastern end of Whyalla. This is evidenced by the timely completion of their commitments under the EIP and regular updates and reviews of the EIP. Providing this continues, the Authority is unlikely to take further regulatory action. This approach is consistent with the Authority's preferred policy of achieving environmental improvement through cooperation and negotiation.

Figure 22. A water truck prevents fugitive particles escaping from roads at the pellet plant (photograph: EPA, August 2001)

Works recently initiated by OneSteel include paper coverings and vegetation on waste ore mounds, a shed for rail off-loading facilities, railway water sprays and walls of material to prevent ore dust escaping from the pellet plant. The work continues.

CONCLUDING REMARKS

Ambient air quality, as determined by the concentration of airborne particulates in Whyalla, varied between sites. At Civic Park, the monitoring site furthest away from the steel works, particulate levels (as TSP) were well below the WHO guideline. At Whitehead Street, an area comprising some residential land use and reasonably close to the steel works, the air quality (TSP) during 2000 exceeded the WHO guideline on four occasions. At Hummock Hill, the monitoring site closest to the steel works and in close proximity to businesses and residences, the air quality during 1999 and 2000 was poor, frequently exceeding the NEPM standard for PM_{10} and the WHO and NHMRC air quality guidelines for TSP.

Analysis of wind direction and speed clearly demonstrated that airborne particles, on days when air quality guidelines were exceeded, were transported from the direction of OneSteel's operations. When compared with background levels from Civic Park, particles sourced from the steel works were estimated to contribute up to 95% of airborne particulate matter, leading to exceedences of the air quality NEPM standard at Hummock Hill, during ten days in 2000.

The higher proportions of metals in dust at Hummock Hill and Whitehead Street are sourced from the steel works. High concentrations of iron pose an amenity problem for the residences of Whyalla as dust containing iron settles on surfaces, staining them red.

The EPA is working closely with OneSteel to develop a more thorough site management program to reduce particulate levels, and is regularly auditing progress towards this end.

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APPENDIX

Hummock Hill site metadata

Site Information (Metadata)	
Site name	Hummock Hill Site 0830 (TSP), 0831 (PM_{10}), 0184 (Meteorology)

Site Details	
Street address	Gay Street, Whyalla
Date established	05/03/1989
Date terminated	Ongoing
Siting guidelines (AS 2922–1987) exceptions	None
Description of surrounding land use	Open parkland 300 metres from steel work pellet plant
Description of nearby emission sources	OneSteel pellet plant (foundry)

Map Coordinates	
Datum	AGD 84
Projection	AMG Zone 53
Easting	741700
Northing	6341600

Notes on data validation and assessment

Zero, span, calibration equation parameters & quality assurance procedures

Data validated and checked in accordance with NEPM requirements

Notes of time and nature of events that may influence data validation or interpretation

Due to sampling difficulties, PM_{10} data from October 2000 were considered inaccurate and not included in the analysis.

Pollutants Measured

Particulate matter (PM_{10}), PM_{10} iron and manganese	Particulate matter (TSP), TSP iron and manganese

Instrument Types

Make	Control Engineering	Make	Control Engineering
Model	PM_{10} Hi-Vol Sampler	Model	TSP Hi-Vol Sampler
Serial number		Serial number	
Minimum detection level	N/A	Minimum detection level	N/A
Units	$\mu g/m^3$	Units	$\mu g/m^3$
Sampling rate	At least one day in every 6	Sampling rate	At least one day in every 6
Logging interval of raw data	24 hours	Logging interval of raw data	24 hours
Data return	N/A	Data return	N/A
Clock adjustment equation	N/A	Clock adjustment equation	N/A

Civic Park site metadata

Site Information (Metadata)	
Site name	Civic Park Site 0820 (TSP)

Site Details	
Street address	Searle Street, Whyalla
Date established	05/03/1989
Date terminated	Ongoing
Siting guidelines (AS 2922–1987) exceptions	None
Description of surrounding land use	Open parkland surrounded by residential, 5 km from steel works pellet plant
Description of nearby emission sources	OneSteel pellet plant (foundry)

Map Coordinates	
Datum	AGD 84
Projection	AMG Zone 53
Easting	736930
Northing	6342730

Pollutants Measured
Particulate matter (TSP), TSP iron and manganese

Instrument Types	
Make	Control Engineering
Model	TSP Hi-Vol Sampler
Serial number	
Minimum detection level	N/A
Units	µg/m^3
Sampling rate	24 hours
Logging interval of raw data	At least one day in every 6
Data return	N/A
Clock adjustment equation	N/A

Notes on data validation and assessment
Zero, span, calibration equation parameters & quality assurance procedures
Data validated and checked in accordance with NEPM requirements
Notes of time and nature of events that may influence data validation or interpretation
No events that influenced data

Whitehead Street site metadata

Site Information (Metadata)	
Site name	Whitehead Street Site (TSP)

Site Details	
Street address	Whitehead Street, Whyalla
Date established	05/03/1989
Date terminated	Ongoing
Siting guidelines (AS 2922–1987) exceptions	None
Description of surrounding land use	Residential, 700 metres from steel work pellet plant
Description of nearby emission sources	OneSteel pellet plant (foundry)

Map Coordinates	
Datum	AGD 84
Projection	AMG Zone 53
Easting	741700
Northing	6341600

Pollutants Measured
Particulate matter (TSP), TSP iron and manganese

Instrument Types	
Make	Control Engineering
Model	TSP Hi-Vol Sampler
Serial number	
Minimum detection level	N/A
Units	$\mu g/m^3$
Sampling rate	24 hours
Logging interval of raw data	At least one day in every 6
Data return	N/A
Clock adjustment equation	N/A

Notes on data validation and assessment
Zero, span, calibration equation parameters & quality assurance procedures
Data validated and checked in accordance with NEPM requirements
Notes of time and nature of events that may influence data validation or interpretation
No events that influenced data

Whyalla meteorological site metadata

Site Information (Metadata)	
Site name	Whyalla, Meteorological Site 0184 (MET)

Site Details	
Street address	Within OneSteel's Property
Date established	01/01/2000
Date terminated	Ongoing
Siting guidelines (AS 2922–1987) exceptions	None
Description of surrounding land use	Inside OneSteel's property
Description of nearby emission sources	OneSteel pellet plant (foundry)

Map Coordinates	
Datum	AGD 84
Projection	AMG Zone 53
Easting	741250
Northing	6342650

Notes on data validation and assessment
Zero, span, calibration equation parameters & quality assurance procedures
Data quality assurance checked
Notes of time and nature of events that may influence data validation or interpretation
No events that influenced data

Pollutants Measured
Meteorology – air temperature (^{o}C), total solar radiation (W/m^{2}), wind speed (m/s), wind direction (sigma theta, degrees), barometric pressure (mb).

Instrument Types	
Make	Uni data logger
Model	N/A
Serial number	N/A
Minimum detection level	N/A
Units	As above
Sampling rate	Continuous
Logging interval of raw data	10 minutes
Data return	N/A
Clock adjustment equation	N/A