Burrup Peninsula Air Pollution Study: Report for 2004/2005 and 2007/2008

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GLOSSARY

Simple definitions of various technical terms are given here to assist the reader. If required, the reader should look to other sources for more formal and technical definitions.

Aerosol	A suspension of fine solid, liquid or mixed-phase particles in air.
BTEX	Gaseous mixture of benzene, toluene, ethylbenzene, o-xylene, m-xylene and p-xylene.
CALM	Conservation and Land Management (WA Government).
CALPUFF	An air pollution dispersion model developed by Earth Tech Inc. (USA). It simulates the transport and diffusion of a plume via the puff approach in which a plume is described as consisting of a series of puffs. CALPUFF typically uses meteorological data generated by the processor CALMET.
CC	Conservation Commission (WA Government).
CMAR	CSIRO Marine and Atmospheric Research http://www.cmar.csiro.au).
CSIRO	Commonwealth Scientific and Industrial Research Organisation (http://www.csiro.au).
Deposition flux	deposition of mass in the form of gas, particle or rainwater to an area of ground over a particular period of time. General units are in mass per area per time.
DOIR	Department of Industry and Resources (WA Government).
GAW station	Global Atmosphere Watch stations are organised through the World meteorological Organisation. Bukit Koto Tabang, Indonesia and Tanah Rata, Malaysia are regional GAW stations.
GC/FID	Gas chromatograph with a flame ionisation detector.
HNO_3	Nitric acid gas.
Limit of detection	The lowest concentration detectable by a measurement system as the concentration of the substance being measured approaches zero.
LNG	Liquified natural gas. It is composed mainly of methane.
LPG	Liquefied petroleum gas. It is composed mainly of propane.
mg	Milligram (1 mg = 10^{-3} gram = 0.001 gram). One thousandth of a gram.

Milli-Q water	High purity water having resistivity of 18 MΩ·cm.
NH_3	ammonia gas.
nm	Nanometre (1 nm = 10^{-9} metre = 0.000000001 metre). One billionth of a metre.
NO_2	Nitrogen dioxide.
PM_{10}	Particulate matter in the air, with an aerodynamic diameter of 10 µm (micrometres) or less.
ppb	Parts per billion (by volume): a unit for the concentration of a gas in the atmosphere based on the mixing ratio approach. A concentration of 1 ppb is equivalent to a volume of 1 cubic metre of pure undiluted gas in 1 thousand million cubic metres of air. The expression ppb is without dimensions. The ppb unit is useful because its value is unaffected by changes in temperature and pressure, and also because many sampling techniques are based on volume concentrations. Concentrations of gaseous compounds can be converted from mixing ratio units, e.g. ppb units (volumetric), to density units, e.g. $\mu g\, m^{-3}$ (mass/volume), using the following formula: $$C(\mu g\, m^{-3}) = \frac{273.15 \times M_w \times C}{22.4136 \times (273.15 + T)}$$ where C is the concentration (ppb), Mw is the molecular weight of the gas, and T is the ambient temperature in degrees Celsius.
ppt	Parts per trillion (by volume): a unit of concentration of a gas in air. 1 ppt = 1 cubic metre in 1million million cubic metres of air.
SKM	Sinclair Knight Merz (an environmental consulting company).
SO_2	Sulfur dioxide gas.
TAPM	The Air Pollution Model. A prognostic meteorological and air pollution dispersion model developed by CSIRO Atmospheric Research (http://www.dar.csiro.au/tapm). The meteorological component of TAPM predicts the local-scale flow, such as sea breezes and terrain-induced circulations, given the larger-scale synoptic meteorology. The air pollution component uses the model-predicted three-dimensional meteorology and turbulence, and consists of a set of species conservation equations and an optional particle trajectory module.
TSP	Total Suspended Particulates all particles below about 50 µm in diameter suspended in the atmosphere.
µg	Microgram (1 µg = 10^{6} gram = 0.000001 gram). One millionth of a gram

µm	Micrometre (1 µm = 10^{-6} metre = 0.000001 metre). One millionth of a metre.
µg m^{-3}	microgram per cubic metre. 1 µg m^{-3} = one millionth of a gram per cubic metre of air.
µmol l^{-1}	one millionth of a mole per litre.
VWM	Volume weighted mean. A method used to calculate the average concentration of ions in rainwater. This accounts for variability in rainwater sample volumes and allows larger samples to influence the average compared with smaller samples.

1. EXECUTIVE SUMMARY

The Burrup Peninsula is located in the Pilbara area of Western Australia, northeast of Dampier. It is bounded by latitude 20.42 °S and 20.65 °S and longitude 116.71 °S and 116.90 °S comprising about 110 km^2. This area is home to a large number of aboriginal petroglyphs or etchings that are of enormous cultural significance to Australia, particularly to the local indigenous communities. The etchings are around 10,000 to 20,000 years old, and provide a glimpse into the life of the early inhabitants of the area. In addition, the rock etchings are still of significant spiritual importance to indigenous people.

In addition to the rock etchings, the Burrup Peninsula has several large industrial complexes including iron ore, liquefied natural gas production (LNG) and salt production. All are located around Dampier and the southern area of the Peninsula. Since some of the rock etchings are adjacent to industrial areas, especially in the southern Peninsula, there has been some concern that the etchings could be damaged by emissions from industry.

To assess the likelihood that air pollution from the industrial area may damage the petroglyphs an air pollution study was carried out on the Burrup Peninsula by CSIRO Marine and Atmospheric Research between August 2004 and September 2005 and between February 2007 and September 2008. The study comprised a total of 10 Sites; two of these were located on the northern Burrup Peninsula area and one at Mardie Station 81 km southwest of Dampier, and were considered to be representative of the local background concentrations of gases and particles. One site was located in the town of Karratha, and the other five were located on the lower Burrup Peninsula, near to the industrial areas.

Since the sites had no power and were quite remote, they were visited on a monthly basis to change samples and to download data. Most of the measurements presented in this study are taken over periods of about one month so they represent monthly averaged results. The range of measurements included concentrations of sulfur dioxide, nitrogen dioxide, nitric acid and ammonia gases and concentrations of benzene, toluene, ethylbenzene, p+m xylene and o-xylene. These were measured at nine sites using passive samplers, ideal for such a sampling program, since they could be deployed for monthly periods at remote sites where power was not available. Total suspended particulate samples were collected at the seven sites located on the Peninsula using Microvol samplers. These sampled at low flow rates and provided monthly integrated samples on Teflon filters which were used to provide gravimetric mass and samples for chemical analyses. Microvol samplers were also installed at two sites to measure PM_{10} concentrations under particular preset wind directions ie chosen to assess the PM_{10} concentrations resulting from the ore loading procedures at Parker Point.

Rainwater samplers were installed at seven sites to collect rainwater during the wet season. The rainwater samples were analysed for pH (acidity) and a range of soluble ions. Unfortunately two samplers experienced problems during 2004/2005 and one during 2006/2007 so that little data was available from those sites. Hence chemical composition data are available for five sites, one background and four in the industrial area in 2005/2007 and at two background sites and four sites in the industrial area. BTEX analysis is not complete on samples collected during the latter part of 2007/2008 because regular maintenance was required for the GC/MS system used to analyse the samplers. This analysis is expected to be completed during the coming weeks.

During one visit to the sites during 2004/2005 an aerosol spectrometer was used measure the particle number distribution in a number of particle sizes at the sites. Although these measurements were only carried out for a short period they did give some valuable information on the magnitude of dust deposition at the various sites.

The results of the nitrogen dioxide gas measurements show that concentrations are low at all sites. The highest monthly averaged concentration at the Burrup sites in 2004/2005 was 3.5 ppb recorded at Site 5 and 3.8 recorded at site 8 during 2007/2008, both sites are in the industrial area of the Burrup Peninsula. Site 5

had the highest annual average concentration of 2.4 ppb and 2.8 ppb during 2004/2005 and 2007/2008 respectively. In contrast to this, the background concentration, defined by the Sites on the northern Burrup and at Mardie Station, was about 0.6 ppb. There was an obvious although small gradient in concentration between the background nitrogen dioxide concentrations and those in the industrial sector. There were some small increases in ammonia gas concentrations at sites 5, 6, 7 and 8 which are located near to industry. At site 5 the increase was due almost entirely to one month in June/July when the concentration averaged 3.0 ppb. Local background concentrations, deduced from sites 1, 3 and 10 during 2004/2005 and 2007/2008 were ammonia 0.5 ppb, nitrogen dioxide 0.6 ppb, sulfur dioxide 116 ppt and nitric acid 154 ppt. The site located in Karratha had higher concentrations than any of the other sites, but this was probably due to local influences such as use of fertilizers etc.

The concentrations of ammonia, nitrogen dioxide, sulfur dioxide and nitric acid are very low compared with measurements made at other remote locations. BTEX concentrations were also very low at all sites and for all sampling periods. The benzene concentration at the background sites 1, 3 and 10 was about 19 ppt and the average at the other sites about 21 ppt. Benzene, and other BTEX gas concentrations showed little enhancement over the background levels suggesting that their concentration has a large natural component probably due to emissions from plants and animals.

Monthly average nitric acid concentrations ranged from 21 ppt at Site 10 to 632 ppt at Site 9. The background nitric acid concentration was about 155 ppt compared with 229 ppt which was the average in the industrial sector, at Sites 4, 5, 6, 7 and 8. Again, there is little evidence of a gradient between background nitric acid concentration and that in the industrial sector.

Sulfur dioxide concentrations were also very low during 2004/2005 and monthly average concentrations ranged from 19 ppt at Site 10 to 367 ppt at Site 4. The annual average sulfur dioxide concentration in the industrial area was 175 ppt and the maximum annual average concentration was 215 ppt at Site 5. These results suggest that the gradient of sulfur dioxide concentration between background sites and those in the industrial sector is low. Monthly average nitric acid concentrations ranged from 21 ppt at Site 10 to 632 ppt at Site 9. The background nitric acid concentration was about 155 ppt compared with 229 ppt which was the average in the industrial sector, at Sites 4, 5, 6, 7 and 8. Again, there is little evidence of a gradient between background nitric acid concentration and that in the industrial sector. The sulfur dioxide and nitric acid concentrations measured during 2007/2008 were very similar to those measured during 2004/2005.

Annual average TSP concentrations ranged from 21.8 $\mu g\ m^{-3}$ at Site 3 to 51.1 $\mu g\ m^{-3}$ at Site 8. Site 1 and 3 represent the background TSP concentrations and the average of those was about 22 $\mu g\ m^{-3}$ compared with an average of 34 $\mu g\ m^{-3}$ for the sites on the lower Burrup area. The TSP loadings at site 8 were higher than other sites, and probably originated from activities at Parker Point. At various sites the influence of TSP derived from iron ore transport and loading was investigated by measuring the iron and sea-salt fractions of TSP. This showed that compared to other sites, Site 1 was least influenced by iron ore loading and transport and was most influenced by sea-salt. At Site 8, close to Parker Point, the iron fraction of the TSP was the highest, compared with other sites and the sea-salt fraction the lowest, indicating that TSP from ore loading was a significant fraction of the total TSP. High frequency PM_{10} concentrations measured at Site 8 showed significantly higher concentrations when the wind came from the Parker Point or from the local road, again indicating that ore loading at Parker Point increases the PM_{10} concentrations at Site 8.

Dust deposition fluxes were measured for brief periods during field studies to the Burrup Peninsula. Although they cover only short periods they indicate that the background flux was about 10 mg m^{-2} day^{-1} compared with 69 mg m^{-2} day^{-1} measured at Site 8 and an average of 32 mg m^{-2} day^{-1} for the industrial area of the Burrup.

The total deposition flux of nitrogen and sulfur was determined at sites 3, 5, 6, 7 and 8 in 2004/2005, and sites 1, 3, 4, 6, 7 and 8 in 2007/2008 by calculating the wet and dry deposition of all nitrogen and sulfur species in the gas and aqueous (rainwater) phases. This included nitrogen dioxide, sulfur dioxide, nitric acid and ammonia gases and ammonium ion, nitrate ion and sulfate in rainwater. The study shows that the total wet and dry deposition flux of nitrogen and sulfur of 14 meq m-2 yr-1 is typical for areas of the Burrup

Peninsula which have no or little anthropogenic influences. It also shows that 60 % - 85 % of the deposition is contributed by dry deposition. At the sites close to industrial influences the deposition fluxes of nitrogen and sulfur ranged from 20 mg m-2 day-1 to 24 mg m-2 day-1 in 2004/2005 and 21 mg m-2 day-1 to 33 mg m-2 day-1 in 2007/2008. The slight increase in the flux from 2004/2005 to 2007/2008 is due largely to an increase in the amount of rainfall in the latter period, and on the Burrup Peninsula this appears to be the major variable in the flux of nitrogen and sulfur to the ground.

Although the enhancement of acid deposition fluxes from the background to the industrial areas is observable it is small. The absolute fluxes are of the magnitude that would only affect soil or rock that is in the most sensitive class of critical loads. As the Burrup area is in a critical load class that can cope with a deposition flux of about 200 meq m^{-2} yr^{-1}, which is significantly greater than the observed deposition fluxes at the sites, acid deposition to the Burrup area is unlikely to cause any deleterious effects to rock or rock art on the Burrup Peninsula.

2. BURRUP PENINSULA AIR POLLUTION STUDY: FINAL REPORT

2.1 Introduction

The Burrup Peninsula is a thin finger of land to the northeast of Dampier, Western Australia in an area bounded by latitude 20.42 °S and 20.65 °S and longitude 116.71 °S and 116.90 °S. The main Peninsula area is about 27 km long and about 5 km wide, and includes a collection of over 40 small islands. It is located in the shire of Roebourne, with a population of 15,281. The population density of the area is about 1 person km^{-2} and the populations of the two adjacent small towns of Karratha and Dampier are about 11,000 and 2,500 respectively.

The Burrup Peninsula has several large industrial complexes including iron ore, liquefied natural gas production (LNG) and salt production. All are located around Dampier and the southern area of the Peninsula. Iron ore is mined at several locations inland from Dampier and transported by rail to Dampier where it is loaded into ships for export to Asia. LNG is produced off shore and transported to the coast via a 132 km pipeline where it is processed. The infrastructure for this includes a complex LNG processing plant, LPG extraction facilities, domestic gas plant, storage tanks and ship loading facilities. In addition, an ammonia plant is currently under construction on the Peninsula and there are plans to construct other industrial plants to produce methanol and dimethyl ether.

In addition to the industrial activity, the Burrup Peninsula is well known for the large collection of aboriginal rock etchings. The etchings, dated to the Pleistocene era, (about 10,000 to 20,000 before present) are clearly of great cultural significance to Australia. It is estimated that as many as 1,000,000 individual etchings may be located on the Burrup Peninsula. Pictures 1 and 2 show typical examples. For a fuller discussion of the origins of the etchings, the methods used to produce them and a descriptive analysis the reader is referred to a paper by Vinnicombe (2002). Since some of the rock etchings are adjacent to industrial areas, especially in the southern Peninsula, there has been some concern that the etchings could be damaged by emissions from industry.

Picture 1. Typical example of Burrup Peninsula rock art.

Picture 2. Typical example of Burrup Peninsula rock art.

To address these concerns the Western Australian Department of Industry and Resources (DOIR) appointed a committee, the Burrup Rock Art Monitoring Management Committee, to coordinate a study of air pollution measurements on the Peninsula.

The set of objectives established by the Committee were to:

- ***Investigate and report on impacts of proposed industrial development on the rock art of the Burrup***

- ***Ensure that the studies are undertaken in an open and transparent manner***

- ***Based on these studies, recommend management actions to the Burrup Rock Art Management Committee***

As a consequence of the objectives listed above the following research questions were posed by the Committee:

- ***Is the natural weathering of the rock art of the Burrup Peninsula being accelerated by industrial emissions?***

- ***Is there a significant and measurable problem?***

- ***If there is a significant issue, what management approaches are recommended?***

The DOIR issued two tenders for work to be carried out on the Burrup Peninsula.

- Tender 32DIR0603, Monitoring of Ambient Concentrations of Air Pollutants, including the following:

    - Establishment of the sampling system
    - A detailed proposal for a measurement system and QA/QC details, including estimates of accuracy and reliability

    - Measurement of nitrogen dioxide concentrations

- Measurement of ammonia gas concentrations (one control and one industrial area location only)
- Measurement of BTEX (benzene, toluene, xylene, total volatile organic compounds)
- Measurement of sulfur dioxide concentrations (one control and one industrial area location only)
- Conducting analyses and reporting progress of the study following each sampling run.
- An interim progress report at six months and a final report after 12 months and
- A commitment to train and use local organisations, Government staff, individuals or volunteers to conduct the sampler replacements in accord with appropriate standards.

- Tender 39DIR0603, Microclimate and Deposition Study, including the following:

  - Measurement of temperature
  - Measurement of relative humidity
  - Measurement of wet deposition – amount and chemical composition
  - Measurement of dry deposition – amount and chemical composition
  - Measurement of bulk deposition – amount and chemical composition
  - Measurement of chemical composition (including pH) of dew on rock surfaces on exposed and protected/shaded faces
  - Chemical composition shall include sodium, chloride, iron, total nitrogen and sulphur.
  - The establishment of the monitoring system
  - A description of sampling and sample collection arrangements
  - A detailed proposal for the measurement system, and QA/QC details, including estimates of
  - accuracy and reliability
  - Conducting analyses and monthly reporting of results and progress.
  - An interim progress report at six months, and a final report for the project and
  - A commitment to train and use local organisations, Government staff, individuals or volunteers to participate in the program in accordance with appropriate standards.

The terms of reference set out in the Tenders were to:

- Research the effect of natural processes and industrial emissions from existing and proposed industrial development on Aboriginal rock art of the Burrup Peninsula

- Ensure that this study is undertaken in an open and transparent manner engaging community input throughout the entire process

- Recommend management measures to the relevant management body, outlining mitigation and remediation measures for the preservation and conservation of the indigenous rock art, whether further industrial development on the Burrup Peninsula proceeds or not.

CSIRO Marine and Atmospheric Research (CMAR) applied for these tenders (32DIR0603 and 39DIR0603) and was subsequently invited to carry out an air pollution study on the Burrup Peninsula

3. SITE SELECTION

The site selection process was carried out during 6th – 9th April 2004, in conjunction with Bill Carr from DOIR, Rob Gillett, CMAR, Geoff Kregor, Conservation and land Management (CALM) and several

aboriginal elders including Trevor Solomons, Wilfred Hicks, Tim Douglas, Robert Boona and Michael Boona. During this visit eight sites were selected on the Burrup Peninsula, (Figure 1) one of which was used only for PM_{10} particulate measurements. Of these, sites 1 and site 3 are considered to be local background sites since they are distant from industrial development and anthropogenic influences. In addition two other sites, away from the Burrup Peninsula, were selected. One was in Karratha, to provide a comparison of gas concentrations on the Burrup with those in an adjacent urban area. The other was located at Mardie Station south west of the Burrup, to provide a comparison of gas concentrations in an adjacent area where there is no industrial activity. Table 1 shows the locations of the ten sites. It should be noted that Site 2 was not used for atmospheric measurements. Picture 3 shows equipment installed at Site 8.

Picture 3. Equipment installed at Site 8.

Table 1. Locations of the ten sampling sites.

Site No.	Site Name	Latitude	Longitude
1	Dolphin Island	20.45233	116.85233
3	North Burrup	20.52611	116.83067
4	Woodside east	20.60167	116.78276
5	Burrup Road	20.62093	116.76928
6	Water Tank	20.61800	116.78516
7	Deep Gorge	20.63692	116.78848
8	King Bay south	20.64416	116.75067
8HI	Hamersley Iron	20.64218	116.74037
9	Karratha	20.73575	116.83662
10	Mardie Station	21.16790	116.12000

Figure 1 shows a map of the sites located on the Burrup Peninsula and the site in Karratha. Site 10, Mardie Station, is not shown on this scale. It is located about 81 km from Dampier at a bearing of about 215^{o}.

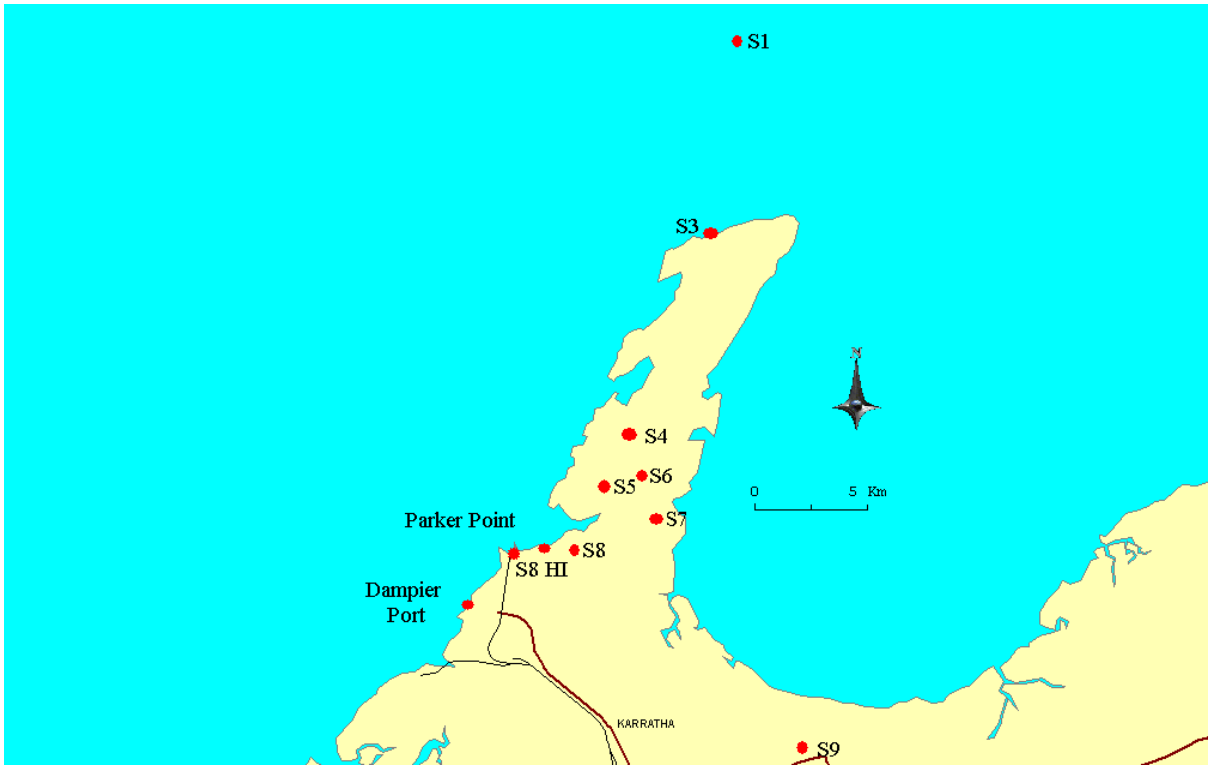


Figure 1. Burrup Peninsula Sampling Sites. Although Site 1 shown on this map Dolphin Island is not. Site 10 is located 81 km southwest.

4. MEASUREMENTS

This study was designed to measure the concentrations of gases, particulate concentrations and chemical composition, dust deposition and rainwater amount and composition. From these measurements acid deposition rates were calculated.

4.1 Passive Gas measurements

Gas concentrations of nitrogen dioxide, sulfur dioxide, nitric acid and ammonia and were measured in duplicate with passive sampling devices, over sampling periods of about one month. Figure 2 shows the construction of the samplers used to measure concentrations of these gases. Passive gas samplers have several important features that make them the most suitable method for this study particularly since the the sample sites are located in remote areas with no power supply.. The samplers are light and easy to install and require no power to sample. In addition they can be used to measure concentrations of a number of gases for periods of about one month.

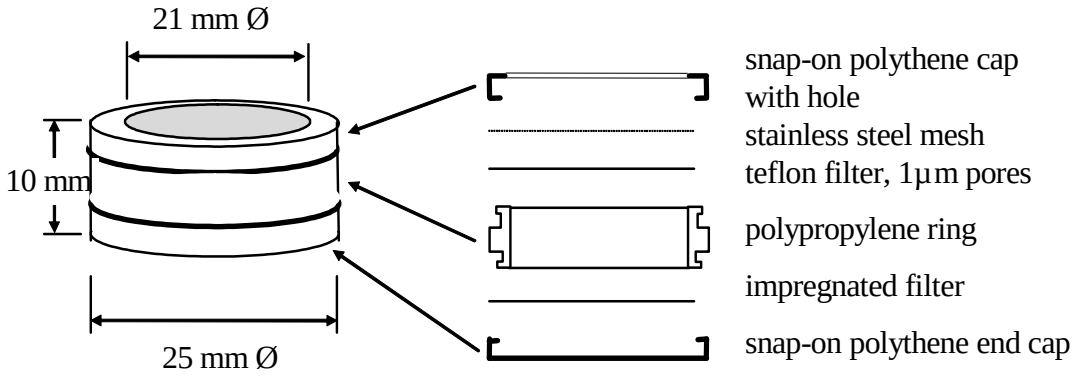


Figure 2. Construction of passive samplers used for measurement of nitrogen dioxide, sulfur dioxide, nitric acid and ammonia gas concentrations.

At each site the passive samplers were housed in a channel underneath an aluminium holder which is mounted on a pole about 1.5 metres above the ground, as shown in Figure 3 and Picture 4. The lid protects the samplers from rain; in addition a sheet of aluminium is mounted about 50 mm above the lid to protect it from direct solar radiation.

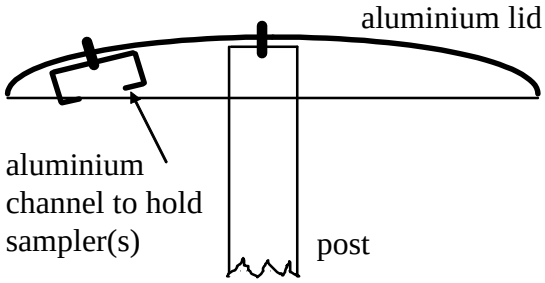


Figure 3. Installation of passive samplers

Picture 4. Installation of passive samplers under lid with aluminium radiation screen.

Passive samplers trap sample gas that diffuses into the cylindrical body of the sampler. This is driven by a concentration gradient of gas in the sampler that decreases from the ambient level down to a very low level at the filter paper interface, where the gas is reacting with the chemical coating. Validation of passive samplers against active sampling has been provided by Ayers et al. (1998). There is also a resistance to the gas moving down the cylindrical body of the sampler and this constant must be included in the calculation of ambient gas concentrations. It comprises four partial resistances as shown below. The major resistance is due to the geometry of the cylinder and the others to the stainless steel mesh, the Teflon filter and the laminar boundary layer. The detail in equation (1) below shows how the total air resistance is calculated in units of m^{-1}.

$$total\ air\ resistance = \frac{LR}{AR} + \frac{LF}{AF} + \frac{LN}{AN} + \frac{LBL}{AR} \quad (1)$$

where :

LR = length of the ring

AF = total pore area of aerosol filter

LF = thickness of aerosol filter

LN = thickness of the steel mesh

AR = Area of the ring (20 mm diameter)

AN = area of steel mesh

LBL = laminar boundary layer

Passive samplers include a filter that is impregnated with a chemical that reacts with the gas of interest, where it is trapped on the filter. For sulfur dioxide and nitric acid, which are measured on the same passive sampler, the gases are trapped on Millipore Grade 223 cellulose filters in an acid base reaction using an impregnation of 50 µl of a 1% (w/v) solution of NaOH prepared in methanol. Sulfur dioxide is trapped as sulfate ion and nitric acid as nitrate ion, as reactions (2) and (3) show.

$$2SO_2 + 2OH^- + O_2 \Longrightarrow 2H^+ + 2SO_4^{2-} \quad (2)$$

$$HNO_3 + OH^- \Longrightarrow NO_3^- + H_2O \quad (3)$$

At the end of the sampling period filters are removed and extracted in clean polythene bags in Milli-Q grade (18 MΩ·cm) water. The aqueous concentrations of sulfate and nitrate ion are determined by ion chromatography using a Dionex DX500 ion chromatograph equipped with a guard column, a 4 mm x 250 mm AS11 analytical column and an ASRS Ultra II suppressor. The ions are separated using a gradient eluent of NaOH producing chromatogram; an example is shown below in Figure 4. The Figure shows a typical anion chromatogram with peaks for the range of ions that are regularly measured in sulfur passive gas samples, rainwater samples and aerosol extracts. The ions are separated using a gradient chromatogram where 5 millimolar and 100 millimolar NaOH are continually mixed with Milli-Q water to produce a smooth increase in eluent concentration during the chromatogram.

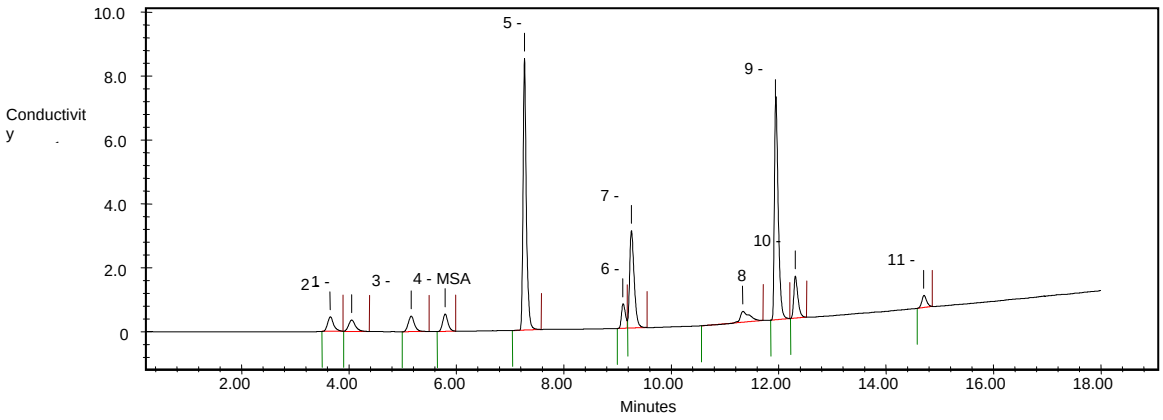


Figure 4. Typical ion chromatograph showing sulfate and nitrate peaks.

The area of the peak is converted to a molar concentration by utilising a calibration line produced from a range of seven standards. Figure 5 shows the relationship between peak area and concentration for a range of seven sulfate standards. Standards are prepared by serial dilution of 1000 µg ml^{-1} NIST traceable reference standards (Ultra Scientific). Table 2 shows the range of standard concentrations used in analysis of sulfur dioxide passive gas extracts, rainwater analysis and analysis of aerosol extracts. Sulfate standards, for example, cover a concentration range from 1 µmol L^{-1} to 64 µmol L^{-1}.

Table 2. Anion standards used in anion chromatography.

Anions	Conc. µmol l^{-1}						
F^-	16	8	4	2	1	0.5	0.25
CH_3COO^-	16	8	4	2	1	0.5	0.25
$HCOO^-$	16	8	4	2	1	0.5	0.25
$CH_3SO_3^-$	16	8	4	2	1	0.5	0.25
Cl^-	128	64	32	16	8	4	2.00
NO_2^-	16	8	4	2	1	0.5	0.25
Br^-	16	8	4	2	1	0.5	0.25
NO_3-	64	32	16	8	4	2	1.00
SO_4^{2-}	64	32	16	8	4	2	1.00
$C_2O_4^{2-}$	16	8	4	2	1	0.5	0.25
PO_4^{3-}	16	8	4	2	1	0.5	0.25

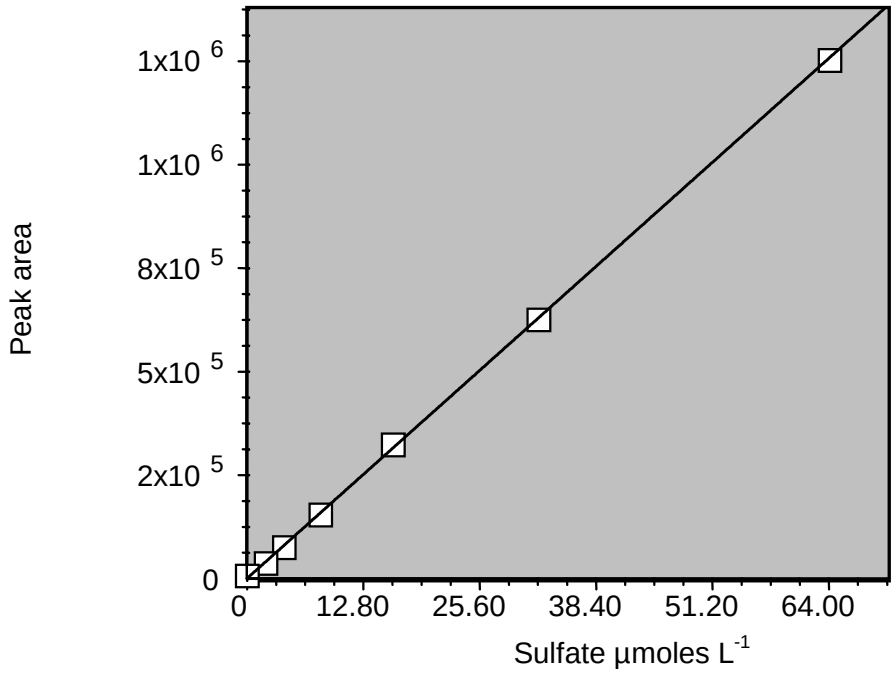


Figure 5. Peak areas plotted against sulfate concentration.

Nitrogen dioxide concentrations are also measured using the passive samplers described in Figure 2. In this case Millipore Grade 223 cellulose filters are impregnated with 50 µl of a solution of 0.44 g NaOH and 3.95 g NaI diluted to 50 ml in a volumetric flask. The reaction to trap NO_2(g) on the filter can be expressed as follows :

$$2NO_2 + 3I^- \Longrightarrow 2NO_2^- + I_3^- \quad (4)$$

After sampling is complete the filters are removed from the sampler and extracted into a known volume of Milli-Q water in clean food grade plastic bags. The nitrite ion concentration is then measured as a diazonium salt, which is produced from a reaction of nitrite ion with sulphanilamide, phosphoric acid and N-1-naphthyl ethylenediamine dihydrochloride (NEDA). The absorbance of the diazonium salt produced in the reaction was measured in a Shimadzu UV-2401PC UV/Vis spectrophotometer at a wavelength of 540 nm. The aqueous nitrite concentrations were determined from nine nitrite standards which are serially

diluted from NIST traceable standards and range from 0 µmoles l^{-1} to 100 µmoles l^{-1}. Figure 6 shows a calibration curve of nitrite concentrations as a function of the absorbance of the diazonium salt at 540 nm.

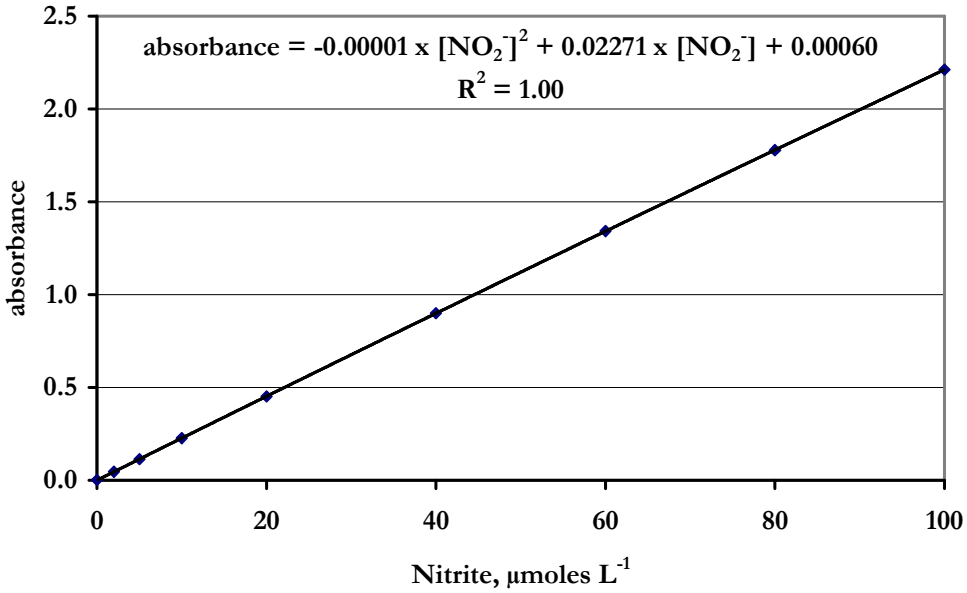
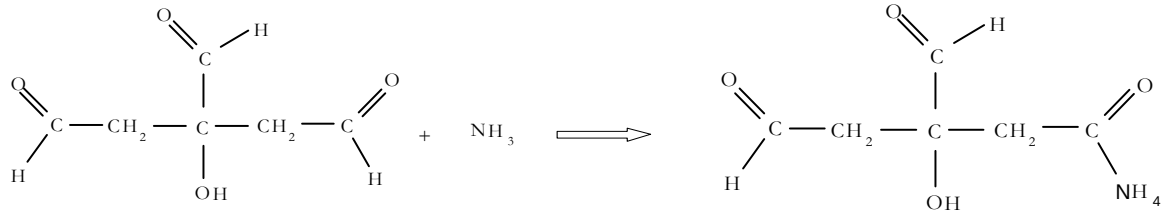


Figure 6. Nitrite concentration as a function of diazonium salt concentration. A quadratic curve is fitted to the data.

Ammonia gas concentrations were also measured with passive samplers using Millipore Grade 223 cellulose filters impregnated with 50 µl of a solution of 2 % w/v citric acid prepared in acetone. Ammonia gas was collected on the filter in an acid base reaction as shown in reaction (5).



(5)

After sampling is complete the impregnated filter is removed from the sampler and extracted in a known volume of Milli-Q water in a food grade plastic bag. The aqueous ammonium concentration is measured using a Dionex DX500 ion chromatograph. The chromatograph is equipped with a CS12A 250 mm x 4 mm analytical column and a CSRS Ultra II suppressor column. The ions are detected with a conductivity detector after they are separated using an isocratic eluent of 20 millimolar methane sulfonic acid. Ammonium standards are prepared by serial dilution of a NIST traceable standard.

Blank samplers were sent from CMAR to the Burrup Peninsula during each sampling period. The blanks were used to determine errors associated with sampler preparation, contamination during sample transport, and from reagents during analysis. The average aqueous blank level was subtracted from the individual samples before concentrations were calculated. Blank samplers were also used to determine the limit of detection for gases measured by the passive samplers. The limit of detection is the lowest concentration that can be detected with a given degree of confidence. This was determined in accordance with ISO 6870 (ISO 1995) which states that a zero sample has a 5% chance of giving a measured concentration above the limit of detection. This is defined in equation (6).

$$LOD = t_{0.95} \; x \; s_{c(0)} \tag{6}$$

Where:
$t_{0.95}$ = the value of the 1-tailed t distribution for P < 0.95 (95% confidence limits).
$S_{c(0)}$ = the standard deviation of the blanks.

Concentrations of sulfur dioxide, nitric acid, nitrogen dioxide and ammonia were calculated in units of ppb or ppt from equation (7) below.

$$p = \frac{C_{aq} \; x \; EV \; x \; Res \; x \; R \; x \; Temp \; x \; 10^6}{D \; x \; Time} \tag{7}$$

Where:
C_{aq} = aqueous analyte concentration in moles l^{-1}
EV = extraction volume in cm^3
Res = resistance (m^{-1}) as described in (1)
Temp = average sampling temperature (K)
D = diffusion coefficient of sampled gas in air ($m^2 \; s^{-1}$)
= 1.32×10^{-5} $m^2 \; s^{-1}$ for nitrogen dioxide and HNO_3 at 20 ºC. (Ferm, 1991)
= 1.54×10^{-5} $m^2 \; s^{-1}$for NO_2 at 21 ºC. (Ferm, 1991)
= 2.54×10^{-5} $m^2 \; s^{-1}$ for NH_3 at 25 ºC (Ferm, 1991)
Time = sample period in seconds
10^6 = conversion to ppt

The precision of sulfur dioxide, nitric acid, nitrogen dioxide and ammonia measurements is expressed in the results as the relative percent difference (RPD), and is determined between the sample pairs at each of the sites. The RPD is the deviation between duplicate pairs of passive samplers calculated as the difference divided by their mean and expressed as a percentage as shown in equation (8).

$$RPD = \frac{abs\left(X_a - X_b\right)}{\left(\frac{X_a + X_b}{2}\right)} \times 100 \tag{8}$$

BTEX gases (benzene, toluene, ethylbenzene and the xylene isomers) were measured using sorbent tubes, and these were used in accordance with International Organisation for Standardisation (ISO 16017-2:2003). Sorbent tubes operate by physically trapping the gas of interest on a sorbent bed due to a concentration gradient which exists between the sorbent bed and the ambient air. During this study gas measurements were carried out over periods of about 30 days at all of the 10 sites. Figure 7 shows the structure of a sorbent tube used for BTEX sampling.

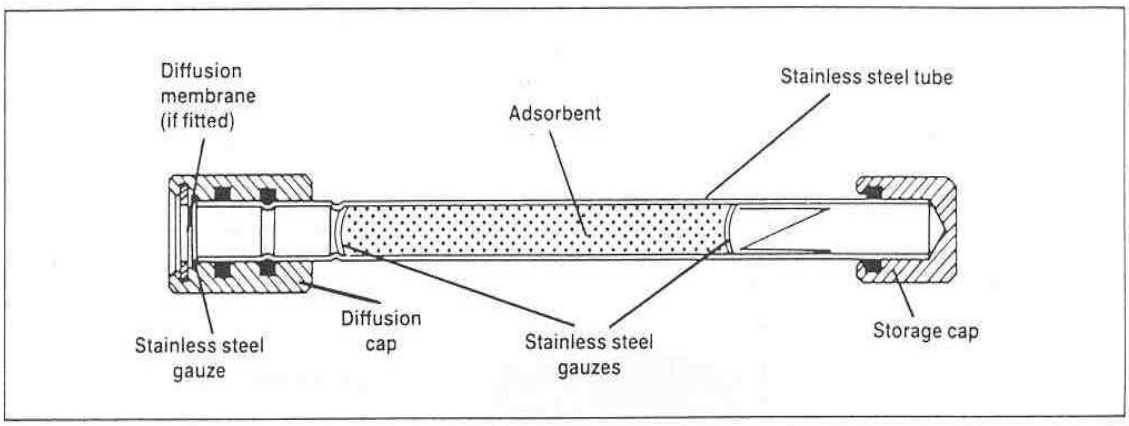


Figure 7. Diagram of a sorbent tube used to measure BTEX gas concentrations.

BTEX sorbent tubes are manufactured from stainless steel tubing 6.35 mm diameter and 88.9 mm long ($^1/_4$″ x $3^1/_2$″) packed with Chromosorb 106 sorbent, and purchased from either Perkin Elmer (USA) or Markes (UK). Tubes were sent to the Burrup Peninsula sealed with Swagelok fittings, wrapped in baked aluminium foil and secured in an uncoated metal tin. The tubes were installed under the aluminium lid after the Swagelok seal is removed from the sampling end and replaced with a diffusion cap. After the tubes were exposed at each site they were sealed with Swagelok fittings, wrapped in clean baked aluminium foil and returned to CMAR in the uncoated sealed metal tin. BTEX species are analysed by gas chromatography with a flame ionisation detector (GC/FID). BTEX gases were desorbed by heating the sorbent tubes under a stream of ultra high purity helium gas at 180°C for 2 minutes, in a Perkin Elmer 400 automated thermal desorber (ATD). The gases were then concentrated on a Tenax cold trap in the ATD at -30°C. The cold trap was then heated to 180°C and the desorbed species are transferred through a heated line to a Perkin Elmer AutoSystem XL gas chromatograph where they were separated by an SGE BP 20 column and detected with a flame ionization detector. Table 3 gives details of the column and temperature program used for the analysis.

Table 3. Gas Chromatography conditions

Item	Description
Column	50 m x 0.32 mm I.D. SGE fused silica capillary column with 1.0 µm BP20 bonded phase
Injector	ATD 400 (mode 2)
Carrier gas	Helium
Oven Temperature	Hold 35°C for 4 minutes programmed at 5°C min^{-1} to 115°C programmed at 45°C min^{-1} to 200°C Hold 200°C for 6 minutes
Detector	Flame Ionization Detector

Peak areas obtained in the GC/FID analysis were converted to mass using a NIST traceable working standard with a mixture of benzene, toluene, ethyl benzene, m-xylene and o-xylene with mixing ratios of 10.1 ppm, 10.1 ppm, 10.1 ppm, 10.1 ppm and 10.0 ppm respectively and an accuracy of ± 2% (Scott Specialty Gases, San Bernadino, CA, USA). Working standards were injected into an 812 µl stainless steel loop heated to 80°C (353K), and then through an empty tube loaded into the ATD which experiences the same desorption conditions as the samples. The mass of each gas injected is calculated from equation 9 below.

$$mass = \frac{v_{loop} \; x \; C_{gas} \; x \; MW_{gas}}{R \; x \; T} \quad (9)$$

Where :
R = gas constant (0.082054 l atm mol^{-1} K^{-1})
T = temperature (353 K)
V_{loop} = loop volume (0.000812 L)
MW_{gas} = molecular weight of gas of interest (g mol^{-1})
C_{gas} = gas concentration (ppmv)

An injection of one loop volume of the working standard gas mixture results in the masses shown in Table 4. Therefore, dividing this mass by the peak area, gives the mass per unit area ratio and multiplication of this ratio by the peak area of each species gives the mass of each species collected by the sorbent tube.

Certified Reference standards (CRS) containing known masses of benzene, toluene and o-xylene were purchased from Markes International Ltd, UK, who prepared the tubes according to ISO Standard 6145 (1981) part 8. The calibration of the results presented here is based on these certified reference standards.

Table 4. Mass of gases for one ATD loop injection

Gas	Mass injected (ng)
Benzene	22.15
Toluene	26.12
Ethyl-benzene	30.12
m-xylene	30.12
o-xylene	29.82

Ambient BTEX concentrations are calculated from the mass collected on each tube, the sampling time and the uptake rate of each gas on Chromosorb 106, as shown in equation 10. The uptake rates, used in equation 10, are taken from ISO 16017-2 (2003) and are for sampling periods of four weeks and are listed in Table 5.

Table 5. Four-weekly uptake rates used to calculate ambient BTEX concentrations

Gas	Adsorbent	Uptake rate ng ppm^{-1} min^{-1}
Benzene	Chromosorb 106	1.28
Toluene	Chromosorb 106	1.82
Ethyl benzene	Chromosorb 106	2.24
p-xylene	Chromosorb 106	1.91
m-xylene	Chromosorb 106	1.91
o-xylene	Chromosorb 106	1.91

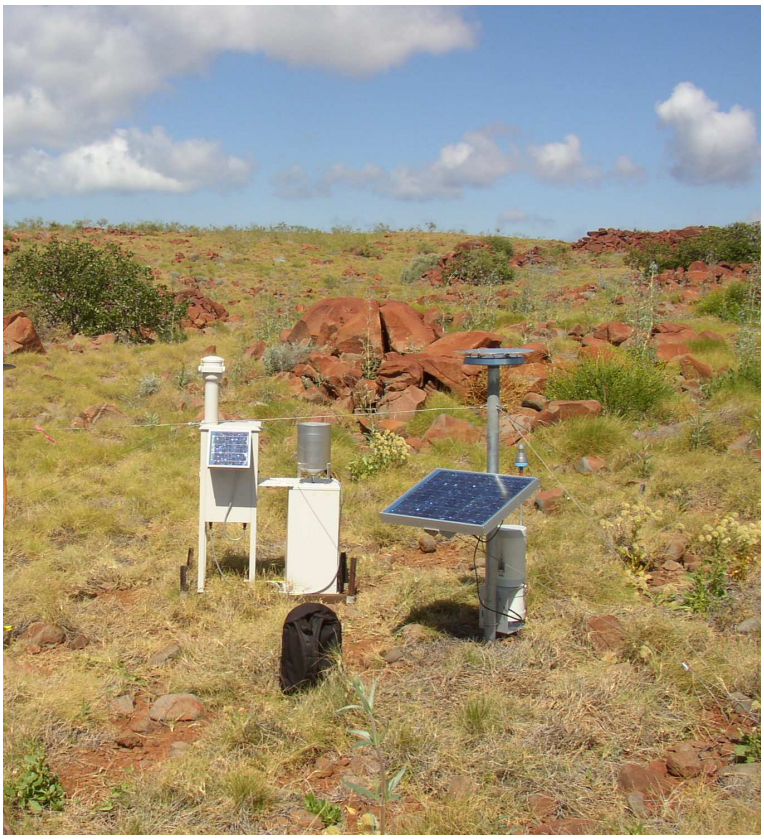
$$p = \frac{Wt \; x \; 10^6}{Up \; x \; T} \quad (10)$$

Where:
p = gas mixing ratio (ppt)

Wt = mass of sample adsorbed onto the Chromosorb 106 (ng)
Up = uptake rate of species on Chromosorb 106 (ng ppm-1 min-1)
T = sampling time (minutes)

4.2 Particulate Sampling

Sampling was carried out for total suspended particulate (TSP) at all sites, except Karratha, Hamersley Iron and Mardie Station, Sites 9, 8HI and 10 respectively. TSP samples were collected on 47 mm diameter Fluoropore PTFE membrane filters (Millipore, USA, FALP 04700) using Microvol 1100 low volume samplers, (Ecotech Pty Ltd, Blackburn, Australia) and the sampling period was about 30 days, the same as for gas sampling. At sites 8 and 8HI PM_{10} samples were collected on 47 mm stretched Teflon filters (Pall K2PJ047, 2.0 µm pore size) using Microvol 1100 samplers fitted with a PM_{10} inlet. The sampling period was the same as for TSP samples. PM_{10} is particulate matter that has an aerodynamic diameter of 10 µm or less. The mass of the filters was measured before and after sampling to determine monthly averaged PM_{10} or TSP concentrations for each sampling period. The mass was measured using NATA (National Association of Testing Authorities) certified protocols on a Mettler UMT2 microbalance, which measures to a maximum of 2100 mg with a resolution of 0.0001 mg (0.1 µg). Picture 5 shows a rainwater sampler and a microvolt sampler on location at Site 1.



Picture 5. Rainwater sampler and Microvol sampler at Site 1.

A DustTrak aerosol monitor (TSI model 8250) was installed at site 8 to measure PM_{10} concentrations at sampling frequencies of two minutes. This sampler was modified to use a battery which is charged using a solar panel. Since the signal from the DustTrak can drift in response to changing temperature it was further modified determine a zero reading for 10 minutes every four hours. . This was done by adding a relay which turned the pump off allowing the sampler chamber to clear by sedimentation and diffusion. The final PM_{10} concentrations were calculated by fitting a line between each zero point and subtracting this zero from the raw concentrations.

4.3 Rainwater Sampling

Model 200 rainwater samplers (Ecotech Pty Ltd, Blackburn, Australia) were installed at all sites except Karratha, Hamersley Iron and Mardie Station, Sites 9, 8HI and 10 respectively. The wet only samplers open after 0.25 mm of rain has fallen in the tipping rain gauge, and close again once no rain has fallen for a full 30 minute period. Samples were collected in polyethylene bottles that had thymol added to preserve the chemical species in the rain against degradation by bacteria (Gillett and Ayers, 1991; Ayers et al., 1998). Bulk wet-only rainwater samples were collected over the usual sampling period of 30 days. After collection the total rainwater volume of each sample was determined. The samples were returned to CMAR where pH was measured and they were analysed for a range of anions and cations by ion chromatography. Picture 5 shows Model 200 rainwater sampler on location at Site 1.

4.4 Meteorological Measurements and Dust Measurements

A range of meteorological measurements were carried out at the sites on the Burrup Peninsula. Temperature and relative humidity were measured at sites 1, 3, 4, 5, 6, 7 and 8 using Hobo Pro Series sensors at 3 minute intervals. An automatic weather station to measured wind speed and wind direction at 2 minute frequencies was installed at site 8. The DustTrak PM_{10} data can be combined with the wind direction data to determine the influence of wind direction on PM_{10} concentrations.

In addition to TSP measured with Microvol samplers, dust deposition was measured at sites 1, 4, 5, 6, 7 and 8. Measurements of dust deposition fluxes can be made in several ways, although none of them necessarily replicates the real flux. In this case measurements were made using a passive dry Frisbee-type dust deposit gauge (Vallack, 1995; Hall et al., 1994). These consist of a stainless steel Frisbee shaped holder with a foam insert mounted on a pole about 1.5 metres from the ground. The foam pads were sealed in resealable plastic bags and weighed before and after the pads were exposed at the Burrup Peninsula. The mass measurements were carried out on a Sartorius Master Pro LA130S-F balance which has a resolution of 0.0001 g and a maximum mass of 150 g, and is calibrated using NATA certified masses. Measurements were made over 3-monthly periods.

During one field visit to the sites a GRIMM Series 1.100 Aerosol Spectrometer (Technik GmbH & Co. Kg) was used to continuously measure particle number distribution in a number of particle sizes. The GRIMM uses either mains power or a battery and employs a laser scattering technique to measure the number of particles in a series of preset size ranges. In this case the 15 size ranges were used from 0.3 µm to 20 µm. The spectrometer has a large dynamic range and can measure particle numbers from $1 – 2 \times 10^6$ particles l^{-1} and dust masses from 0.1 – 100,000 µg m^{-3}.

4.5 Particle-Induced X-ray Emission

The particulate samples collected at sites 1, 3, 4, 5, 6 and 8 were analysed for a range of 19 elements by particle-induced X-ray emission (PIXE) analysis at the Australian Nuclear Science and Technology Organisation (ANSTO). PIXE is a non destructive ion beam analysis technique that can be used to analyse particle filter samples for a range of 19 elements. The PIXE analysis was carried out after the gravimetric measurements were completed, and before the samples were analysed by ion chromatography.

PIXE analysis was carried out by irradiating an 8 mm diameter section of each filter with a beam of 10 nano amp beam current, 2.6 MeV protons generated by a 3 MV Van de Graaff accelerator. Each filter is irradiated for about 5 min. As charged particles move through the filter and the particulate on the surface they lose energy by exciting electrons in the K and L shells. These electrons can then be ejected, causing other electrons in the higher shells to drop down the fill the vacancies, and releasing energy in the form of x-rays in the process. Each element emits x-rays over a short range of energies unique to that element, allowing each element to be identified. The mass of each element on the filter is determined from the area

of each peak shown in Figure 8, since the area is proportional to the absolute concentration of the element on the filter. The ambient concentration of each element is then calculated from the volume of air sampled.

Several previous studies have used PIXE analysis, along with other techniques, to determine particulate composition and sources of particulates in a number of Australian sites. For example, PIXE techniques have been used in studies of particulate in Sydney (Cohen et al., 1993; Cohen et al., 2004) and Brisbane (Chan et al., 2000).

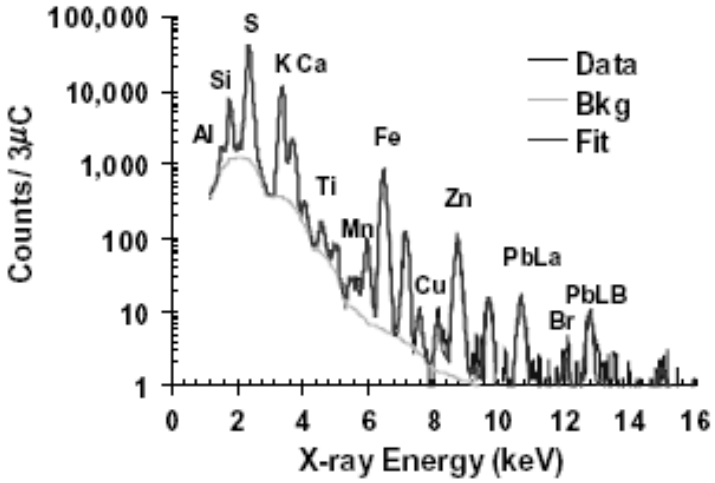


Figure 8. PIXE spectrum of an aerosol sample showing the characteristic X-ray lines and intensities from the trace elements in the aerosol particles Cohen et al., (2004).

4.6 Soluble ions and pH

Soluble ions concentration in rainwater and aerosol extract and sulfur dioxide passive sampler extracts are analysed with an Dionex DX 500 ion chromatograph according to the NATA accreditation held by CMAR (CMAR-NATA-WI-WC-09 Ion chromatography). Cations were separated with a Dionex AS11 analytical column and the conductivity was suppressed with a SRS Ultra II cation suppressor. Anions were separated using AS11 analytical column and an Ultra II anion suppressor. Peak areas are integrated with Dionex software, and the ion concentrations are calculated from the peak areas of the samples and standards, which are injected at the start of and analytical run and periodically during the run.

The pH measurements were carried out on rainwater samples and aerosol, extracts according to the NATA accreditation held by CMAR (CMAR-NATA-WI-WC-11 pH analysis. The pH was measured on rainwater and aerosol extracts using an EA940 Orion Expandable Ion Analyser pH meter and a low Ross semi-micro combination pH electrode. The pH electrode was standardised using Orion low ionic strength buffers that have pH values of 4.100 and 6.970. These buffers are designed to measure the pH of low ionic strength solutions such as rainwater. At various times the calibration of the electrode is checked by measuring the pH of a 0.05 molar sulfuric acid standard serially diluted to 50 µmolar. The rainwater and aerosol extracts are stirred by with a teflon coated magnetic stirrer during the measurement, and a ionic strength adjustor is added at the rate of 1%.

5. RESULTS AND DISCUSSION

5.1 Gas measurements

Tables 6a and 6b present the results of passive gas measurements of ammonia and nitrogen dioxide carried out at the seven Burrup sites and at the Karratha and Mardie Station sites during 2004/2005 and 2007/2008 respectively. The Tables lists the individual concentrations of ammonia and nitrogen dioxide at each site for each sampling period, and the average concentrations measured from the beginning of August 2004 until the mid September 2005. Where both pairs are less than the limit of detection the average was set to half the limit of detection. There are several pairs of samplers that have large differences in ammonia concentrations between the duplicate pairs. For example, site 3, site 4 and site 6 have large differences in ammonia concentration during the sampling period beginning on 21/11/04, 20/11/04 and 20/11/04 respectively. One reason for this difference may be due to contamination of the sampler with ammonium salt. Ammonium salts are ubiquitous, especially in a hot environment where they are present in sweat. Although the samplers are handled very carefully ammonia contamination during preparation and or sampling cannot be excluded for these measurements.

The monthly mean ammonia concentrations for 2004/2005 are shown in Table 6a. Detection limits for ammonia were calculated from the blanks sent with each batch of samplers on a monthly basis, and they ranged from 0.1 ppb to 0.6 ppb. If only one duplicate was above the limit of detection that value is entered as the mean. However, the mean of a duplicate pair was set half the limit of detection when both duplicates were less than the limit of detection. Ammonia concentrations ranged from 0.1 ppb on the Burrup Peninsula and Mardie Station to more than 4 ppb at the Karratha site. Karratha (Site 9) has ammonia concentrations that range from about 2 ppb to 4 ppb with an average of close to 2.6 ppb; this is significantly higher than concentrations at the other sites, and may be due to a local urban source. Average annual ammonia concentrations at the Burrup Peninsula sites range from 0.3 ppb at site 1 to 0.5 ppb at site 6. At site 10, Mardie Station, the annual average ammonia concentration was 0.8 ppb; slightly higher than the Burrup sites. Since sites 1, 3 are situated on the northern end of the Burrup, away from the industrial areas, those, and site 10 could be considered to represent the local background concentration. The average ammonia concentration of the background is then about 0.5 ppb. There appears to be no real differences in concentration at any of these sites, indicating that ammonia is not enhanced above the local background.

The monthly mean ammonia concentrations for the 2007/2008 sampling period are shown in Table 6b. The detection limits for this set of data was 0.4 ppb. The criteria for assigning values to periods which recorded concentrations below the detection limits, is as described above. Monthly averaged ammonia concentrations ranged from 0.2 ppb at several sites to 19.1 ppb at site 1 during January/February 2008. This ammonia concentration is greater than any other recorded at any of the Burrup sites. Because it was not recorded at other sites such as 3 or 4, it is assumed that this was probably due to a natural local emission of ammonia, from a dead animal, for example. For this reason it was not included in the deposition calculations.

The annual average ammonia concentrations for the 2007/2008 sampling period are given for each site in Table 6b, and in a summarised form in Table 10. The study shows that the annual mean concentrations range from 0.3 ppb at sites 1 and 2 to 0.8 ppb at Mardie Station and 2.6 ppb at the Karratha site. The background sites, 1, 3 and 10 and site 9, in Karratha, show no or very little change in the annual average ammonia concentrations. However, annual average ammonia concentrations at sites 5, 6, 7 and 8 show a very small increase in ammonia concentrations in 2007/2008 compared with the 2004/2005 sampling period. For site 5, this increase was due almost entirely to the period from 3rd June to 14th July, when the monthly average ammonia was 3.0 ppb. This is a significant increase in concentration over the 2004/2005 sampling period when the maximum monthly ammonia concentration was 0.8 ppb, but the difference in the annual average concentration between the two annual sampling periods is insignificant. In fact the ammonia concentrations at all the sites on the Peninsula are much lower than the annual average in Karratha.

Ammonia concentrations for the 2004/2005 period are shown in Figure 9 plotted against the sampling mid-date. It shows that except for Site 9, ammonia concentrations on the Burrup are generally quite consistent from site to site. Site 10 has slightly elevated ammonia concentrations during most sampling periods, and this may be due to activities carried out at the Station such as fertilizer use.

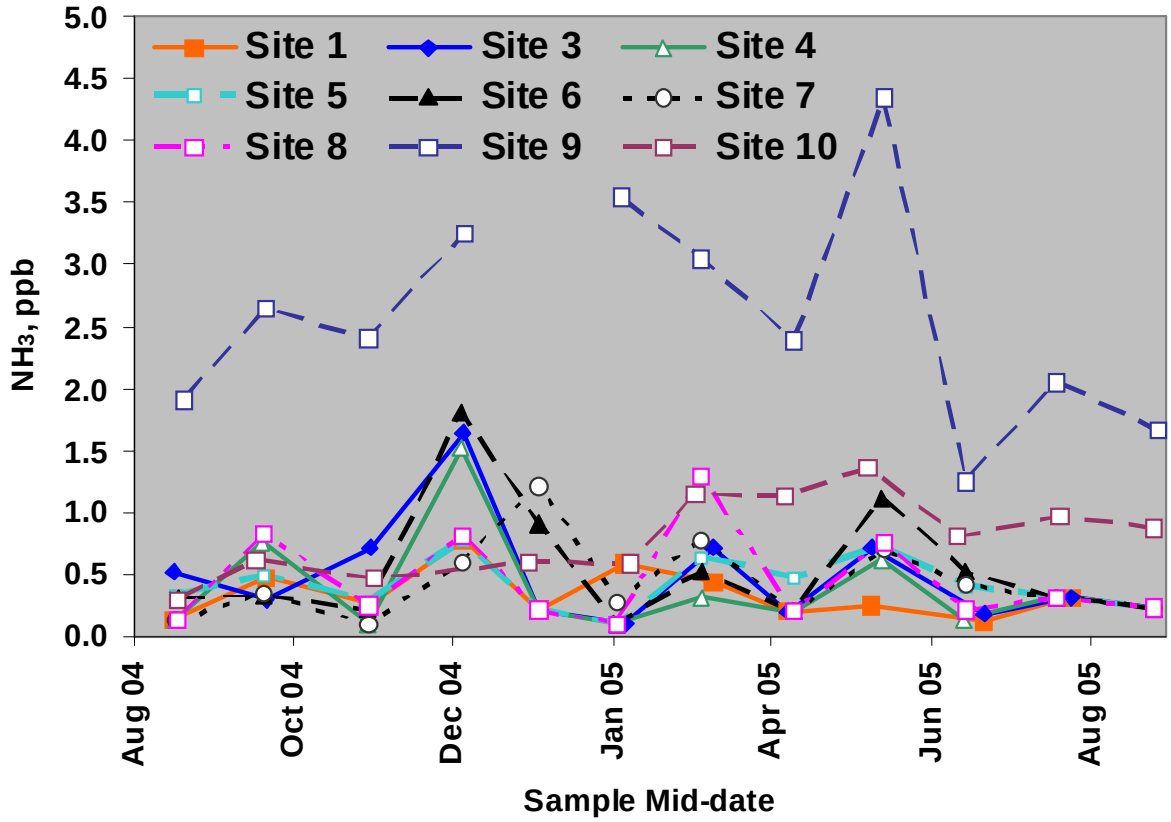


Figure 9a. Ammonia concentrations plotted against the mid-date of the sampling period from August 2004 to August 2005.

Figure 9b is a plot of ammonia concentrations at the sites measured during the 2007/2008 period. The ammonia concentrations from site 1 are plotted against the right axis to accommodate the high concentration measured during January/February 2008. The monthly concentrations show little monthly variation except perhaps due to rain in some monthly sampling periods.

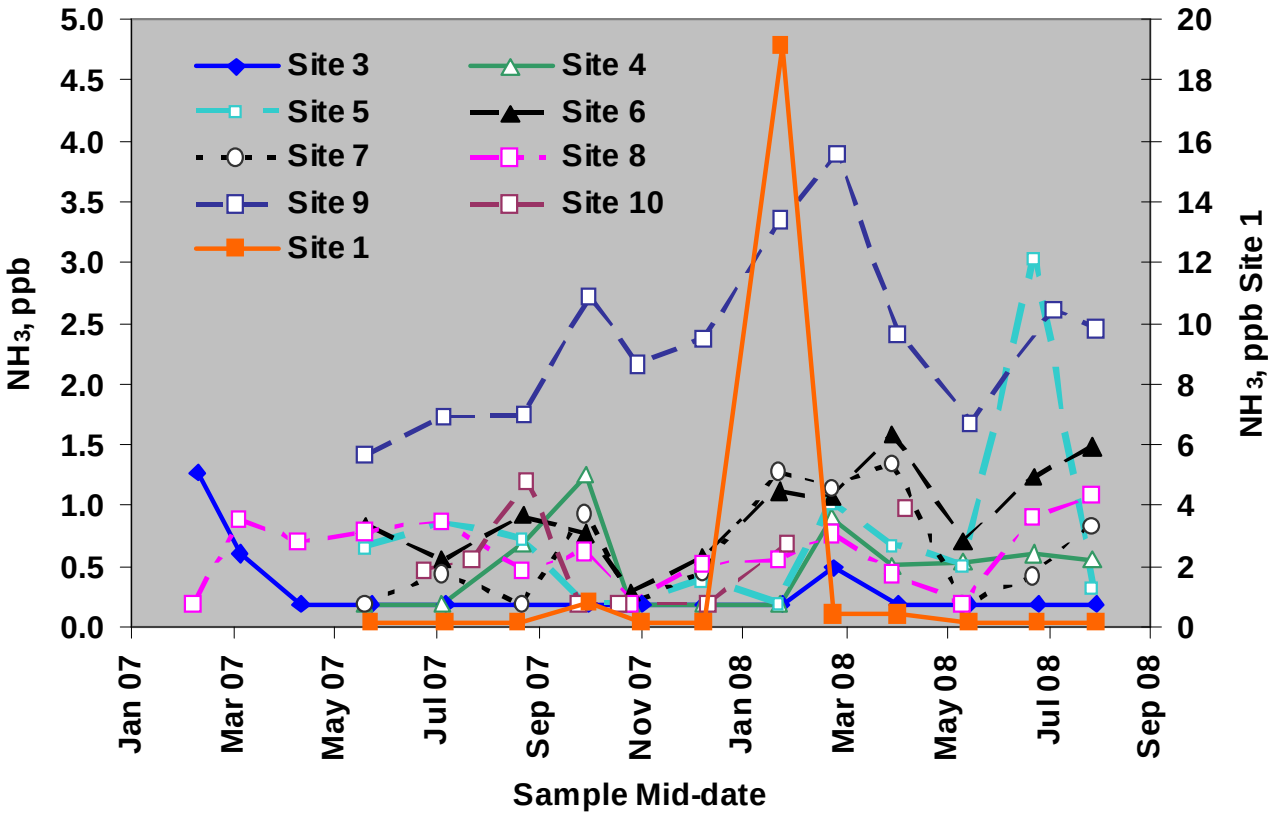


Figure 9b. Ammonia concentrations plotted against the mid-date of the sampling period from February 2007 to August 2008.

The ammonia data presented in Tables 6a and 6b can be compared to ammonia concentrations of 0.09 ppb measured in maritime air at the Cape Grim Baseline Air Pollution Station by Ayers and Gras, (1983). A series of unpublished passive gas measurements of ammonia during monthly sampling at Kuala Lumpur show that the average concentration is 8.3 ppb with a maximum of 35.2 ppb. Table 6 shows that concentrations on the Burrup are much closer to concentrations measured at Cape Grim than those measured in a polluted urban environment of Kuala Lumpur.

The monthly mean nitrogen dioxide concentrations for the 2004/2005 period are also presented in Table 6a. Monthly mean concentrations ranged from 0.2 ppb at site 10 during September 2004 to 3.8 ppb at site 9, during May 2004. The nitrogen dioxide concentrations averaged over the 12 sampling periods show that the lowest annual average concentration of 0.5 ppb were measured at Mardie Station, although Sites 1 and 3, at 0.6 ppb and 0.7 ppb, on the Northern end of the Burrup, are also very low. Assuming these sites define a regional background the local background concentration for nitrogen dioxide is about 0.6 ppb. The limit of detection for nitrogen dioxide measurements using passive samplers for 30 days is about 0.06 ppb.

Sites 4 to 8 are all located on the lower Burrup, closer to industry and anthropogenic influences and they could be reasonably be expected to show elevated nitrogen dioxide concentrations. The annual average concentrations at these sites range from 1.4 ppb to 2.4 ppb. Taken together, they have nitrogen dioxide concentrations of about 1.9 ppb, and this is only a moderate enhancement over the local background sites on the northern Burrup and Mardie Station.

Table 6b lists the monthly and annual mean nitrogen dioxide concentrations for the 2007/2008 sampling phase. The detection limit, calculated from the standard deviation of the blanks using equation (6) was 0.05 ppb for the 2007/2008 sampling period; this is very similar to that calculated in the previous annual sampling period. The background level for this sampling time is about 0.7 ppb taking sites 1, 3 and 10 as representing the local nitrogen dioxide background concentration. During this period sites 4 to 8 averaged

about 2.0 ppb which is very similar to the 2004/2005 period, and, as noted previously, this is a small enhancement over the background sites.

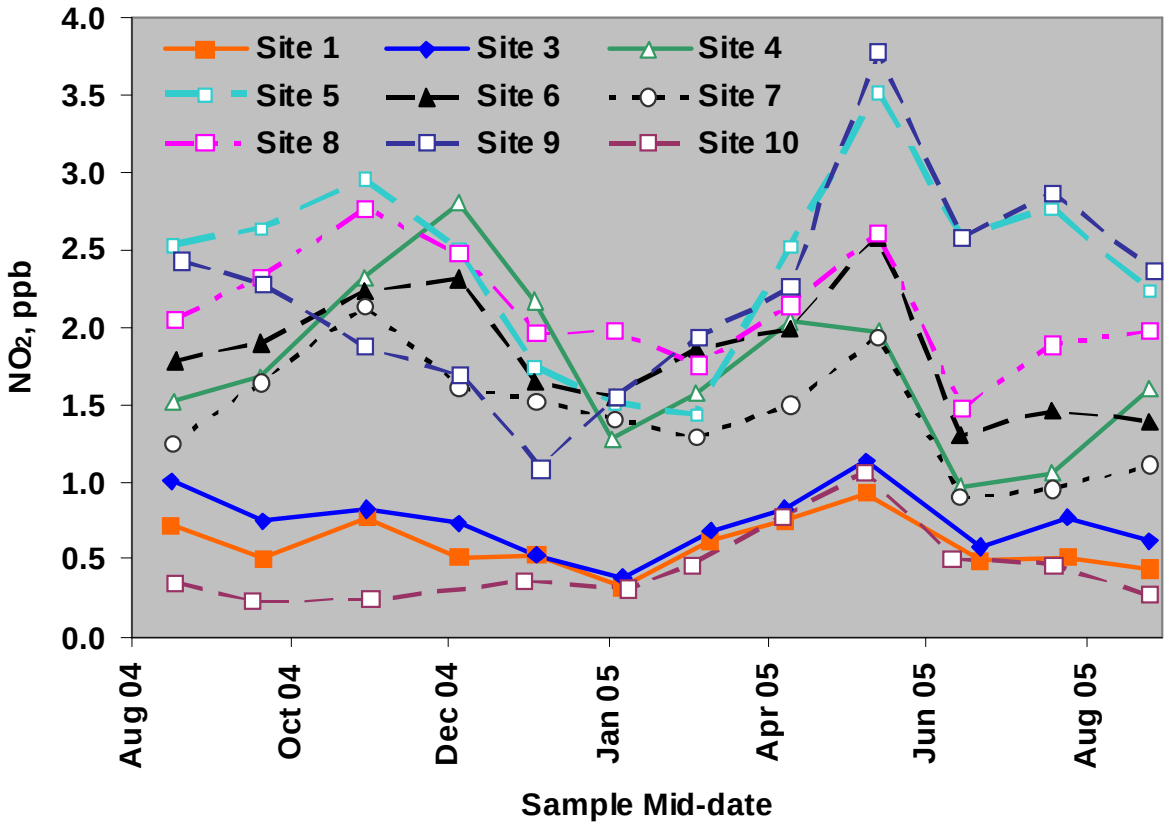


Figure 10a. Nitrogen dioxide concentrations plotted against the mid-date of the sampling period from August 2004 to August 2005.

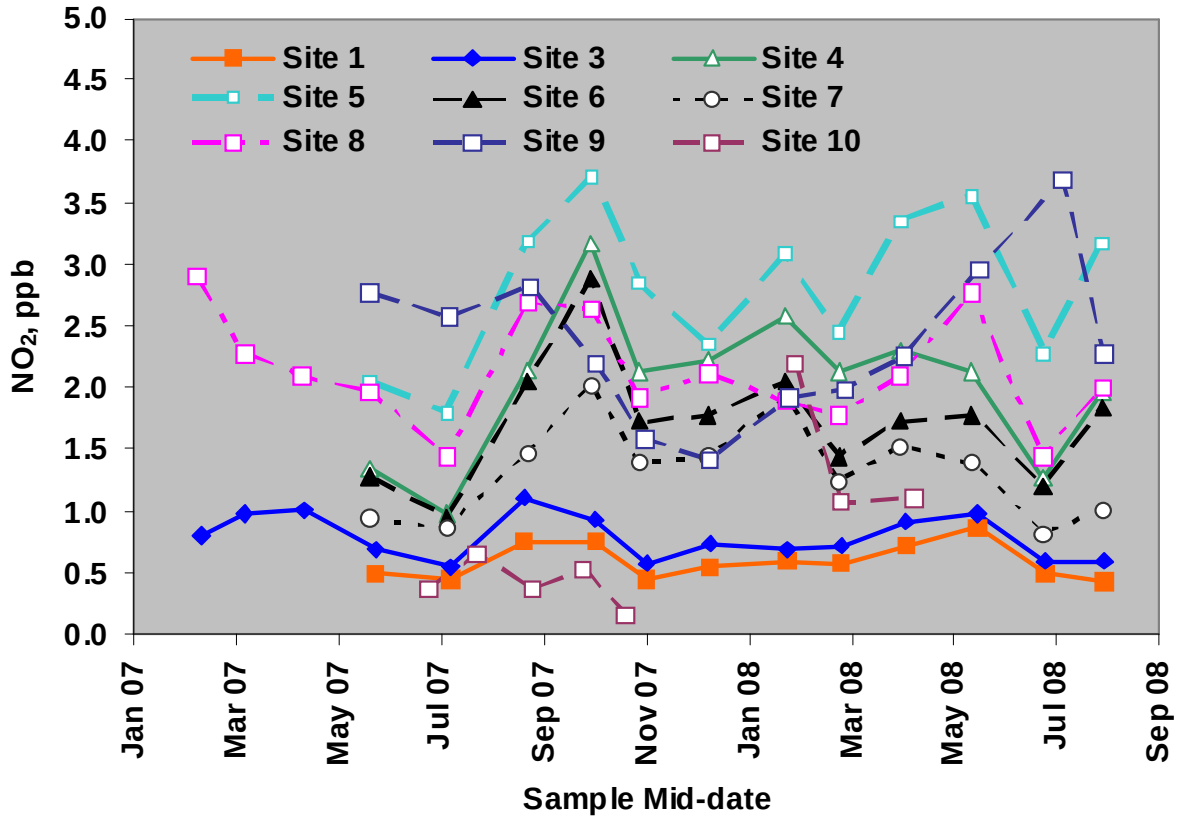


Figure 10b. Nitrogen dioxide concentrations plotted against the mid-date of the sampling period from February 2007 to August 2008.

Nitrogen dioxide concentrations, plotted against the sampling mid-date are displayed in Figure 10a. They show clearly the slight enhancement in concentrations at sites closer to the industrial area of the Burrup relative to those observed at the local background, at Sites 1, 3 and 10. Figure 19b shows the corresponding plot for the 2007/2008 sampling interval. The same level of small enhancement of nitrogen dioxide concentrations at the lower Burrup Peninsula sites is evident. The nitrogen dioxide concentrations at site 10 were elevated over three sampling periods from January to April, but the reasons for this are not clear.

The nitrogen dioxide concentrations measured on the Burrup Peninsula can be compared with measurements in several other regions. Several studies have produced nitrogen dioxide concentrations at terrestrial "background" sites. In Indonesia, Gillett et al. (2000) measured nitrogen dioxide concentrations of about 1.2 ppb at the Global Atmosphere Watch (GAW) Station at Bukit Koto Tabang, Sumatra. Passive gas measurements were made over approximately monthly periods at a remote site west of Darwin over several years using passive samplers. At this site the annual average nitrogen dioxide concentration was 0.75 ppb (Ayers et al., 2000). Ayers et al. (2002) measured nitrogen dioxide using passive samplers of 0.8 ppb at a Malaysian "background" site at Tanah Rata, in the Cameron Highlands, north of Kuala Lumpur. The results from Bukit Koto Tabang, Charles Point and Tanah Rata are comparable to the concentrations at Sites 1, 3 and 10, confirming that a regional background of about 0.5 ppb is quite reasonable, and that a range of 0.5 ppb to 1 ppb could be expected.

In comparison, very high concentrations of nitrogen dioxide have been measured at several large Asian cities. Nitrogen dioxide concentrations of about 29 ppb have been measured in Jakarta (Gillett et al., 2000). In a study in Petaling Jaya, (Kuala Lumpur) Malaysia Ayers et al. (2000) measured annual average nitrogen dioxide concentrations ranging from 27.0 ppb to 30.3 ppb from 1994 to 1998. The results from the Burrup sites show that nitrogen dioxide concentrations are much lower than those experienced in large polluted Asian cities.

Table 6a. Concentrations of ammonia and nitrogen dioxide at the nine sampling sites from August 2004 until late March 2005. Concentrations are in ppb. Relative percent differences are calculated using equation (10). Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration. C signifies contaminated sample.

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
Site 1							
29/07/04 11:50	02/09/04 15:35	<0.2	0.1		0.7	0.7	12.5
29/07/04 11:50	02/09/04 15:35	<0.2			0.8		
02/09/04 15:40	08/10/04 09:35	0.6	0.5	50.5	0.4	0.5	21.6
02/09/04 15:40	08/10/04 09:35	0.4			0.6		
08/10/04 09:45	21/11/04 12:05	<0.2	0.3		0.6	0.8	36.6
08/10/04 09:45	21/11/04 12:05	0.3			0.9		
21/11/04 12:05	17/12/04 12:10	0.9	0.7	22.7	0.5	0.5	2.9
21/11/04 12:05	17/12/04 12:10	0.7			0.5		
17/12/04 12:10	19/01/05 13:02	<0.4	0.2		0.5	0.5	2.6
17/12/04 12:10	19/01/05 13:02	<0.4			0.5		
19/01/05 13:07	21/02/05 12:55	0.6	0.6		0.3	0.3	2.0
19/01/05 13:07	21/02/05 12:55				0.3		
21/02/05 13:12	28/03/05 11:14	0.4	0.4	0.86	0.6	0.6	11.0
21/02/05 13:12	28/03/05 11:14	0.4			0.7		
28/03/05 11:20	18/04/05 09:55	<0.4	0.2		0.8	0.7	4.7
28/03/05 11:20	18/04/05 09:55	<0.4			0.7		
18/04/05 11:17	31/05/05 11:24	<0.5	0.2		1.0	0.9	5.1
18/04/05 11:17	31/05/05 11:24	<0.5			0.9		
31/05/05 11:25	13/07/05 11:50	0.1	0.1		0.5	0.5	9.0
31/05/05 11:25	13/07/05 11:50	<0.1			0.5		
13/07/05 11:45	07/08/05 11:40	<0.6	0.3		0.4	0.5	29.8
13/07/05 11:45	07/08/05 11:40	<0.6			0.6		
07/08/05 11:50	14/09/05 09:53	<0.4	0.2		0.4	0.4	1.4
07/08/05 11:50	14/09/05 09:53	<0.4			0.4		
mean			***0.3***			***0.6***	
Site 3							
29/07/04 16:00	02/09/04 13:10	<0.3	0.5		0.9	1.0	11.4
29/07/04 16:00	02/09/04 13:10	0.5			1.1		
02/09/04 13:20	08/10/04 11:25	0.2	0.3	45.5	0.8	0.8	4.0
02/09/04 13:20	08/10/04 11:25	0.4			0.7		
08/10/04 11:30	21/11/04 15:45	1.1	0.7	124.9	0.9	0.9	
08/10/04 11:30	21/11/04 15:45	0.3					
21/11/04 15:45	17/12/04 14:15	2.5	1.6	98.6	0.8	0.7	7.2
21/11/04 15:45	17/12/04 14:15	0.8			0.7		
17/12/04 14:15	19/01/05 16:40	<0.4	0.2		0.6	0.3	
17/12/04 14:15	19/01/05 16:40	<0.4			0.0		
19/01/05 16:40	21/02/05 10:31	<0.2	0.1		0.4	0.4	9.6
19/01/05 16:40	21/02/05 10:31	<0.2			0.4		
21/02/05 09:53	28/03/05 12:28	0.9	0.7	46.8	0.6	0.7	13.2
21/02/05 09:53	28/03/05 12:28	0.5			0.7		
28/03/05 12:30	18/04/05 14:41	<0.4	0.2		0.8	0.8	0.6
28/03/05 12:30	18/04/05 14:41	<0.4			0.8		
18/04/05 14:41	31/05/05 13:15	0.8	0.7	22.4	1.1	1.1	2.3
18/04/05 14:41	31/05/05 13:15	0.6			1.2		

Table 6a cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
31/05/05 13:20	13/07/05 16:05	0.2	0.2	29.8	0.6	0.6	11.3
31/05/05 13:20	13/07/05 16:05	0.1			0.6		
13/07/05 15:46	07/08/05 15:05	<0.6	0.3		0.8	0.8	1.2
13/07/05 15:46	07/08/05 15:05	<0.6			0.8		
07/08/05 15:10	14/09/05 13:00	<0.4	0.2		0.6	0.6	11.6
07/08/05 15:10	14/09/05 13:00	<0.4			0.7		
Mean			***0.5***			***0.7***	
Site 4							
01/08/04 12:09	01/09/04 09:17	<0.3	0.1		1.6	1.5	3.2
01/08/04 12:09	01/09/04 09:17	<0.3			1.5		
01/09/04 09:25	07/10/04 09:15	<0.3	0.8		1.7	1.7	3.2
01/09/04 09:25	07/10/04 09:15	0.8			1.6		
07/10/04 09:20	20/11/04 08:20	<0.2	0.1		2.3	2.3	1.8
07/10/04 09:20	20/11/04 08:20	<0.2			2.3		
20/11/04 08:20	18/12/04 06:30	2.2	1.5	96.9	2.8	2.8	1.2
20/11/04 08:20	18/12/04 06:30	0.8			2.8		
18/12/04 06:30	18/01/05 10:02	<0.4	0.2		2.2	2.2	0.0
18/12/04 06:30	18/01/05 10:02	<0.4			2.2		
18/01/05 10:07	16/02/05 06:30	<0.2	0.1		1.3	1.3	1.5
18/01/05 10:07	16/02/05 06:30	<0.2			1.3		
16/02/05 06:45	23/03/05 09:53	0.3	0.3	37.8	1.6	1.6	2.7
16/02/05 06:45	23/03/05 09:53	0.4			1.6		
23/03/05 09:53	28/04/05 08:48	<0.4	0.2		2.1	2.0	1.5
23/03/05 09:53	28/04/05 08:48	<0.4			2.0		
28/04/05 08:49	30/05/05 10:40	0.6	0.6	11.7	2.0	2.0	1.8
28/04/05 08:49	30/05/05 10:40	0.6			2.0		
30/05/05 10:40	30/06/05 08:45	0.1	0.1		0.9	1.0	14.5
30/05/05 10:40	30/06/05 08:45	<0.1			1.0		
30/06/05 08:48	08/08/05 08:47	<0.6	0.3		1.0	1.1	2.6
30/06/05 08:48	08/08/05 08:47	<0.6			1.1		
08/08/05 08:47	13/09/05 08:43	<0.4	0.2		1.4	1.6	22.3
08/08/05 08:47	13/09/05 08:43	<0.4			1.8		
Mean			***0.4***			***1.8***	
Site 5							
01/08/04 16:04	01/09/04 13:35	0.4	0.3	23.3	2.4	2.5	11.5
01/08/04 16:04	01/09/04 13:35	0.3			2.7		
01/09/04 13:40	07/10/04 11:15	0.6	0.5	37.2	2.6	2.6	3.6
01/09/04 13:40	07/10/04 11:15	0.4			2.7		
07/10/04 11:20	20/11/04 12:40	0.3	0.3		2.8	3.0	8.5
07/10/04 11:20	20/11/04 12:40	<0.2			3.1		
20/11/04 12:40	18/12/04 07:45	0.9	0.8	30.5	2.6	2.5	3.7
20/11/04 12:40	18/12/04 07:45	0.7			2.5		
18/12/04 07:45	18/01/05 12:38	<0.4	0.2		1.7	1.7	1.4
18/12/04 07:45	18/01/05 12:38	<0.4			1.8		
18/01/05 12:44	16/02/05 08:30	<0.2	0.1		1.5	1.5	0.0
18/01/05 12:44	16/02/05 08:30	<0.2			1.5		
16/02/05 08:15	23/03/05 11:56	0.7	0.6	19.3	1.4	1.4	5.3
16/02/05 08:15	23/03/05 11:56	0.6			1.5		
23/03/05 11:56	28/04/05 10:22	<0.4	0.5		2.5	2.5	1.2
23/03/05 11:56	28/04/05 10:22	0.5			2.5		

Table 6a cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
28/04/05 10:22	30/05/05 11:40	<0.5	0.7		3.5	3.5	0.5
28/04/05 10:22	30/05/05 11:40	0.7			3.5		
30/05/05 11:40	30/06/05 09:15	0.4	0.4	18.3	2.6	2.6	1.0
30/05/05 11:40	30/06/05 09:15	0.4			2.6		
30/06/05 09:20	08/08/05 09:35	<0.6	0.3		2.8	2.8	5.9
30/06/05 09:20	08/08/05 09:35	<0.6			2.7		
08/08/05 09:35	13/09/05 10:32	<0.4	0.2		2.1	2.2	7.9
08/08/05 09:35	13/09/05 10:32	<0.4			2.3		
Mean			***0.4***			***2.4***	
Site 6							
03/08/04 12:29	01/09/04 12:00	0.3	0.3		1.9	1.8	8.2
03/08/04 12:29	01/09/04 12:00	<0.3			1.7		
01/09/04 12:10	07/10/04 10:30	0.3	0.3	0.4	2.0	1.9	9.3
01/09/04 12:10	07/10/04 10:30	0.3			1.8		
07/10/04 10:35	20/11/04 10:30	0.2	0.2	27.1	2.2	2.2	2.4
07/10/04 10:35	20/11/04 10:30	0.2			2.3		
20/11/04 10:30	18/12/04 08:45	0.8	1.8	113.8	2.4	2.3	4.5
20/11/04 10:30	18/12/04 08:45	2.8			2.3		
18/12/04 08:45	18/01/05 11:15	0.5	0.9	95.3	1.6	1.7	2.8
18/12/04 08:45	18/01/05 11:15	1.3			1.7		
18/01/05 11:25	16/02/05 07:20	<0.2	0.1		1.7	1.6	16.3
18/01/05 11:25	16/02/05 07:20	<0.2			1.4		
16/02/05 07:30	23/03/05 10:52	0.6	0.5	48.8	1.8	1.9	5.0
16/02/05 07:30	23/03/05 10:52	0.4			1.9		
23/03/05 10:52	28/04/05 09:35	<0.4	0.2		2.1	2.0	6.8
23/03/05 10:52	28/04/05 09:35	<0.4			1.9		
28/04/05 09:36	30/05/05 13:00	1.1	1.1	9.1	2.6	2.6	1.6
28/04/05 09:36	30/05/05 13:00	1.2			2.6		
30/05/05 13:00	30/06/05 10:20	0.3	0.5	69.4	1.3	1.3	1.1
30/05/05 13:00	30/06/05 10:20	0.7			1.3		
30/06/05 10:15	08/08/05 10:21	<0.6	0.3		1.4	1.5	1.7
30/06/05 10:15	08/08/05 10:21	<0.6			1.5		
08/08/05 10:21	13/09/05 14:35	<0.4	0.2		1.6	1.4	27.4
08/08/05 10:21	13/09/05 14:35	<0.4			1.2		
Mean			***0.5***			***1.8***	
Site 7							
01/08/04 15:01	01/09/04 08:24	<0.3	0.1		1.3	1.3	1.5
01/08/04 15:01	01/09/04 08:24	<0.3			1.2		
01/09/04 13:45	07/10/04 13:30	0.4	0.3	53.6	1.6	1.6	4.0
01/09/04 13:45	07/10/04 13:30	0.3			1.7		
07/10/04 13:35	20/11/04 14:35	<0.2	0.1		2.1	2.1	1.4
07/10/04 13:35	20/11/04 14:35	<0.2			2.1		
20/11/04 14:35	18/12/04 09:40	0.5	0.6	16.9	1.7	1.6	6.5
20/11/04 14:35	18/12/04 09:40	0.6			1.6		
18/12/04 09:40	18/01/05 15:10	1.0	1.2	27.6	1.5	1.5	3.6
18/12/04 09:40	18/01/05 15:10	0.3			1.6		
18/01/05 15:16	16/02/05 09:15	0.3	0.3	36.3	1.4	1.4	4.3
18/01/05 15:16	16/02/05 09:15	0.2			1.4		
16/02/05 09:30	23/03/05 13:05	0.6	0.8	41.1	1.3	1.3	0.4
16/02/05 09:30	23/03/05 13:05	0.9			1.3		

Table 6a cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
23/03/05 13:12	28/04/05 11:20	<0.4	0.2		1.5	1.5	2.7
23/03/05 13:12	28/04/05 11:20	<0.4			1.5		
28/04/05 11:20	30/05/05 14:10	0.6	0.7	16.9	1.9	1.9	7.6
28/04/05 11:20	30/05/05 14:10	0.7			2.0		
30/05/05 14:10	30/06/05 11:25	0.4	0.4		1.0	0.9	15.4
30/05/05 14:10	30/06/05 11:25	<0.1			0.8		
30/06/05 11:23	08/08/05 11:25	<0.6	0.3		1.0	1.0	0.1
30/06/05 11:23	08/08/05 11:25	<0.6			1.0		
08/08/05 11:25	13/09/05 11:41	<0.4	0.2		1.1	0.6	175.8
08/08/05 11:25	13/09/05 11:41	<0.4			0.1		
Mean			***0.4***			***1.4***	
Site 8							
03/08/04 09:07	01/09/04 11:05	<0.3	0.1		2.1	2.1	4.4
03/08/04 09:07	01/09/04 11:05	<0.3			2.0		
01/09/04 11:15	07/10/04 15:00	0.9	0.8	7.0	2.4	2.3	5.5
01/09/04 11:15	07/10/04 15:00	0.8			2.3		
07/10/04 15:05	20/11/04 16:30	0.2	0.2	11.7	2.8	2.8	3.9
07/10/04 15:05	20/11/04 16:30	0.3			2.7		
20/11/04 16:30	18/12/04 11:30	0.8	0.8	1.8	2.5	2.5	1.0
20/11/04 16:30	18/12/04 11:30	0.8			2.5		
18/12/04 11:30	18/01/05 17:17	<0.4	0.2		2.0	2.0	0.4
18/12/04 11:30	18/01/05 17:17	<0.4			2.0		
18/01/05 17:25	16/02/05 10:40	<0.2	0.1		1.9	2.0	2.9
18/01/05 17:25	16/02/05 10:40	<0.2			2.0		
16/02/05 11:15	23/03/05 14:31	0.6	0.6	224.9	1.7	1.8	6.5
16/02/05 11:15	23/03/05 14:31	2.0[C]			1.8		
23/03/05 14:35	28/04/05 11:50	<0.4	0.2		2.1	2.1	0.3
23/03/05 14:35	28/04/05 11:50	<0.4			2.1		
28/04/05 11:51	30/05/05 16:00	0.8	0.8	10.2	2.7	2.6	3.4
28/04/05 11:51	30/05/05 16:00	0.7			2.6		
30/05/05 16:01	30/06/05 12:30	0.2	0.2	26.4	1.5	1.5	0.4
30/05/05 16:01	30/06/05 12:30	0.2			1.5		
30/06/05 12:35	08/08/05 12:35	<0.6	0.3		1.9	1.9	2.7
30/06/05 12:35	08/08/05 12:35	<0.6			1.9		
08/08/05 12:35	13/09/05 15:50	<0.4	0.2		2.0	2.0	2.2
08/08/05 12:35	13/09/05 15:50	<0.4			2.0		
mean			***0.4***			***2.1***	
Site 9							
05/08/04 15:00	03/09/04 18:00	1.8	1.9	7.8	2.3	2.4	12.9
05/08/04 15:00	03/09/04 18:00	2.0			2.6		
03/09/04 18:00	07/10/04 20:30	2.6	2.6	1.2	2.3	2.3	1.7
03/09/04 18:00	07/10/04 20:30	2.6			2.3		
07/10/04 20:35	20/11/04 18:00	2.4	2.4	0.7	1.8	1.9	3.6
07/10/04 20:35	20/11/04 18:00	2.4			1.9		
20/11/04 18:00	20/12/04 11:30	3.2	3.2	3.3	1.7	1.7	1.0
20/11/04 18:00	20/12/04 11:30	3.3			1.7		
20/12/04 11:30	20/01/05 10:15				1.1	1.1	
20/12/04 11:30	20/01/05 10:15						
20/01/05 10:45	16/02/05 18:00	3.2	3.5	21.8	1.5	1.6	6.4
20/01/05 10:45	16/02/05 18:00	3.9			1.6		

Table 6a cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
16/02/05 18:10	23/03/05 15:20	3.2	3.0	8.9	1.8	1.9	18.3
16/02/05 18:10	23/03/05 15:20	2.9			2.1		
23/03/05 15:26	28/04/05 13:42	2.2	2.4	13.7	2.2	2.3	0.9
23/03/05 15:26	28/04/05 13:42	2.6			2.3		
28/04/05 13:45	30/05/05 18:04	4.4	4.3	3.5	3.8	3.8	1.5
28/04/05 13:45	30/05/05 18:04	4.3			3.8		
30/05/05 18:08	30/06/05 13:30	1.5	1.2	42.1	2.6	2.6	0.5
30/05/05 18:08	30/06/05 13:30	1.0			2.6		
30/06/05 13:25	08/08/05 17:30	2.5	2.0	48.7	3.0	2.9	8.8
30/06/05 13:25	08/08/05 17:30	1.5			2.7		
08/08/05 17:45	15/09/05 18:00	1.6	1.7	8.2	2.2	2.4	10.1
08/08/05 17:45	15/09/05 18:00	1.7			2.5		
Mean			***2.6***			***2.2***	
Site10							
02/08/04 15:00	01/09/04 10:50	0.3	0.3		0.4	0.3	18.2
02/08/04 15:00	01/09/04 10:50	<0.3			0.3		
01/09/04 10:50	01/10/04 12:35	0.7	0.6	39.2	0.2	0.2	7.1
01/09/04 10:50	01/10/04 12:35	0.5			0.2		
01/10/04 12:35	01/12/04 10:30	0.5	0.5	16.6	0.2	0.2	7.1
01/10/04 12:35	01/12/04 10:30	0.4			0.3		
01/12/04 12:00	27/01/05 14:00	0.8	0.6	60.5	0.4	0.4	1.2
01/12/04 12:00	27/01/05 14:00	0.4			0.4		
27/01/05 14:00	18/02/05 09:30	0.3	0.6	82.6	0.3	0.3	
27/01/05 14:00	18/02/05 09:30	0.8					
18/02/05 09:30	17/03/05 11:30	1.1	1.1	0.4	0.5	0.5	3.7
18/02/05 09:30	17/03/05 11:30	1.2			0.5		
17/03/05 11:30	28/04/05 08:00	0.9	1.1	48.3	0.8	0.8	2.0
17/03/05 11:30	28/04/05 08:00	1.4			0.8		
28/04/05 08:00	19/05/05 10:00	0.5	1.4	122.6	1.1	1.1	3.0
28/04/05 08:00	19/05/05 10:00	2.2			1.0		
19/05/05 10:15	05/07/05 11:05	0.5	0.8	72.6	0.5	0.5	0.3
19/05/05 10:15	05/07/05 11:05	1.1			0.5		
05/07/05 11:15	05/08/05 13:20	0.8	1.0	42.7	0.4	0.5	12.0
05/07/05 11:15	05/08/05 13:20	1.2			0.5		
05/08/05 13:20	15/09/05 12:00	0.7	0.9	26.4	0.3	0.3	8.4
05/08/05 13:20	15/09/05 12:00	1.0			0.3		
Mean			***0.8***			***0.5***	

Table 6b. Concentrations of ammonia and nitrogen dioxide at the nine sampling sites from January 2007 until August 2008. Concentrations are in ppb. Relative percent differences are calculated using equation (10). Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration. ^{C} signifies contaminated sample.

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
Site 1							
04/05/07 11:22	14/06/07 09:39	<0.4	0.2		0.5	0.5	0.28
04/05/07 11:22	14/06/07 09:39	<0.4			0.5		
14/06/07 09:39	02/08/07 11:05	<0.4	0.2		0.4	0.4	9.33
14/06/07 09:39	02/08/07 11:05	<0.4			0.5		
02/08/07 11:10	09/09/07 10:30	<0.4	0.2		0.7	0.8	3.97
02/08/07 11:10	09/09/07 10:30	<0.4			0.8		
09/09/07 10:35	25/10/07 16:10	0.6	0.8	25.3	0.8	0.8	1.02
09/09/07 10:35	25/10/07 16:10	0.8			0.7		
25/10/07 16:20	09/11/07 09:22	<0.4	0.2		0.4	0.4	28.89
25/10/07 16:20	09/11/07 09:22	<0.4			0.5		
09/11/07 09:18	09/01/08 09:15	<0.4	0.2		0.6	0.5	11.91
09/11/07 09:18	09/01/08 09:15	0.4			0.5		
09/01/08 09:25	08/02/08 12:20	18.6	19.1	4.9	0.5	0.6	29.87
09/01/08 09:25	08/02/08 12:20	19.5			0.7		
08/02/08 12:30	12/03/08 13:15	<0.4	0.4		0.6	0.6	3.30
08/02/08 12:30	12/03/08 13:15	0.4			0.6		
12/03/08 13:15	27/04/08 10:50	0.4	0.5	32.9	0.7	0.7	1.11
12/03/08 13:15	27/04/08 10:50	0.6			0.7		
27/04/08 11:10	04/06/08 10:30	<0.4	0.2		0.8	0.9	21.70
27/04/08 11:10	04/06/08 10:30	<0.4			1.0		
04/06/08 10:30	17/07/08 09:45	<0.4	0.2		0.5	0.5	11.02
04/06/08 10:30	17/07/08 09:45	<0.4			0.5		
17/07/08 09:48	14/08/08 11:05	<0.4	0.2		0.4	0.4	2.63
17/07/08 09:48	14/08/08 11:05	<0.4			0.4		
Mean			***1.9***		***0.6***		
Site 3							
29/01/07 11:00	22/02/07 10:51	1.0	1.3	43.2	0.8	0.8	4.67
29/01/07 11:00	22/02/07 10:51	1.5			0.8		
22/02/07 11:00	20/03/07 08:51	0.5	0.6	26.2	1.0	1.0	5.71
22/02/07 11:00	20/03/07 08:51	0.7			0.9		
20/03/07 08:55	04/05/07 12:59	<0.4	0.2		1.0	1.0	4.35
20/03/07 08:55	04/05/07 12:59	<0.4			1.0		
04/05/07 12:59	14/06/07 08:24	<0.4	0.2		0.7	0.7	1.52
04/05/07 12:59	14/06/07 08:24	<0.4			0.7		
14/06/07 08:24	02/08/07 13:20	<0.4	0.2		0.6	0.5	0.18
14/06/07 08:24	02/08/07 13:20	<0.4			0.5		
02/08/07 13:23	09/09/07 12:30	<0.4	0.2		1.1	1.1	5.81
02/08/07 13:23	09/09/07 12:30	<0.4			1.1		
09/09/07 12:35	25/10/07 14:10	<0.4	0.2		0.9	0.9	4.31
09/09/07 12:35	25/10/07 14:10	<0.4			1.0		
25/10/07 14:20	09/11/07 10:42	<0.4	0.2		0.5	0.6	26.96
25/10/07 14:20	09/11/07 10:42	<0.4			0.6		
09/11/07 10:46	09/01/08 10:46	<0.4	0.2		0.8	0.7	5.52
09/11/07 10:46	09/01/08 10:46	<0.4			0.7		

Table 6b cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
09/01/08 10:50	08/02/08 13:50	<0.4	0.2		0.7	0.7	4.57
09/01/08 10:50	08/02/08 13:50	<0.4			0.7		
08/02/08 14:05	12/03/08 11:25	<0.4	0.5		0.7	0.7	3.14
08/02/08 14:05	12/03/08 11:25	0.5			0.7		
12/03/08 11:30	27/04/08 14:03	<0.4	0.2		0.9	0.9	1.59
12/03/08 11:30	27/04/08 14:03	<0.4			0.9		
27/04/08 15:00	04/06/08 12:20	<0.4	0.2		1.0	1.0	
27/04/08 15:00	04/06/08 12:20	<0.4					
04/06/08 12:30	17/07/08 11:17	<0.4	0.2		0.6	0.6	3.30
04/06/08 12:30	17/07/08 11:17	<0.4			0.6		
17/07/08 11:25	14/08/08 09:00	<0.4	0.2		0.6	0.6	1.20
17/07/08 11:25	14/08/08 09:00	<0.4			0.6		
Mean			***0.3***		***0.8***		
Site 4							
03/05/07 10:12	07/06/07 09:12	<0.4	0.2		1.5	1.4	17.14
03/05/07 10:12	07/06/07 09:12	<0.4			1.2		
07/06/07 09:12	04/08/07 08:05	<0.4	0.2		1.0	1.0	6.47
07/06/07 09:12	04/08/07 08:05	<0.4			1.0		
04/08/07 08:25	12/09/07 09:19	0.6	0.7	21.34	2.2	2.2	0.64
04/08/07 08:25	12/09/07 09:19	0.8			2.2		
12/09/07 09:26	16/10/07 14:10	1.3	1.3		3.1	3.2	7.11
12/09/07 09:26	16/10/07 14:10	<0.4			3.3		
16/10/07 14:11	08/11/07 09:40	<0.4	0.2		2.1	2.1	0.42
16/10/07 14:11	08/11/07 09:40	<0.4			2.1		
08/11/07 09:36	08/01/08 09:35	<0.4	0.2		2.2	2.2	0.53
08/11/07 09:36	08/01/08 09:35	<0.4			2.2		
08/01/08 09:45	07/02/08 11:00	<0.4	0.2		2.5	2.6	4.96
08/01/08 09:45	07/02/08 11:00	<0.4			2.6		
07/02/08 11:00	11/03/08 08:55	1.0	0.9	31.49	2.1	2.1	2.46
07/02/08 11:00	11/03/08 08:55	0.8			2.2		
11/03/08 09:05	21/04/08 07:55	0.4	0.5	27.72	2.4	2.3	2.95
11/03/08 09:05	21/04/08 07:55	0.6			2.3		
21/04/08 07:46	03/06/08 11:19	<0.4	0.5		2.2	2.1	6.38
21/04/08 07:46	03/06/08 11:19	0.5			2.1		
03/06/08 11:25	14/07/08 09:50	0.9	0.9	10.37	1.3	1.3	6.02
03/06/08 11:25	14/07/08 09:50	1.0			1.2		
14/07/08 09:55	14/08/08 11:05	0.5	0.6	8.23	2.0	2.0	1.47
14/07/08 09:55	14/08/08 11:05	0.6			2.0		
Mean			***0.5***		***2.0***		
Site 5							
03/05/07 10:53	07/06/07 09:50	0.6	0.7	27.78	2.1	2.0	2.54
03/05/07 10:53	07/06/07 09:50	0.7			2.0		
07/06/07 09:50	04/08/07 09:50	1.0	0.9	31.32	1.8	1.8	5.67
07/06/07 09:50	04/08/07 09:50	0.7			1.8		
04/08/07 10:00	12/09/07 10:05	0.7	0.7	14.13	3.2	3.2	3.73
04/08/07 10:00	12/09/07 10:05	0.8			3.1		
12/09/07 10:07	16/10/07 15:16	<0.4	0.2		3.6	3.7	6.37
12/09/07 10:07	16/10/07 15:16	<0.4			3.8		

Table 6b cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
16/10/07 15:31	08/11/07 10:37	<0.4	0.2		2.8	2.9	2.85
16/10/07 15:31	08/11/07 10:37	<0.4			2.9		
08/11/07 10:45	08/01/08 10:50	0.4	0.4		2.4	2.4	3.52
08/11/07 10:45	08/01/08 10:50	<0.4			2.3		
08/01/08 11:00	07/02/08 13:50	<0.4	0.2		3.1	3.1	2.22
08/01/08 11:00	07/02/08 13:50	<0.4			3.0		
07/02/08 11:10	11/03/08 10:10	0.9	1.0	24.88	2.5	2.4	2.50
07/02/08 11:10	11/03/08 10:10	1.1			2.4		
11/03/08 10:16	21/04/08 08:26	0.6	0.7	8.26	3.4	3.4	3.98
11/03/08 10:16	21/04/08 08:26	0.7			3.3		
21/04/08 08:30	03/06/08 12:57	0.5	0.5	0.74	3.6	3.6	0.53
21/04/08 08:30	03/06/08 12:57	0.5			3.6		
03/06/08 13:04	14/07/08 11:10	2.9	3.0	7.94	2.3	2.3	1.86
03/06/08 13:04	14/07/08 11:10	3.2			2.2		
14/07/08 11:15	13/08/08 09:55	0.3	0.3	8.44	3.2	3.2	0.28
14/07/08 11:15	13/08/08 09:55	0.3			3.2		
Mean			***0.7***		***2.8***		
Site 6							
03/05/07 11:16	07/06/07 10:20	0.9	0.8	0.9	1.3	1.3	4.63
03/05/07 11:16	07/06/07 10:20	0.8		0.8	1.2		
07/06/07 10:20	04/08/07 09:12	0.6	0.6	0.6	0.9	1.0	6.62
07/06/07 10:20	04/08/07 09:12	0.5		0.5	1.0		
04/08/07 09:25	12/09/07 10:27	0.8	0.9	0.8	2.0	2.0	0.00
04/08/07 09:25	12/09/07 10:27	1.0		1.0	2.0		
12/09/07 10:30	16/10/07 14:55	0.4	0.8	0.4	2.9	2.9	3.12
12/09/07 10:30	16/10/07 14:55	1.1		1.1	2.8		
16/10/07 14:55	08/11/07 10:07	0.4	0.3	0.4	1.2	1.7	61.75
16/10/07 14:55	08/11/07 10:07	<0.4		<0.4	2.3		
08/11/07 10:17	08/01/08 10:15	0.5	0.6	0.5	1.8	1.8	4.10
08/11/07 10:17	08/01/08 10:15	0.6		0.6	1.8		
08/01/08 10:20	07/02/08 12:10	0.4	1.1	0.4	2.0	2.0	1.94
08/01/08 10:20	07/02/08 12:10	1.8		1.8	2.0		
07/02/08 12:20	11/03/08 09:35	1.1	1.1	1.1	1.5	1.4	2.97
07/02/08 12:20	11/03/08 09:35	1.0		1.0	1.4		
11/03/08 09:59	21/04/08 09:20	1.6	1.6	1.6	1.7	1.7	3.58
11/03/08 09:59	21/04/08 09:20	1.6		1.6	1.8		
21/04/08 09:30	03/06/08 12:20	0.6	0.7	0.6	1.7	1.8	6.22
21/04/08 09:30	03/06/08 12:20	0.8		0.8	1.8		
03/06/08 12:35	14/07/08 12:00	1.2	1.2	1.2	1.2	1.2	5.50
03/06/08 12:35	14/07/08 12:00	1.3		1.3	1.2		
14/07/08 12:05	13/08/08 10:49	1.4	1.5	1.4	1.9	1.8	4.74
14/07/08 12:05	13/08/08 10:49	1.6		1.6	1.8		
Mean			***0.9***		***1.7***		
Site 7							
03/05/07 11:40	07/06/07 11:10	<0.4	0.2		0.9	0.9	0.79
03/05/07 11:40	07/06/07 11:10	<0.4			1.0		
07/06/07 11:10	03/08/07 10:45	0.5	0.5		1.0	0.9	24.19
07/06/07 11:10	03/08/07 10:45	<0.4			0.8		
03/08/07 11:05	12/09/07 11:05	<0.4	0.2		1.5	1.5	1.02
03/08/07 11:05	12/09/07 11:05	<0.4			1.5		

Table 6b cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
12/09/07 11:05	16/10/07 16:08	0.6	0.9	75.7	1.9	2.0	9.58
12/09/07 11:05	16/10/07 16:08	1.3			2.1		
16/10/07 16:15	08/11/07 10:57	<0.4	0.2		1.4	1.4	0.93
16/10/07 16:15	08/11/07 10:57	<0.4			1.4		
08/11/07 11:00	08/01/08 14:45	0.5	0.5	31.6	1.4	1.4	4.74
08/11/07 11:00	08/01/08 14:45	0.4			1.5		
08/01/08 12:20	07/02/08 14:37	1.1	1.3	32.1	1.9	1.9	1.23
08/01/08 12:20	07/02/08 14:37	1.5			1.9		
07/02/08 14:45	11/03/08 10:58	1.2	1.1	2.1	1.2	1.2	2.09
07/02/08 14:45	11/03/08 10:58	1.1			1.2		
11/03/08 11:05	21/04/08 10:05	1.5	1.3	19.3	1.5	1.5	0.00
11/03/08 11:05	21/04/08 10:05	1.2			1.5		
21/04/08 10:20	03/06/08 14:16	<0.4	0.2		1.4	1.4	3.17
21/04/08 10:20	03/06/08 14:16	<0.4			1.4		
03/06/08 14:17	14/07/08 13:01	0.4	0.4		0.8	0.8	6.67
03/06/08 14:17	14/07/08 13:01	<0.4			0.8		
14/07/08 13:10	13/08/08 11:40	0.6	0.8	60.6	1.0	1.0	0.17
14/07/08 13:10	13/08/08 11:40	1.1			1.0		
Mean			***0.6***		***1.3***		
Site 8							
24/01/07 15:00	22/02/07 09:15	<0.4	0.2		2.9	2.9	
24/01/07 15:00	22/02/07 09:15	<0.4					
22/02/07 09:20	20/03/07 12:22	1.0	0.9	20.1	2.3	2.3	3.50
22/02/07 09:20	20/03/07 12:22	0.8			2.2		
20/03/07 12:22	03/05/07 13:55	<0.4	0.7		2.0	2.1	6.82
20/03/07 12:22	03/05/07 13:55	0.7			2.2		
03/05/07 13:55	07/06/07 12:20	0.7	0.8	21.1	2.0	2.0	
03/05/07 13:55	07/06/07 12:20	0.9					
07/06/07 12:20	03/08/07 10:00	0.8	0.9	18.8	1.4	1.4	3.84
07/06/07 12:20	03/08/07 10:00	1.0			1.5		
03/08/07 10:15	12/09/07 12:11	0.4	0.5	16.4	2.7	2.7	2.23
03/08/07 10:15	12/09/07 12:11	0.5			2.7		
12/09/07 12:20	16/10/07 11:00	0.6	0.6		2.6	2.6	0.64
12/09/07 12:20	16/10/07 11:00	<0.4			2.6		
16/10/07 11:05	08/11/07 11:38	<0.4	0.2		1.9	1.9	1.44
16/10/07 11:05	08/11/07 11:38	<0.4			1.9		
08/11/07 11:55	08/01/08 12:05	0.6	0.5	31.1	2.1	2.1	5.91
08/11/07 11:55	08/01/08 12:05	0.4			2.2		
08/01/08 14:55	07/02/08 15:35	<0.4	0.6		2.0	1.9	14.03
08/01/08 14:55	07/02/08 15:35	0.6			1.8		
07/02/08 15:50	11/03/08 11:55	0.7	0.8	24.1	1.8	1.8	1.51
07/02/08 15:50	11/03/08 11:55	0.9			1.8		
11/03/08 12:00	21/04/08 10:57	0.4	0.4	0.9	2.2	2.1	4.88
11/03/08 12:00	21/04/08 10:57	0.4			2.0		
21/04/08 11:08	03/06/08 14:55	<0.4	0.2		2.7	2.8	6.88
21/04/08 11:08	03/06/08 14:55	<0.4			2.9		
03/06/08 15:13	14/07/08 14:02	1.0	0.9	22.5	1.3	1.4	25.39
03/06/08 15:13	14/07/08 14:02	0.8			1.6		
14/07/08 14:02	13/08/08 13:09	1.1	1.1	1.9	2.0	2.0	3.05
14/07/08 14:02	13/08/08 13:09	1.1			2.0		
Mean			***0.6***		***2.1***		

Table 6b cont

Date on	Date off	NH_3 (ppb)	NH_3 (ppb) mean	RPD %	NO_2 (ppb)	NO_2 (ppb) mean	RPD %
Site 9							
04/05/07 17:20	07/06/07 13:00	1.4	1.4	6.72	2.7	2.8	6.13
04/05/07 17:20	07/06/07 13:00	1.5			2.8		
07/06/07 13:00	06/08/07 17:30	1.8	1.7	3.44	2.5	2.6	6.70
07/06/07 13:00	06/08/07 17:30	1.7			2.7		
06/08/07 17:40	11/09/07 17:36	1.8	1.7	4.62	2.8	2.8	0.72
06/08/07 17:40	11/09/07 17:36	1.7			2.8		
11/09/07 17:43	22/10/07 17:45	2.5	2.7	17.98	2.4	2.2	15.43
11/09/07 17:43	22/10/07 17:45	3.0			2.0		
22/10/07 17:50	09/11/07 17:45	1.7	2.2	44.59	1.6	1.6	3.03
22/10/07 17:50	09/11/07 17:45	2.6			1.6		
09/11/07 17:50	08/01/08 16:00	2.4	2.4	3.34	1.4	1.4	1.05
09/11/07 17:50	08/01/08 16:00	2.3			1.4		
08/01/08 16:15	10/02/08 18:15	3.3	3.3	0.67	1.9	1.9	3.05
08/01/08 16:15	10/02/08 18:15	3.4			2.0		
10/02/08 18:30	16/03/08 12:10	3.8	3.9	2.95	2.0	2.0	2.09
10/02/08 18:30	16/03/08 12:10	3.9			2.0		
16/03/08 12:10	21/04/08 18:00	2.3	2.4	6.20	2.2	2.2	6.37
16/03/08 12:10	21/04/08 18:00	2.5			2.3		
21/04/08 18:15	12/06/08 17:00	1.6	1.7	8.58	3.1	3.0	6.77
21/04/08 18:15	12/06/08 17:00	1.8			2.9		
23/06/08 12:30	18/07/08 10:20	2.6	2.6		3.7	3.7	1.83
23/06/08 12:30	18/07/08 10:20				3.7		
18/07/08 10:30	13/08/08 17:51	1.3	2.5	94.46	2.4	2.3	9.79
18/07/08 10:30	13/08/08 17:51	3.6			2.2		
Mean			***2.4***		***2.4***		
Site10							
07/06/07 13:20	12/07/07 16:30	<0.4	0.5		0.4	0.4	0.37
07/06/07 13:20	12/07/07 16:30	0.5			0.4		0.38
12/07/07 16:30	03/08/07 09:20	0.6	0.6	29.57	0.7	0.7	0.66
12/07/07 16:30	03/08/07 09:20	0.5			0.7		0.66
03/08/07 09:30	16/09/07 14:00	<0.4	1.2		0.3	0.4	0.33
03/08/07 09:30	16/09/07 14:00	1.2			0.4		0.41
16/09/07 14:00	04/10/07 18:00	<0.4	0.2		0.5	0.5	0.47
16/09/07 14:00	04/10/07 18:00	<0.4			0.6		0.57
04/10/07 18:00	05/11/07 11:20	0.4	0.2				
04/10/07 18:00	05/11/07 11:20	0.5					
05/11/07 11:20	19/01/08 13:00	<0.4	0.2		0.2	0.2	0.15
05/11/07 11:20	19/01/08 13:00	<0.4			0.2		0.16
19/01/08 13:00	07/02/08 16:30	0.8	0.7	20.78	2.2	2.2	2.20
19/01/08 13:00	07/02/08 16:30	0.6			2.2		2.19
07/02/08 16:30	14/03/08 21:30				1.0	1.1	1.05
07/02/08 16:30	14/03/08 21:30				1.1		1.09
14/03/08 13:00	03/05/08 15:30	1.1	1.0	18.03	1.0	1.1	11.12
14/03/08 13:00	03/05/08 15:30	0.9			1.2		
Mean			***0.6***		***0.8***		

Table 7a displays the concentrations of sulphur dioxide and nitric acid measured at the Burrup sites and at Mardie Station over the annual period from August 2004 to mid September 2005. Average monthly concentrations of sulphur dioxide range from 19 ppt during August 2005 at Site 10 to 367 ppt at Site 4 during April 2005. The average annual sulphur dioxide concentrations range from 83 ppt at Site 10 to 215 ppt at Site 5. The concentrations, measured at sites 1, 3 and 10, are assumed to be regional background levels and appear to be in the range of about 83 ppt to 139 ppt, with an annual average of about 108 ppt. The annual average concentration at sites 4 – 8 is only about 175 ppt, with a maximum of 215 ppt, so the enhancement in sulphur dioxide concentrations at these sites is very small. Detection limits for sulphur dioxide and nitric acid, calculated from the standard deviation of blanks, using an ISO (1994) technique, were 28 ppt and 45 ppt respectively over a 30 day sampling period.

The results of the sulfur dioxide measurements during the 2007/2008 period are displayed in Table 7b. They show that the monthly averaged concentrations ranged from 51 ppt during May/June 2007 to 285 ppt during January/February 2008 at site 5. The annual averages for this episode ranged from 105 ppt at site 9 and 223 ppt at site 5. The annual average for the three background sites was 115 ppt and 180 ppt for sites 4 – 8. Although the background sites tend to have lower sulfur dioxide concentrations the enhancement in sulfur dioxide from the background sites to those recorded at the lower Burrup Peninsula sites is very small. These results were very similar for those in the 2004/2005 sampling period when 108 ppt and 175 ppt were recorded for the background sites and sites 4 – 8 respectively.

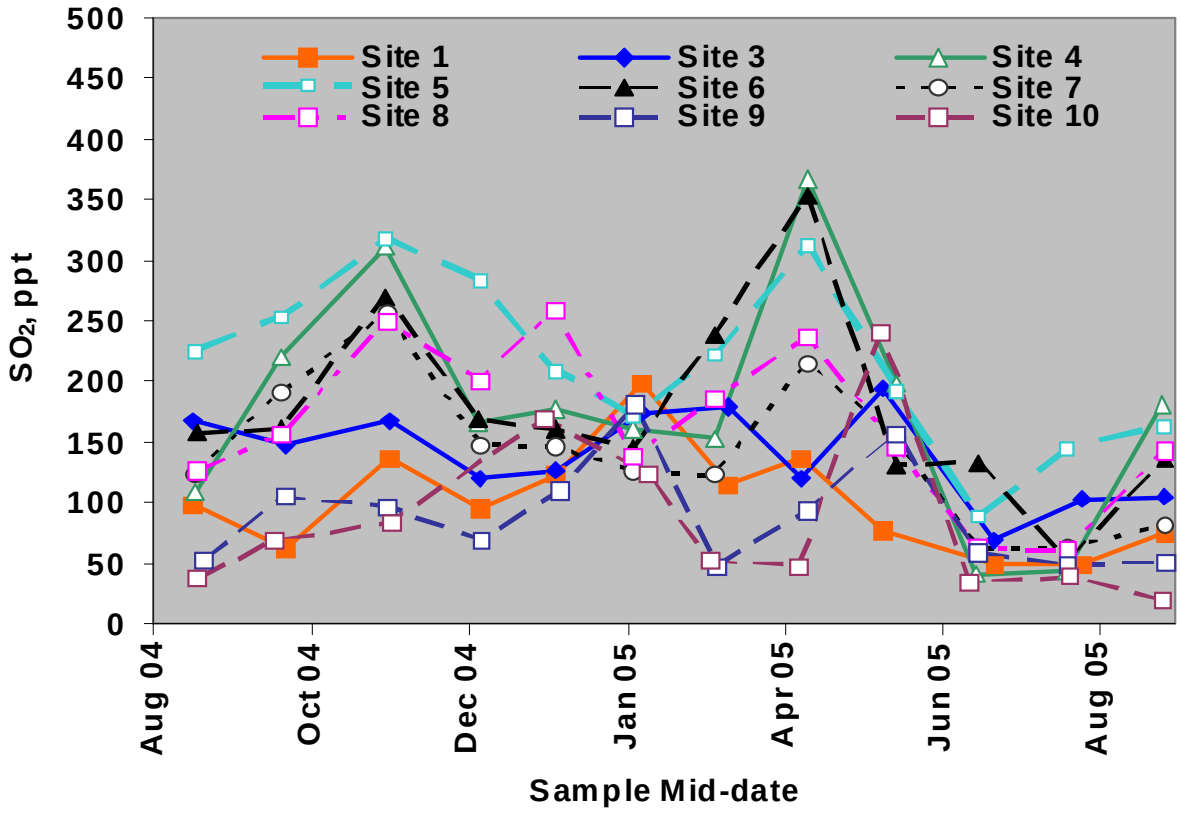


Figure 11a. Sulfur dioxide concentrations plotted against the mid-date of the sampling period from August 2004 to August 2005.

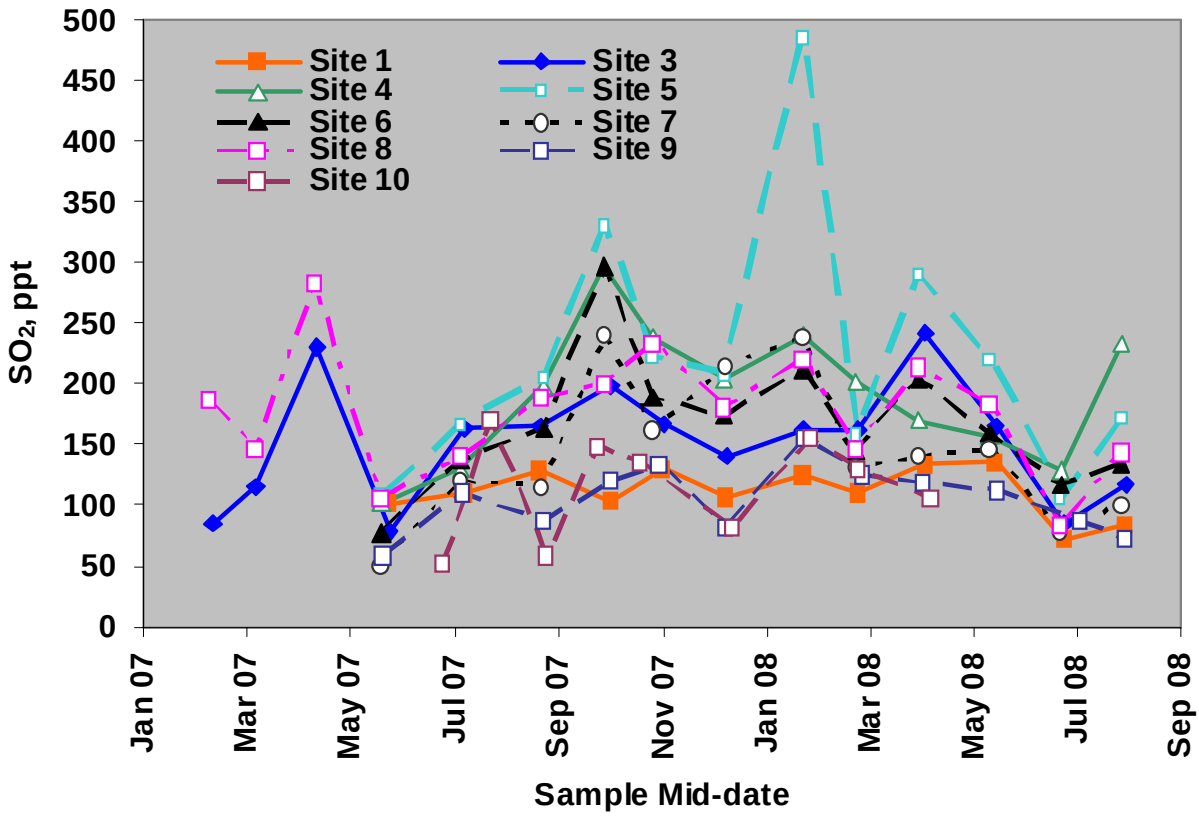


Figure 11b. Sulfur dioxide concentrations plotted against the mid-date of the sampling period from February 2007 to August 2008.

Sulfur dioxide concentrations at each site are plotted against the sampling mid-time in Figure 11a. The Figure shows that there is a small elevation in sulphur dioxide concentrations at some sites, such as 4, 5 and 6. Concentrations at the local background sites, 1, 3 and 10 tend to have lower concentrations, although Site 9 can also have concentrations near the background at least during some sampling periods. Figure 11b displays the monthly sulfur dioxide concentrations at each site measured during 2007/2008. The concentrations tend to be lower at the background sites, especially at sites 1 and 10.

Several studies have determined sulphur dioxide concentrations in remote terrestrial regions using passive samplers, and in pristine areas using active sampling techniques, and these can be used to compare with the background concentrations on the Burrup Peninsula. In pristine areas very low concentrations of sulphur dioxide have been recorded. For example at the South Pole a 7-day average concentration of less 20 ppt was measured using a chemical ionisation mass spectrometer (Hueya et al., 2004). De bruyn et al. (2002) measured sulphur dioxide concentrations at Baring Head, New Zealand over a period of 15 hours and found a diurnal cycle and average concentration of less than 15 ppt. These studies show that very low sulphur dioxide concentrations are possible in areas that are considered to be pristine and where air is not impacted by anthropogenic pollution.

At Bukit Koto Tabang, GAW station on Sumatra the annual average sulphur dioxide concentrations were 1.3 ppb during 1996 (Gillett et al., 2000). At Charles Point, West of Darwin average sulphur dioxide concentrations were 0.75 ppb between June 1993 and June 1997 (Ayers et al., 2000) and at Tanah Rata, north of Kuala Lumpur, Malaysia the average concentration was 0.5 ppb from August 1990 to January 1992 (Ayers et al., 2002). These "background" concentrations are significantly higher than the measurements recorded at the Burrup sites.

Sulfur dioxide concentrations have also been recorded in large polluted Asian cities such as Kuala Lumpur, Jakarta and Bogor. In Jakarta annual average concentrations of sulphur dioxide were 7.1 ppb and 4.4 ppb in 1992 and 1996 respectively and in Bogor the annual average concentration was 1.9 ppb in 1996 (Gillett et

al., 2000). The concentrations in Petaling Jaya, near Kuala Lumpur averaged 6.3 ppb over a five year period from March 1994 to March 1998 (Ayers et al., 2000). In other sites near Kuala Lumpur concentrations were recorded from August 1996 to January 1997 at Klang, April 1996 to April 1997 at Ulu Langat and August 1996 to June 1997 Johor Baru Malaysia where concentrations were 6.2 ppb, 0.9 ppb and 1.9 ppb respectively. These concentrations are typical of areas that are heavily impacted with anthropogenic pollution and are obviously much higher than those observed on the Burrup Peninsula.

Nitric acid concentrations measured during 2004/2005 are also presented in Table 7a; these were measured as nitrate ion which is collected with the sulphur dioxide passive sampler. The monthly average concentrations shown in the Table range from 21 ppt at site 10 during August 2004 to 632 ppt at site 9 during May 2005. The assumed background sites of 1, 3 and 10 have nitric acid concentrations of 144 ppt, 162 ppt and 160 ppt respectively, indicating an average annual background concentration of about 155 ppt. At Sites 4 – 8, on the southern Burrup Peninsula, annual average concentrations ranged from 198 ppt at site 4 to 250 ppt at site 8 giving a southern area average of 229 ppt. Although the concentration increase from the background to the southern Burrup sites is noticeable, the enhancement is small, and the concentrations are very low.

Table 7b displays the nitric acid concentrations measured during 2007/2008. The monthly average concentrations ranged from 46 ppt at site 3 during to May/June 2008 to 458 ppt at site 9 during April/May 2008. The annual average concentrations 143 ppt at site 10 to 280 ppt at site 9. The annual average concentrations for the background sites was 159 ppt compared with an average of 222 ppt for sites 4 – 8. These concentrations are very similar to those recorded at the background and lower sites on the Burrup sites during 2004/2005. As noted previously the enhancement in nitric acid concentrations from the background sites to those on the lower Burrup is very small.

Figure 12a shows concentrations of nitric acid at each site plotted against the mid-time of the sampling period. It shows only a small enhancement in nitric acid concentrations at the sites on the lower Burrup compared with those at the local background sites. The concentrations have some temporal trends; most sites had low concentrations during the January/February sampling period and higher concentrations during the May sampling period. A similar temporal trend can also be observed for nitrogen dioxide concentrations, in Figure 10a. The concentrations of nitric acid measured during 2007/2008 are displayed in Figure 10b. They show that there is some indication of an increase in nitric acid concentrations during the May/June sampling periods of 2007 and 2008. This was also observed during 2004/2005, but the reason for this is unclear.

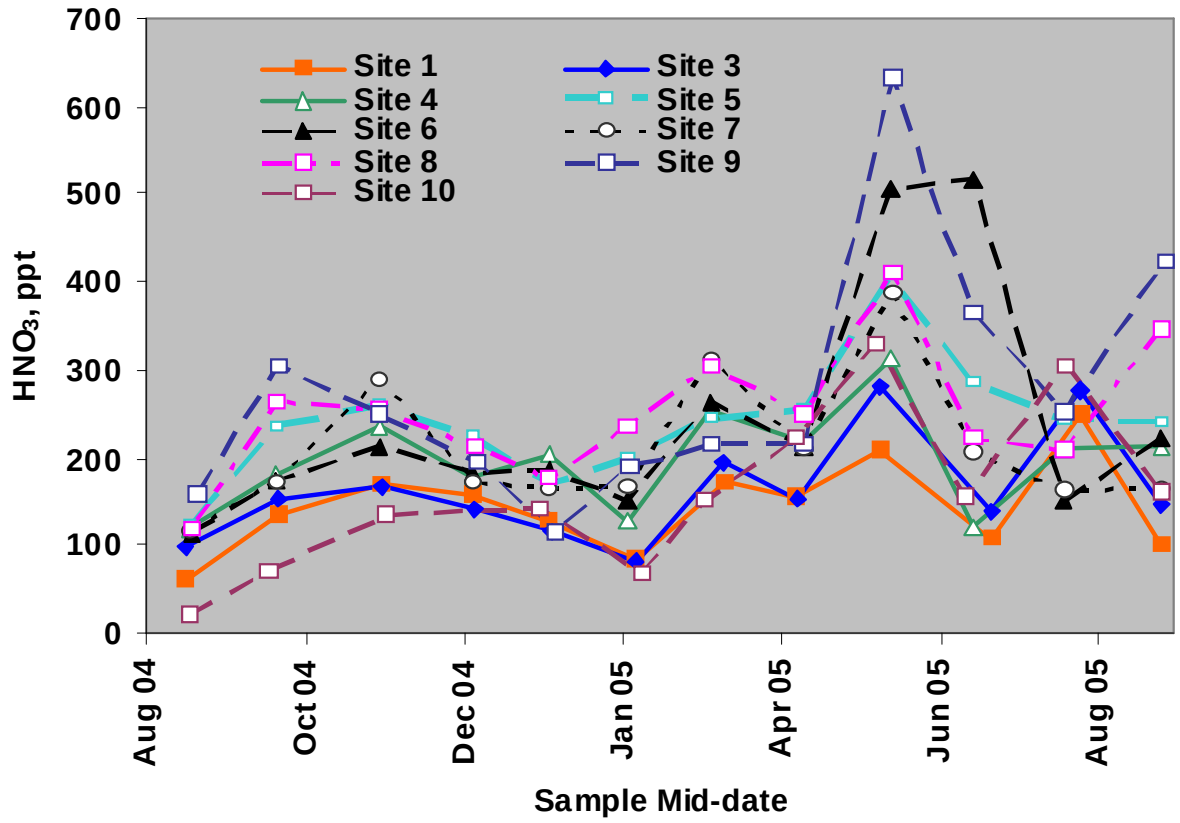


Figure 12a. Nitric acid concentrations plotted against the mid-date of the sampling period from August 2004 to August 2005

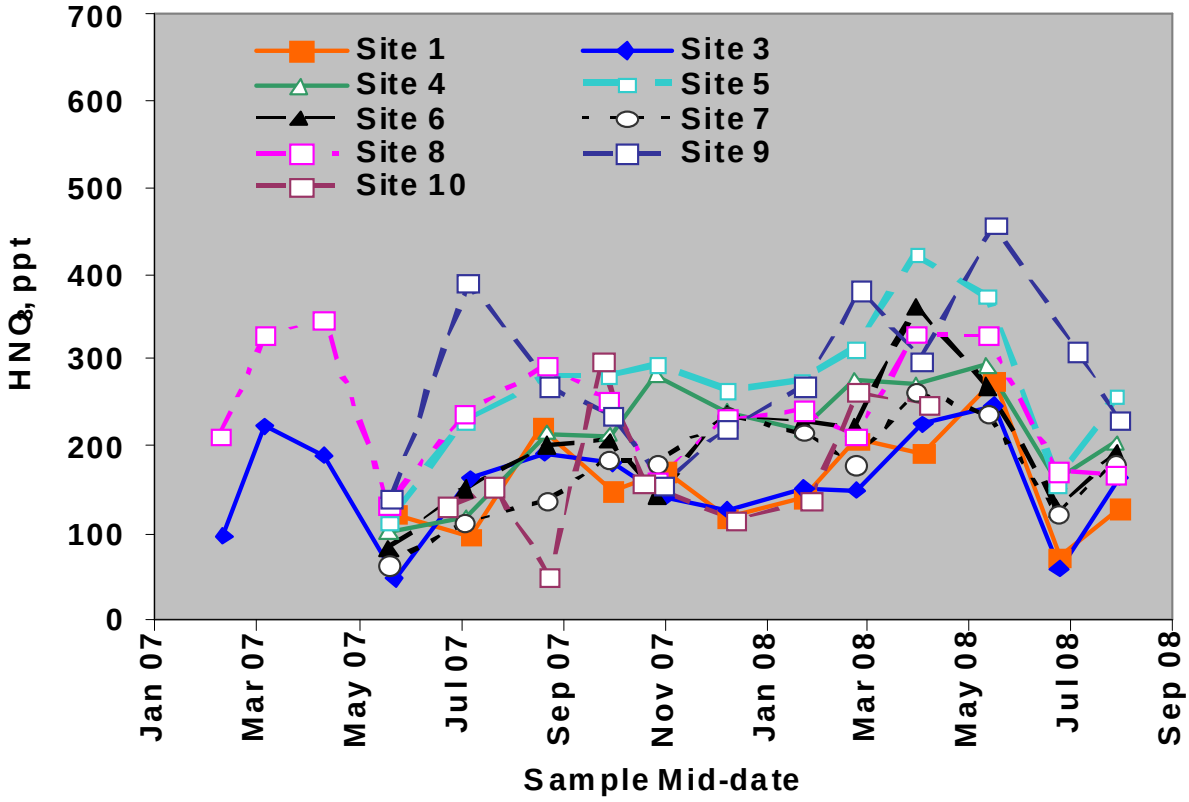


Figure 12b. Nitric acid concentrations plotted against the mid-date of the sampling period from February 2007 to August 2008.

By way of comparison "background" concentrations of 0.34 ppb have been measured at Charles Point from June 1993 to June 1997 (Ayers et al., 2000) and they are in excess of measurements on the Burrup. In heavily polluted areas in Asia concentrations of nitric acid average 1.1 ppb at Petaling Jaya, Malaysia (Ayers et al., 2000) and 2.0 ppb at Klang, Malaysia (Ayers et al., 2002). These concentrations are much higher than those measured on the Burrup Peninsula.

Table 7a. Concentrations of sulphur dioxide and nitric acid at the nine sampling sites from August 2004 until late March 2005. Concentrations are in ppt. Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration.

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
Site 1							
29/07/04 11:50	02/09/04 15:35	116	99	35.8	60	61	3.7
29/07/04 11:50	02/09/04 15:35	81			62		
02/09/04 15:40	08/10/04 09:35	59	62	10.9	116	135	28.4
02/09/04 15:40	08/10/04 09:35	66			154		
08/10/04 09:45	21/11/04 12:05	128	137	12.9	167	169	2.2
08/10/04 09:45	21/11/04 12:05	146			171		
21/11/04 12:05	17/12/04 12:10	120	96	51.1	162	159	5.0
21/11/04 12:05	17/12/04 12:10	71			155		
17/12/04 12:10	19/01/05 13:02	90	123	53.7	97	127	47.1
17/12/04 12:10	19/01/05 13:02	156			157		
19/01/05 13:07	21/02/05 12:55	204	199	5.1	81	86	10.2
19/01/05 13:07	21/02/05 12:55	193			90		
21/02/05 13:12	28/03/05 11:14	76	114	67.8	158	171	14.9
21/02/05 13:12	28/03/05 11:14	153			184		
28/03/05 11:20	18/04/05 09:55	115	136	31.4	143	155	15.5
28/03/05 11:20	18/04/05 09:55	158			167		
18/04/05 11:17	31/05/05 11:24	75	78	6.2	214	207	6.0
18/04/05 11:17	31/05/05 11:24	80			201		
31/05/05 11:25	13/07/05 11:50	52	49	10.2	113	109	8.6
31/05/05 11:25	13/07/05 11:50	47			104		
13/07/05 11:45	07/08/05 11:40	60	49	42.2	250	249	0.6
13/07/05 11:45	07/08/05 11:40	39			248		
07/08/05 11:50	14/09/05 09:53	81	75	14.3	97	100	6.7
07/08/05 11:50	14/09/05 09:53	70			103		
mean			***101***			***144***	
Site 3							
29/07/04 16:00	02/09/04 13:10	183	168	17.8	112	98	29.3
29/07/04 16:00	02/09/04 13:10	153			84		
02/09/04 13:20	08/10/04 11:25	145	147	3.0	151	152	1.5
02/09/04 13:20	08/10/04 11:25	150			154		
08/10/04 11:30	21/11/04 15:45	159	168	10.5	162	166	4.5
08/10/04 11:30	21/11/04 15:45	177			170		
21/11/04 15:45	17/12/04 14:15	100	121	34.1	127	142	22.3
21/11/04 15:45	17/12/04 14:15	141			158		
17/12/04 14:15	19/01/05 16:40	126	126	0.0	127	116	18.2
17/12/04 14:15	19/01/05 16:40	126			106		
19/01/05 16:40	21/02/05 10:31	153	174	24.6	84	82	6.2
19/01/05 16:40	21/02/05 10:31	196			79		
21/02/05 09:53	28/03/05 12:28	215	179	40.2	204	194	10.3
21/02/05 09:53	28/03/05 12:28	143			184		
28/03/05 12:30	18/04/05 14:41	128	121	11.3	148	153	6.4
28/03/05 12:30	18/04/05 14:41	114			158		
18/04/05 14:41	31/05/05 13:15	176	194	18.2	270	280	7.5
18/04/05 14:41	31/05/05 13:15	211			291		
31/05/05 13:20	13/07/05 16:05	76	69	21.6	134	140	8.6

Table 7a cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
31/05/05 13:20	13/07/05 16:05	61			146		
13/07/05 15:46	07/08/05 15:05	113	103	18.7	290	276	10.5
13/07/05 15:46	07/08/05 15:05	93			261		
07/08/05 15:10	14/09/05 13:00	93	105	22.2	173	147	35.2
07/08/05 15:10	14/09/05 13:00	117			121		
Mean			***139***			***162***	
Site 4							
01/08/04 12:09	01/09/04 09:17	108	109	2.4	107	120	20.6
01/08/04 12:09	01/09/04 09:17	110			132		
01/09/04 09:25	07/10/04 09:15	223	220	2.5	190	180	11.2
01/09/04 09:25	07/10/04 09:15	217			170		
07/10/04 09:20	20/11/04 08:20	335	311	15.3	207	236	24.9
07/10/04 09:20	20/11/04 08:20	288			266		
20/11/04 08:20	18/12/04 06:30	158	167	10.6	184	179	5.8
20/11/04 08:20	18/12/04 06:30	176			174		
18/12/04 06:30	18/01/05 10:02	199	177	24.7	192	203	10.5
18/12/04 06:30	18/01/05 10:02	155			213		
18/01/05 10:07	16/02/05 06:30	135	160	32.1	120	127	11.3
18/01/05 10:07	16/02/05 06:30	186			134		
16/02/05 06:45	23/03/05 09:53	130	154	30.7	220	255	26.9
16/02/05 06:45	23/03/05 09:53	177			289		
23/03/05 09:53	28/04/05 08:48	351	367	8.4	193	217	22.7
23/03/05 09:53	28/04/05 08:48	382			242		
28/04/05 08:49	30/05/05 10:40	216	200	16.5	301	314	8.1
28/04/05 08:49	30/05/05 10:40	183			326		
30/05/05 10:40	30/06/05 08:45	20	40	102.5	127	121	9.6
30/05/05 10:40	30/06/05 08:45	61			115		
30/06/05 08:48	08/08/05 08:47	37	44	32.4	210	210	0.5
30/06/05 08:48	08/08/05 08:47	52			209		
08/08/05 08:47	13/09/05 08:43	198	182	18.4	254	212	38.8
08/08/05 08:47	13/09/05 08:43	165			171		
Mean			***178***			***198***	
Site 5							
01/08/04 16:04	01/09/04 13:35	239	225	13.2	105	123	29.5
01/08/04 16:04	01/09/04 13:35	210			141		
01/09/04 13:40	07/10/04 11:15		252				
01/09/04 13:40	07/10/04 11:15	252			235		
07/10/04 11:20	20/11/04 12:40	311	317	3.8	245	258	10.1
07/10/04 11:20	20/11/04 12:40	323			271		
20/11/04 12:40	18/12/04 07:45	290	283	5.2	272	224	42.9
20/11/04 12:40	18/12/04 07:45	275			176		
18/12/04 07:45	18/01/05 12:38	196	209	12.0	160	169	11.0
18/12/04 07:45	18/01/05 12:38	221			178		
18/01/05 12:44	16/02/05 08:30	182	171	13.4	249	199	50.4
18/01/05 12:44	16/02/05 08:30	159			149		
16/02/05 08:15	23/03/05 11:56	116	222	95.6	238	246	6.2
16/02/05 08:15	23/03/05 11:56	328			253		
23/03/05 11:56	28/04/05 10:22	321	313	5.5	257	255	1.3
23/03/05 11:56	28/04/05 10:22	304			253		
28/04/05 10:22	30/05/05 11:40	194	192	2.6	390	406	7.8

Table 7a cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
28/04/05 10:22	30/05/05 11:40	189			422		
30/05/05 11:40	30/06/05 09:15	84	88	8.7	348	286	43.2
30/05/05 11:40	30/06/05 09:15	92			224		
30/06/05 09:20	08/08/05 09:35	158	145	18.4	246	242	3.0
30/06/05 09:20	08/08/05 09:35	131			239		
08/08/05 09:35	13/09/05 10:32	171	163	9.5	265	240	21.3
08/08/05 09:35	13/09/05 10:32	156			214		
Mean			***215***			***240***	
Site 6							
03/08/04 12:29	01/09/04 12:00	175	158	21.8	114	114	0.0
03/08/04 12:29	01/09/04 12:00	141			114		
01/09/04 12:10	07/10/04 10:30	170	162	9.7	183	173	11.0
01/09/04 12:10	07/10/04 10:30	154			164		
07/10/04 10:35	20/11/04 10:30	248	270	16.3	212	212	0.4
07/10/04 10:35	20/11/04 10:30	292			213		
20/11/04 10:30	18/12/04 08:45	161	169	9.6	187	184	3.2
20/11/04 10:30	18/12/04 08:45	177			181		
18/12/04 08:45	18/01/05 11:15		161			185	
18/12/04 08:45	18/01/05 11:15	161			185		
18/01/05 11:25	16/02/05 07:20	125	144	26.8	160	151	12.3
18/01/05 11:25	16/02/05 07:20	164			142		
16/02/05 07:30	23/03/05 10:52	239	239	0.0	256	263	5.4
16/02/05 07:30	23/03/05 10:52	239			270		
23/03/05 13:12	28/04/05 11:20	357	353	2.3	214	212	2.7
23/03/05 13:12	28/04/05 11:20	349			209		
28/04/05 11:20	30/05/05 14:10	115	131	24.1	452	506	21.5
28/04/05 11:20	30/05/05 14:10	147			561		
30/05/05 14:10	30/06/05 11:25	118	134	24.1	461	517	21.5
30/05/05 14:10	30/06/05 11:25	150			572		
30/06/05 11:23	08/08/05 11:25	50	51	2.0	185	151	45.5
30/06/05 11:23	08/08/05 11:25	51			117		
08/08/05 11:25	13/09/05 11:41	145	137	12.1	192	223	27.3
08/08/05 11:25	13/09/05 11:41	129			253		
Mean			***176***			***241***	
Site7							
01/08/04 15:01	01/09/04 08:24	123	123	0.0	91	118	45.4
01/08/04 15:01	01/09/04 08:24	123			144		
01/09/04 13:45	07/10/04 13:30	193	191	2.4	177	172	5.2
01/09/04 13:45	07/10/04 13:30	188			168		
07/10/04 13:35	20/11/04 14:35	253	256	2.5	292	289	1.9
07/10/04 13:35	20/11/04 14:35	260			286		
20/11/04 14:35	18/12/04 09:40	135	148	18.0	166	171	6.1
20/11/04 14:35	18/12/04 09:40	162			176		
18/12/04 09:40	18/01/05 15:10	145	147	2.7	171	164	8.1
18/12/04 09:40	18/01/05 15:10	149			157		
18/01/05 15:16	16/02/05 09:15	157	127	47.6	166	166	
18/01/05 15:16	16/02/05 09:15	97					
16/02/05 09:30	23/03/05 13:05	142	124	29.6	311	311	0.4
16/02/05 09:30	23/03/05 13:05	105			310		
23/03/05 13:12	28/04/05 11:20	206	215	8.0	212	209	2.2

Table 7a cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
23/03/05 13:12	28/04/05 11:20	224			207		
28/04/05 11:20	30/05/05 14:10	160	154	7.4	403	386	8.9
28/04/05 11:20	30/05/05 14:10	148			368		
30/05/05 14:10	30/06/05 11:25	73	62	35.6	154	205	49.9
30/05/05 14:10	30/06/05 11:25	51			256		
30/06/05 11:23	08/08/05 11:25	66	63	9.8	182	162	25.3
30/06/05 11:23	08/08/05 11:25	60			141		
08/08/05 11:25	13/09/05 11:41	95	81	32.8	150	166	18.8
08/08/05 11:25	13/09/05 11:41	68			181		
Mean			***141***			***210***	
Site8							
03/08/04 09:07	01/09/04 11:05	107	127	30.4	108	119	18.4
03/08/04 09:07	01/09/04 11:05	146			130		
01/09/04 11:15	07/10/04 15:00	143	156	17.1	260	263	1.7
01/09/04 11:15	07/10/04 15:00	169			265		
07/10/04 15:05	20/11/04 16:30	250	250	0.0	262	254	7.0
07/10/04 15:05	20/11/04 16:30	250			245		
20/11/04 16:30	18/12/04 11:30	206	201	5.2	214	212	2.1
20/11/04 16:30	18/12/04 11:30	196			210		
18/12/04 11:30	18/01/05 17:17	261	258	2.0	173	176	3.0
18/12/04 11:30	18/01/05 17:17	255			178		
18/01/05 17:25	16/02/05 10:40	147	137	13.6	228	235	5.5
18/01/05 17:25	16/02/05 10:40	128			241		
16/02/05 11:15	23/03/05 14:31	134	187	56.9	301	304	2.3
16/02/05 11:15	23/03/05 14:31	240			308		
23/03/05 14:35	28/04/05 11:50	225	237	10.2	253	249	3.2
23/03/05 14:35	28/04/05 11:50	250			244		
28/04/05 11:51	30/05/05 16:00	181	146	47.5	406	410	2.2
28/04/05 11:51	30/05/05 16:00	111			414		
30/05/05 16:01	30/06/05 12:30	49	63	43.1	220	222	2.3
30/05/05 16:01	30/06/05 12:30	77			225		
30/06/05 12:35	08/08/05 12:35	62	61	1.7	155	208	51.3
30/06/05 12:35	08/08/05 12:35	61			261		
08/08/05 12:35	13/09/05 15:50	146	143	5.4	390	345	25.7
08/08/05 12:35	13/09/05 15:50	139			301		
Mean			***164***			***250***	
Site 9							
05/08/04 15:00	03/09/04 18:00	57	53	12.9	158	159	1.7
05/08/04 15:00	03/09/04 18:00	50			160		
03/09/04 18:00	07/10/04 20:30	103	105	3.4	274	303	19.5
03/09/04 18:00	07/10/04 20:30	107			333		
07/10/04 20:35	20/11/04 18:00	100	97	6.7	260	250	7.9
07/10/04 20:35	20/11/04 18:00	94			240		
20/11/04 18:00	20/12/04 11:30	75	69	18.1	197	195	2.8
20/11/04 18:00	20/12/04 11:30	62			192		
20/12/04 11:30	20/01/05 10:15	110	110		115	115	
20/12/04 11:30	20/01/05 10:15						
20/01/05 10:45	16/02/05 18:00	197	182	16.6	190	189	0.8
20/01/05 10:45	16/02/05 18:00	167			189		
16/02/05 18:10	23/03/05 15:20	49	48	2.5	207	215	7.7

Table 7a cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
16/02/05 18:10	23/03/05 15:20	48			223		
23/03/05 15:26	28/04/05 13:42	84	94	20.8	199	214	13.9
23/03/05 15:26	28/04/05 13:42	104			229		
28/04/05 13:45	30/05/05 18:04	105	156	64.9	673	632	13.0
28/04/05 13:45	30/05/05 18:04	206			591		
30/05/05 18:08	30/06/05 13:30	77	60	56.3	343	363	11.1
30/05/05 18:08	30/06/05 13:30	43			384		
30/06/05 13:25	08/08/05 17:30	83	49	136.9	252	251	0.8
30/06/05 13:25	08/08/05 17:30	16			250		
08/08/05 17:45	15/09/05 18:00	47	50	14.7	439	422	7.7
08/08/05 17:45	15/09/05 18:00	54			406		
Mean			***89***			***276***	
Site 10							
02/08/04 15:00	01/09/04 10:50	14	37	126.3	25	21	45.6
02/08/04 15:00	01/09/04 10:50	61			16		
01/09/04 10:50	01/10/04 12:35	82	69	39.1	69	71	3.8
01/09/04 10:50	01/10/04 12:35	55			72		
01/10/04 12:35	01/12/04 10:30	87	85	5.6	152	135	25.5
01/10/04 12:35	01/12/04 10:30	82			118		
01/12/04 12:00	27/01/05 14:00	158	169	13.3	150	142	11.7
01/12/04 12:00	27/01/05 14:00	180			134		
27/01/05 14:00	18/02/05 09:30	123	123		68	68	
27/01/05 14:00	18/02/05 09:30						
18/02/05 09:30	17/03/05 11:30	55	52	11.7	168	152	21.1
18/02/05 09:30	17/03/05 11:30	49			136		
17/03/05 11:30	28/04/05 08:00	43	48	24.4	217	223	5.7
17/03/05 11:30	28/04/05 08:00	54			229		
28/04/05 08:00	19/05/05 10:00	236	240	3.2	301	329	17.0
28/04/05 08:00	19/05/05 10:00	243			357		
19/05/05 10:15	05/07/05 11:05	38	35	19.4	164	154	12.1
19/05/05 10:15	05/07/05 11:05	32			145		
05/07/05 11:15	05/08/05 13:20	41	39	13.2	297	305	5.1
05/07/05 11:15	05/08/05 13:20	36			312		
05/08/05 13:20	15/09/05 12:00	17	19	25.4	193	161	40.0
05/08/05 13:20	15/09/05 12:00	22			129		
Mean			***83***			***160***	

Table 7b. Concentrations of sulphur dioxide and nitric acid at the nine sampling sites from February 2007 until August 2008. Concentrations are in ppt. Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration.

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
Site 1							
04/05/07 11:22	14/06/07 09:39	129	102	51.78	119	122	4.2
04/05/07 11:22	14/06/07 09:39	76			124		
14/06/07 09:39	02/08/07 11:05	115	110	8.31	107	97	21.6
14/06/07 09:39	02/08/07 11:05	106			86		
02/08/07 11:10	09/09/07 10:30	131	129	3.02	282	223	52.4
02/08/07 11:10	09/09/07 10:30	127			165		
09/09/07 10:35	25/10/07 16:10	118	103	28.79	176	149	36.5
09/09/07 10:35	25/10/07 16:10	88			122		
25/10/07 16:20	09/11/07 09:22	147	131	24.54	105	171	77.3
25/10/07 16:20	09/11/07 09:22	115			237		
09/11/07 09:18	09/01/08 09:15	111	106	9.95	120	118	3.5
09/11/07 09:18	09/01/08 09:15	101			116		
09/01/08 09:25	08/02/08 12:20	120	125	7.95	156	141	21.0
09/01/08 09:25	08/02/08 12:20	130			127		
08/02/08 12:30	12/03/08 13:15	112	109	4.36	273	207	63.6
08/02/08 12:30	12/03/08 13:15	107			141		
12/03/08 13:15	27/04/08 10:50	134	134	0.40	194	191	3.2
12/03/08 13:15	27/04/08 10:50	133			188		
27/04/08 11:10	04/06/08 10:30	155	136	29.04	358	277	58.1
27/04/08 11:10	04/06/08 10:30	116			197		
04/06/08 10:30	17/07/08 09:45	72	72	2.31	70	71	1.5
04/06/08 10:30	17/07/08 09:45	71			71		
17/07/08 09:48	14/08/08 11:05	91	83	18.31	110	128	29.0
17/07/08 09:48	14/08/08 11:05	76			147		
Mean			***112***			***158***	
Site 3							
29/01/07 11:00	22/02/07 10:51	78	84	16.06	122	98	48.5
29/01/07 11:00	22/02/07 10:51	91			74		
22/02/07 11:00	20/03/07 08:51	122	116	11.60	257	224	29.3
22/02/07 11:00	20/03/07 08:51	109			191		
20/03/07 08:55	04/05/07 12:59	193	230	31.74	164	189	26.7
20/03/07 08:55	04/05/07 12:59	266			214		
04/05/07 12:59	14/06/07 08:24	80	79	3.04	48	46	9.1
04/05/07 12:59	14/06/07 08:24	78			44		
14/06/07 08:24	02/08/07 13:20	176	164	14.68	163	163	0.2
14/06/07 08:24	02/08/07 13:20	152			163		
02/08/07 13:23	09/09/07 12:30	150	166	19.53	199	193	6.0
02/08/07 13:23	09/09/07 12:30	182			187		
09/09/07 12:35	25/10/07 14:10	187	198	11.06	126	181	61.2
09/09/07 12:35	25/10/07 14:10	209			237		
25/10/07 14:20	09/11/07 10:42	183	166	19.99	160	142	25.5
25/10/07 14:20	09/11/07 10:42	150			124		
09/11/07 10:46	09/01/08 10:46	140	140	0.02	119	127	13.2
09/11/07 10:46	09/01/08 10:46	140			135		
09/01/08 10:50	08/02/08 13:50	140	162	28.16	138	152	17.7
09/01/08 10:50	08/02/08 13:50	185			165		

Table 7b cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
08/02/08 14:05	12/03/08 11:25	138	161	28.59	145	149	5.3
08/02/08 14:05	12/03/08 11:25	184			153		
12/03/08 11:30	27/04/08 14:03	166	242	62.87	195	226	27.7
12/03/08 11:30	27/04/08 14:03	318			258		
27/04/08 15:00	04/06/08 12:20	148	164	20.19	245	247	2.2
27/04/08 15:00	04/06/08 12:20	181			250		
04/06/08 12:30	17/07/08 11:17	83	85	3.03	63	57	22.2
04/06/08 12:30	17/07/08 11:17	86			51		
17/07/08 11:25	14/08/08 09:00	126	117	14.71	179	164	17.7
17/07/08 11:25	14/08/08 09:00	109			150		
Mean			**152**			**157**	
Site 4							
03/05/07 10:12	07/06/07 09:12	102	101	1.83	128	103	47.2
03/05/07 10:12	07/06/07 09:12	100			79		
07/06/07 09:12	04/08/07 08:05	130	130	0.34	107	118	18.7
07/06/07 09:12	04/08/07 08:05	130			129		
04/08/07 08:25	12/09/07 09:19	197	199	1.89	234	216	16.1
04/08/07 08:25	12/09/07 09:19	201			199		
12/09/07 09:26	16/10/07 14:10	286	297	7.65	210	215	4.5
12/09/07 09:26	16/10/07 14:10	308			220		
16/10/07 14:11	08/11/07 09:40	180	238	48.49	262	283	14.7
16/10/07 14:11	08/11/07 09:40	296			304		
08/11/07 09:36	08/01/08 09:35	180	203	23.00	246	242	3.9
08/11/07 09:36	08/01/08 09:35	227			237		
08/01/08 09:45	07/02/08 11:00	242	240	1.15	240	220	18.1
08/01/08 09:45	07/02/08 11:00	239			200		
07/02/08 11:00	11/03/08 08:55	182	201	18.51	270	276	4.3
07/02/08 11:00	11/03/08 08:55	220			282		
11/03/08 09:05	21/04/08 07:55	170	170		271	271	
11/03/08 09:05	21/04/08 07:55						
21/04/08 07:46	03/06/08 11:19	157	157		293	293	
21/04/08 07:46	03/06/08 11:19						
04/06/08 11:25	14/07/08 09:50	125	122	6.37	152	153	1.8
04/06/08 11:25	14/07/08 09:50	118			155		
14/07/08 09:55	14/08/08 11:05	242	249	5.46	244	219	22.9
14/07/08 09:55	14/08/08 11:05	255			194		
Mean			***192***			***218***	
Site 5							
03/05/07 10:53	07/06/07 09:50	97	109	21.75	108	115	11.6
03/05/07 10:53	07/06/07 09:50	120			121		
07/06/07 09:50	04/08/07 09:50	176	166	11.87	250	230	17.0
07/06/07 09:50	04/08/07 09:50	156			211		
04/08/07 10:00	12/09/07 10:05	197	205	7.85	261	282	14.8
04/08/07 10:00	12/09/07 10:05	213			302		
12/09/07 10:07	16/10/07 15:16	327	330	1.72	281	281	0.3
12/09/07 10:07	16/10/07 15:16	333			282		
16/10/07 15:31	08/11/07 10:37	250	222	25.90	199	294	64.4
16/10/07 15:31	08/11/07 10:37	193			388		
08/11/07 10:45	08/01/08 10:50	227	209	17.38	279	265	10.6
08/11/07 10:45	08/01/08 10:50	191			251		

Table 7b cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) Mean	RPD %
08/01/08 11:00	07/02/08 13:50	483	485	0.73	291	275	11.0
08/01/08 11:00	07/02/08 13:50	487			260		
07/02/08 11:10	11/03/08 10:10	169	159	13.02	327	312	9.5
07/02/08 11:10	11/03/08 10:10	149			297		
11/03/08 10:16	21/04/08 08:26	281	290	6.45	406	420	6.9
11/03/08 10:16	21/04/08 08:26	300			435		
21/04/08 08:30	03/06/08 12:57	212	220	7.73	379	374	2.7
21/04/08 08:30	03/06/08 12:57	229			369		
03/06/08 13:04	14/07/08 11:10	115	107	13.84	145	155	13.0
03/06/08 13:04	14/07/08 11:10	100			165		
14/07/08 11:15	13/08/08 09:55	164	171	8.31	271	258	10.3
14/07/08 11:15	13/08/08 09:55	179			244		
Mean			***223***			***272***	
Site 6							
03/05/07 11:16	07/06/07 10:20	69	77	19.28	63	83	47.8
03/05/07 11:16	07/06/07 10:20	84			103		
07/06/07 10:20	04/08/07 09:12	146	137	12.20	157	153	5.3
07/06/07 10:20	04/08/07 09:12	129			149		
04/08/07 09:25	12/09/07 10:27	158	163	6.96	199	200	1.2
04/08/07 09:25	12/09/07 10:27	169			201		
12/09/07 10:30	16/10/07 14:55	286	297	7.41	201	208	7.0
12/09/07 10:30	16/10/07 14:55	308			215		
16/10/07 14:55	08/11/07 10:07	146	188	44.58	128	142	20.7
16/10/07 14:55	08/11/07 10:07	230			157		
08/11/07 10:17	08/01/08 10:15	164	173	10.47	241	239	2.5
08/11/07 10:17	08/01/08 10:15	182			236		
08/01/08 10:20	07/02/08 12:10	208	212	3.76	240	229	9.2
08/01/08 10:20	07/02/08 12:10	216			219		
07/02/08 12:20	11/03/08 09:35	157	145	16.45	232	223	8.1
07/02/08 12:20	11/03/08 09:35	133			214		
11/03/08 09:59	21/04/08 09:20	178	203	24.12	281	364	45.7
11/03/08 09:59	21/04/08 09:20	227			447		
21/04/08 09:30	03/06/08 12:20	169	159	12.79	253	269	11.9
21/04/08 09:30	03/06/08 12:20	149			285		
03/06/08 12:35	14/07/08 12:00	110	116	11.33	89	130	62.7
03/06/08 12:35	14/07/08 12:00	123			171		
14/07/08 12:05	13/08/08 10:49	126	134	11.07	222	191	32.2
14/07/08 12:05	13/08/08 10:49	141			160		
Mean			***167***			***203***	
Site 7							
03/05/07 11:40	07/06/07 11:10	44	51	27.77	40	63	72.1
03/05/07 11:40	07/06/07 11:10	58			86		
07/06/07 11:10	03/08/07 10:45	104	120	26.91	107	114	12.0
07/06/07 11:10	03/08/07 10:45	136			121		
03/08/07 11:05	12/09/07 11:05	115	115		139	139	
03/08/07 11:05	12/09/07 11:05						
12/09/07 11:05	16/10/07 16:08	240	239	1.02	177	186	9.0
12/09/07 11:05	16/10/07 16:08	238			194		
16/10/07 16:15	08/11/07 10:57	159	162	4.04	183	181	2.2
16/10/07 16:15	08/11/07 10:57	165			179		

Table 7b cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
08/11/07 11:00	08/01/08 14:45	214	216	1.32	223	237	11.9
08/11/07 11:00	08/01/08 14:45	217			251		
08/01/08 12:20	07/02/08 14:37	232	238	5.33	217	215	1.9
08/01/08 12:20	07/02/08 14:37	244			213		
07/02/08 14:45	11/03/08 10:58	119	132	18.86	172	179	8.2
07/02/08 14:45	11/03/08 10:58	144			186		
11/03/08 11:05	21/04/08 10:05	146	140	7.68	309	264	34.3
11/03/08 11:05	21/04/08 10:05	135			219		
21/04/08 10:20	03/06/08 14:16	142	146	4.99	217	239	18.1
21/04/08 10:20	03/06/08 14:16	150			260		
03/06/08 14:17	14/07/08 13:01	75	78	7.53	127	123	6.6
03/06/08 14:17	14/07/08 13:01	81			118		
14/07/08 13:10	13/08/08 11:40	95	99	8.65	180	177	3.2
14/07/08 13:10	13/08/08 11:40	104			175		
Mean			***145***			***176***	
Site 8							
24/01/07 15:00	22/02/07 09:15	179	186	7.30	201	212	10.1
24/01/07 15:00	22/02/07 09:15	193			223		
22/02/07 09:20	20/03/07 12:22	126	147	27.32	367	327	24.0
22/02/07 09:20	20/03/07 12:22	167			288		
20/03/07 12:22	03/05/07 13:55	304	283	14.63	332	348	9.0
20/03/07 12:22	03/05/07 13:55	262			364		
03/05/07 13:55	07/06/07 12:20	105	105		133	133	
03/05/07 13:55	07/06/07 12:20						
07/06/07 12:20	03/08/07 10:00	129	139	14.77	249	238	8.4
07/06/07 12:20	03/08/07 10:00	149			228		
03/08/07 10:15	12/09/07 12:11	195	189	6.27	304	295	6.4
03/08/07 10:15	12/09/07 12:11	183			286		
12/09/07 12:20	16/10/07 11:00	198	201	2.79	231	254	18.1
12/09/07 12:20	16/10/07 11:00	204			277		
16/10/07 11:05	08/11/07 11:38	281	233	40.73	118	160	52.1
16/10/07 11:05	08/11/07 11:38	186			202		
08/11/07 11:55	08/01/08 12:05	156	179	26.40	228	234	5.0
08/11/07 11:55	08/01/08 12:05	203			239		
08/01/08 14:55	07/02/08 15:35	214	220	5.72	262	243	15.5
08/01/08 14:55	07/02/08 15:35	227			224		
07/02/08 15:50	11/03/08 11:55	137	147	14.15	214	212	2.6
07/02/08 15:50	11/03/08 11:55	158			209		
11/03/08 12:00	21/04/08 10:57	214	214	0.11	323	330	4.1
11/03/08 12:00	21/04/08 10:57	214			337		
21/04/08 11:08	03/06/08 14:55	178	183	5.27	332	328	2.7
21/04/08 11:08	03/06/08 14:55	188			323		
03/06/08 15:13	14/07/08 14:02	82	84	2.60	146	171	29.1
03/06/08 15:13	14/07/08 14:02	85			196		
14/07/08 14:02	13/08/08 13:09	144	143	1.12	156	166	12.3
14/07/08 14:02	13/08/08 13:09	142			176		
Mean			***177***			***243***	
Site 9							
04/05/07 17:20	07/06/07 13:00	47	58	39.62	152	140	17.4
04/05/07 17:20	07/06/07 13:00	70			127		

Table 7b cont

Date on	Date off	SO_2 (ppt)	SO_2 (ppt) mean	RPD %	HNO_3 (ppt)	HNO_3 (ppt) mean	RPD %
07/06/07 13:00	06/08/07 17:30	113	109	6.38	315	389	38.1
07/06/07 13:00	06/08/07 17:30	106			463		
06/08/07 17:40	11/09/07 17:36	92	87	12.10	321	271	37.1
06/08/07 17:40	11/09/07 17:36	82			220		
11/09/07 17:43	22/10/07 17:45	121	121	0.80	228	237	7.9
11/09/07 17:43	22/10/07 17:45	120			247		
22/10/07 17:50	09/11/07 17:45	151	133	28.03	141	156	18.3
22/10/07 17:50	09/11/07 17:45	114			170		
09/11/07 17:50	08/01/08 16:00	81	81	1.38	202	220	16.8
09/11/07 17:50	08/01/08 16:00	82			239		
08/01/08 16:15	10/02/08 18:15	181	154	34.25	291	271	15.2
08/01/08 16:15	10/02/08 18:15	128			250		
10/02/08 18:30	16/03/08 12:10	131	125	9.70	333	382	25.8
10/02/08 18:30	16/03/08 12:10	119			432		
16/03/08 12:10	21/04/08 18:00	101	119	30.11	316	299	11.6
16/03/08 12:10	21/04/08 18:00	137			282		
21/04/08 18:15	12/06/08 17:00	116	112	7.55	475	458	7.5
21/04/08 18:15	12/06/08 17:00	108			440		
23/06/08 12:30	18/07/08 10:20	85	87	5.00	320	310	6.5
23/06/08 12:30	18/07/08 10:20	90			300		
18/07/08 10:30	13/08/08 17:51	76	72	10.00	254	231	19.9
18/07/08 10:30	13/08/08 17:51	68			208		
Mean			***105***			***280***	
Site 10							
07/06/07 13:20	12/07/07 16:30	52	52	0.47	206	131	115.1
07/06/07 13:20	12/07/07 16:30	52			56		
12/07/07 16:30	03/08/07 09:20	187	171	19.44	158	155	3.7
12/07/07 16:30	03/08/07 09:20	154			152		
03/08/07 09:30	16/09/07 14:00	54	58	14.66	57	50	26.7
03/08/07 09:30	16/09/07 14:00	63			43		
16/09/07 14:00	04/10/07 18:00	170	148	29.57	341	300	27.8
16/09/07 14:00	04/10/07 18:00	127			258		
04/10/07 18:00	05/11/07 11:20	166	135	45.79	163	159	5.4
04/10/07 18:00	05/11/07 11:20	104			154		
05/11/07 11:20	19/01/08 13:00	82	82	0.65	127	117	18.3
05/11/07 11:20	19/01/08 13:00	83			106		
19/01/08 13:00	07/02/08 16:30	138	155	21.44	125	139	19.1
19/01/08 13:00	07/02/08 16:30	171			152		
07/02/08 16:30	14/03/08 21:30	146	131	23.09	288	262	19.5
07/02/08 16:30	14/03/08 21:30	116			237		
14/03/08 13:00	03/05/08 15:30	105	106	1.14	250	250	0.5
14/03/08 13:00	03/05/08 15:30	106			249		
Mean			***111***			***143***	

Table 8a presents the concentrations of benzene, toluene and ethylbenzene at the sites on the Burrup Peninsula and at Karratha and Mardie Station measured during 2004/2005. At some sites the measurements were below the limit of detection, and in those cases the average was set to half the limit of detection. Limits of detection for benzene, calculated on a monthly basis from the standard deviation of blanks using an ISO (1994) technique, ranged from 1 ppt to 14 ppt over a 30 day sampling period. There were a number of instances where samplers were obviously contaminated. For most of these samplers contamination resulted because the ends of the samplers were not sealed sufficiently to prevent ambient air diffusing to the adsorbent during transport to Melbourne. Contaminated samplers are signified with [c], and these have not been used to calculate averages. Some samplers at Site 9, Karratha may have been contaminated, but they were all included in the averages since it is more difficult to discern contamination in an urban area where petrol is often used. The maximum monthly mean of benzene concentration of 158 ppt was recorded at Site 9, Karratha and the minimum was 4 ppt at Site 10. The annual average benzene concentrations at sites 1, 3 and Mardie Station were about 19 ppt, and with an average of 21 ppt, sites 4 – 8 show no real enhancement above the background concentration.

The results of benzene, toluene and ethyl benzene measurements made during 2007/2008 are presented I Table 8b. The results for the last three monthly periods have not been entered into the Table because the GC/MS system was undergoing a scheduled maintenance inspection. The samples have been collected for these periods, and they will be entered into the table as soon as the analysis is complete. The detection limits for benzene, toluene and ethyl benzene during this sampling period were 7 ppt, 6 ppt and 5 ppt respectively over a 30-day sampling period. Where both duplicates were below the limit of detection the result was set to half the limit of detection. The results of some sampling periods showed vey high concentrations and these are assumed to have been contaminated during transport because the tubes were not sealed tightly; they are with signified with [c]. The concentrations of benzene, toluene and ethyl benzene show little change from the 2004/2005 measurements. The monthly average concentration ranged from about 4 ppt during May/June 2007 to 94 ppt at site 9 during September/October 2008. Site 9 had the highest annual average benzene concentration and a toluene to benzene ratio of about 8 compared with a corresponding ratio of about 10 during 2004/2005. The annual average benzene concentrations at the background sites was about 18 ppt compared with 20 ppt at sites 4 – 8. This is indicates that a very small difference in benzene concentrations exist between the background areas of the Burrup Peninsula and the areas closer to industrial the activity.

The data in Table 8a and 8b can be compared with concentrations of benzene, toluene and ethyl benzene measured in outer urban areas of Melbourne. In Aspendale, Melbourne concentrations of BTEX gases were measured during 7-day sampling times for a period of 10 months (Lawson et al., 2005). The average concentrations for that period were 300 ppt, 800 ppt and 1100 ppt for benzene, toluene and ethyl benzene respectively; minimum concentrations were 90 ppt, 220 ppt and 30 ppt. Similar concentrations were observed during 7-day sampling periods in March, 2003 in Launceston. Mean concentrations of benzene were 230 ppt with a standard deviation of 120 ppt (Galbally et al., 2003; Galbally et al., 2004).

Table 8a. Concentrations of benzene, toluene and ethyl benzene measured at the nine sites from the beginning of August 2004 until the end of January 2005. Concentrations are in ppt. Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration. Results marked with [c] are considered to be contaminated and were not used to produce averages.

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
Site 1							
29/07/04 11:50	02/09/04 15:35	8	8	25	25	10	6
29/07/04 11:50	02/09/04 15:35	7		<2		2	
02/09/04 15:35	08/10/04 09:40	41[c]	2	226 [c]	8	56 [c]	3
02/09/04 15:35	08/10/04 09:40	<4		<15		<6	
08/10/04 09:45	21/11/04 12:05	14	14	7	8	<9	4
08/10/04 09:45	21/11/04 12:05	<9		8		<9	
21/11/04 12:05	19/01/05 13:05	18	11	8	7	<11	6
21/11/04 12:05	19/01/05 13:05	4		7		<11	
19/01/05 13:05	21/02/05 12:55	<9	4	5	5	<5	2
19/01/05 13:05	21/02/05 12:55	<9		5		<5	
21/02/05 12:58	28/03/05 11:15	9	9	92	58	<5	2
21/02/05 12:58	28/03/05 11:15	<9		24		<5	
21/03/05 13:12	18/04/05 11:15	19	21	12	13	<6	11
21/03/05 13:12	18/04/05 11:15	23		14		11	
18/04/05 11:18	31/05/05 11:15	26	24	18	17	4	4
18/04/05 11:18	31/05/05 11:15	23		17		4	
31/05/05 11:19	13/07/05 11:45	137[c]	148[c]	<11	27	<7	4
31/05/05 11:19	13/07/05 11:45	158[c]		27		<7	
13/07/05 11:47	07/08/05 11:43	19	22	10	13	<6	3
13/07/05 11:47	07/08/05 11:43	24		16		<6	
17/08/05 11:45	14/09/05 09:53		56[c]	1154[c]	1033[c]	16[c]	20
17/08/05 11:45	14/09/05 09:53	56[c]		913[c]		25[c]	
Mean			***13***		***18***		***5***
Site 3							
29/07/04 16:00	02/09/04 13:10	20	20	30	25	7	8
29/07/04 16:00	02/09/04 13:10	21		21		9	
02/09/04 13:15	08/10/04 11:30	15	15	85	85	<6	3
02/09/04 13:15	08/10/04 11:30	16		<15		<6	
08/10/04 11:30	21/11/04 15:40	26	23	16	17	<9	4
08/10/04 11:30	21/11/04 15:40	20		18		<9	
21/11/04 15:40	18/01/05 10:02	10	12	16	17	<11	6
21/11/04 15:40	18/01/05 10:02	15		18		<11	
21/01/05 10:28	21/02/05 09:44	<9	15	<10	10	<5	2
21/01/05 10:28	21/02/05 09:44	15		10		<5	
21/02/05 09:48	28/03/05 12:28	<9	13	75	52	<5	5
21/02/05 09:48	28/03/05 12:28	13		29		5	
28/03/05 12:30	18/04/05 14:36	29	29	22	19	<6	3
28/03/05 12:30	18/04/05 14:36	<8		15		<6	
18/04/05 14:40	31/05/05 13:15	9	9	13	14	6	6
18/04/05 14:40	31/05/05 13:15	9		15		5	
31/05/05 13:20	13/07/05 15:46	141	11	19	19	<7	4
31/05/05 13:20	13/07/05 15:46	11		<11		<7	
13/07/05 15:50	07/08/05 15:07	79	14	12	18	<6	3
13/07/05 15:50	07/08/05 15:07	14		24		<6	
07/08/05 15:10	14/09/05 13:00	N/A	12	379 [c]	321 [c]	4	4
07/08/05 15:10	14/09/05 13:00	12		263 [c]		<2	

Table 8a cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
Mean			***16***		***28***		***4***
Site 4							
01/08/04 12:09	01/09/04 09:17	28	26	19	17	20	14
01/08/04 12:09	01/09/04 09:17	23		15		8	
01/09/04 09:32	07/10/04 09:15	23	22	242 [c]	361 [c]	9	10
01/09/04 09:32	07/10/04 09:15	22		480 [c]		11	
07/10/04 09:15	20/11/04 08:20	21	18	30	29	10	9
07/10/04 09:15	20/11/04 08:20	14		29		8	
20/11/04 08:20	18/01/05 10:20	34	34	73	74	<11	6
20/11/04 08:20	18/01/05 10:20	35		76		<11	
18/01/05 10:07	16/02/05 06:40	32	39	79	91	5	5
18/01/05 10:07	16/02/05 06:40	47		104		6	
16/02/05 06:30	23/03/05 09:45	36	33	83	92	12	10
16/02/05 06:30	23/03/05 09:45	29		101		9	
23/03/05 09:50	28/04/05 08:44	37	25	63	65	12	11
23/03/05 09:50	28/04/05 08:44	13		67		11	
28/04/05 08:45	30/05/05 10:36	16	19	29	26	7	9
28/04/05 08:45	30/05/05 10:36	22		24		11	
30/05/05 10:39	30/06/05 08:48	46	46	<11	6	<7	4
30/05/05 10:39	30/06/05 08:48	<12		<11		<7	
30/06/05 08:50	08/08/05 09:30	387 [c]	27	14	18	<6	6
30/06/05 08:50	08/08/05 09:30	27		22		6	
08/08/05 08:47	15/09/05 08:43	9	7	252 [c]	189 [c]	3	3
08/08/05 08:47	15/09/05 08:43	4		126 [c]		3	
Mean			***27***		***47***		***8***
Site 5							
01/08/04 16:04	01/09/04 12:00	21	19	36	33	17	15
01/08/04 16:04	01/09/04 12:00	18		30		13	
01/09/04 12:00	07/10/04 11:15	41	30	5252 [c]	2640	40	26
01/09/04 12:00	07/10/04 11:15	20		28		13	
07/10/04 11:21	20/11/04 12:20	19	14	23	23	19	17
07/10/04 11:21	20/11/04 12:20	10		22		15	
20/11/04 12:40	18/01/05 00:00	12	16	28	28	11	12
20/11/04 12:40	18/01/05 00:00	21		29		13	
18/01/05 12:44	16/02/05 08:07	12	16	28	31	8	10
18/01/05 12:44	16/02/05 08:07	20		33		12	
16/02/05 08:10	23/03/05 11:55	<9	23	39	37	18	19
16/02/05 08:10	23/03/05 11:55	23		35		21	
23/03/05 11:50	28/04/05 10:18	28	22	35	36	21	18
23/03/05 11:50	28/04/05 10:18	15		38		15	
28/04/05 10:17	30/05/05 10:43	6	12	47	43	13	14
28/04/05 10:17	30/05/05 10:43	18		38		15	
30/05/05 11:45	30/06/05 09:20	28	28	31	32	7	7
30/05/05 11:45	30/06/05 09:20	N/A		34		7	
30/06/05 09:22	08/08/05 10:25	36	30	52	45	17	15
30/06/05 09:22	08/08/05 10:25	30		39		14	
08/08/05 09:30	13/09/05 10:32	240 [c]	240 [c]	2280 [c]	2381 [c]	344 [c]	349 [c]
08/08/05 09:30	13/09/05 10:32	N/A		2483 [c]		354 [c]	
Mean			***21***		***34***		***14***

Table 8a cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
Site 6							
03/08/04 12:09	01/09/04 11:15	24	26	22	23	10	10
03/08/04 12:09	01/09/04 11:15	27		24		11	
01/09/04 11:15	07/10/04 10:30	16	19	11	13	11	12
01/09/04 11:15	07/10/04 10:30	23		14		13	
07/10/04 10:35	20/11/04 12:20	19	10	22	11	11	11
07/10/04 10:35	20/11/04 12:20	<9		<13		<9	
20/11/04 10:40	18/01/05 11:20	10	17	28	32	<11	15
20/11/04 10:40	18/01/05 11:20	24		36		15	
18/01/05 11:25	16/02/05 07:20	9	16	19	24	4	6
18/01/05 11:25	16/02/05 07:20	22		30		8	
16/02/05 07:25	23/03/05 10:52	13	23	35	41	10	11
16/02/05 07:25	23/03/05 10:52	23		41		11	
23/03/05 10:52	28/04/05 09:36	24	20	42	44	13	12
23/03/05 10:52	28/04/05 09:36	15		47		12	
28/04/05 09:33	30/05/05 12:50	19	18	20	22	7	6
28/04/05 09:33	30/05/05 12:50	18		25		5	
30/05/05 12:56	30/06/05 10:15	17	17	<11	6	<7	4
30/05/05 12:56	30/06/05 10:15	39		<11		<7	
30/06/05 10:15	08/08/05 10:25	15	17	16	19	<6	3
30/06/05 10:15	08/08/05 10:25	17		19		<6	
08/08/05 10:25	13/09/05 14:35	42	26	231 [c]	192 [c]	6	5
08/08/05 10:25	13/09/05 14:35	11		154 [c]		4	
Mean			***19***		***24***		***9***
Site 7							
01/08/04 15:01	01/09/04 13:34	21	22	20	18	7	8
01/08/04 15:01	01/09/04 13:34	22		17		8	
01/09/04 13:34	07/10/04 13:35	70 [c]	47	10882 [c]	25	76 [c]	10
01/09/04 13:34	07/10/04 13:35	23		25		10	
07/10/04 13:25	20/11/04 14:45	16	16	<13	17	<9	8
07/10/04 13:25	20/11/04 14:45	16		17		8	
20/11/04 15:00	18/01/05 15:12	22	18	30	30	<11	6
20/11/04 15:00	18/01/05 15:12	14		31		<11	
18/01/05 15:16	16/02/05 09:04	31	25	25	26	<5	8
18/01/05 15:16	16/02/05 09:04	18		27		8	
16/02/05 09:38	23/03/05 13:05	10	22	41	41	10	9
16/02/05 09:38	23/03/05 13:05	22		460 [c]		9	
23/03/05 13:12	28/04/05 11:05	18	18	27	28	8	11
23/03/05 13:12	28/04/05 11:05	19		30		13	
28/04/05 11:20	30/05/05 14:10	16	17	17	18	5	6
28/04/05 11:20	30/05/05 14:10	18		19		6	
30/05/05 14:45	30/06/05 11:23	12	12	<11	6	<7	4
30/05/05 14:45	30/06/05 11:23	29		<11		<7	
30/06/05 11:25	08/08/05 11:27	13	15	15	21	<6	3
30/06/05 11:25	08/08/05 11:27	15		21		<6	
08/08/05 11:25	13/09/05 11:41	9	7	302 [c]	280 [c]	3	3
08/08/05 11:25	13/09/05 11:41	5		258 [c]		3	
Mean			***18***		***23***		***7***
Site 8							
03/08/04 09:07	01/09/04 15:43	31	28	33	30	14	12
03/08/04 09:07	01/09/04 15:43	26		27		10	

Table 8a cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
01/09/04 15:43	07/10/04 15:00	24		23		17	
01/09/04 15:43	07/10/04 15:00	37	30	5904	23	40	29
07/10/04 15:10	20/11/04 16:20	19	19	25	25	13	13
07/10/04 15:10	20/11/04 16:20	19		25		13	
20/11/04 16:30	18/01/05 17:17	14	13	26	26	10	9
20/11/04 16:30	18/01/05 17:17	13		25		9	
18/01/05 17:25	16/02/05 10:20	<9	4	24	23	8	7
18/01/05 17:25	16/02/05 10:20	<9		22		7	
16/02/05 11:10	23/03/05 14:34	12	12	201	34	9	10
16/02/05 11:10	23/03/05 14:34	<9		34		11	
23/03/05 14:35	28/04/05 11:50	19	19	33	32	10	9
23/03/05 14:35	28/04/05 11:50	18		31		9	
28/04/05 12:34	30/05/05 16:00	59632 [c]	8	13366 [c]	21	90 [c]	6
28/04/05 12:34	30/05/05 16:00	8		21		6	
30/05/05 16:01	30/06/05 12:35	20	35	<11	22	<7	4
30/05/05 16:01	30/06/05 12:35	51		22		<7	
30/06/05 13:25	08/08/05 17:33	13	20	18	22	<6	3
30/06/05 13:25	08/08/05 17:33	27		25		<6	
08/08/05 12:36	13/09/05 15:50	9	11	254	206	4	3
08/08/05 12:36	13/09/05 15:50	12		159		3	
Mean			***18***		***26***		***9***
Site 9							
05/08/04 15:00	03/09/04 18:00	29	29	32	32	7	7
05/08/04 15:00	03/09/04 18:00	<1		1		<2	
03/09/04 15:30	07/10/04 20:30	40	39	264	244	59	59
03/09/04 15:30	07/10/04 20:30	39		225		47	
07/10/04 20:40	20/11/04 18:00	32	32	174	174	34	34
07/10/04 20:40	20/11/04 18:00	<9		<13		<9	
20/11/04 18:00	20/01/05 10:26	53	46	305	268	61	52
20/11/04 18:00	20/01/05 10:26	38		230		43	
20/01/05 10:45	16/02/05 18:00	39	42	203	212	37	42
20/01/05 10:45	16/02/05 18:00	46		221		46	
16/02/05 18:00	23/03/05 15:22	49	59	477	675	47	47
16/02/05 18:00	23/03/05 15:22	69		873		52	
23/03/05 15:26	28/04/05 13:45	83	81	808	816	71	73
23/03/05 15:26	28/04/05 13:45	79		823		75	
28/04/05 13:45	30/05/05 18:04	157	158	2062	2080	266	270
28/04/05 13:45	30/05/05 18:04	158		2099		275	
30/05/05 18:06	30/06/05 13:25	66	118	589	585	57	58
30/05/05 18:06	30/06/05 13:25	170		581		60	
30/06/05 13:25	08/08/05 17:33	68	65	544	533	51	51
30/06/05 13:25	08/08/05 17:33	63		522		49	
08/08/05 17:45	15/09/05 18:00	149	127	2491	2552	308	330
08/08/05 17:45	15/09/05 18:00	105		2612		352	
Mean			***72***		***743***		***93***
Site 10							
02/08/04 15:00	01/09/04 10:45	20	20	24	24	5	5
02/08/04 15:00	01/09/04 10:45	67 [c]		547 [c]		35 [c]	
01/09/04 10:50	01/10/04 12:35	18	21	1344 [c]	1106 [c]	7	10
01/09/04 10:50	01/10/04 12:35	24		868 [c]		13	

Table 8a cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
01/10/04 12:35	01/12/04 10:30	<9	9	<13	6	<9	4
01/10/04 12:35	01/12/04 10:30	9		<13		<9	
01/12/04 12:00	27/01/05 14:00	5	7	4	3	<11	6
01/12/04 12:00	27/01/05 14:00	9		3		<11	
18/02/05 09:30	17/03/05 11:30	<9	4	16	14	6	6
18/02/05 09:30	17/03/05 11:30	<9		11		7	
17/03/05 11:30	28/04/05 08:00	20	20	116 [c]	118 [c]	8	7
17/03/05 11:30	28/04/05 08:00	19		121 [c]		7	
28/04/05 08:00	19/05/05 10:00	21	19	16	17	9	8
28/04/05 08:00	19/05/05 10:00	17		18		7	
19/05/05 10:15	05/07/05 11:05	4	7	5	7	<1	1
19/05/05 10:15	05/07/05 11:05	9		9		1	
05/07/05 11:15	05/08/05 13:20	<12	12	19	19	<7	16
05/07/05 11:15	05/08/05 13:20	12		174 [c]		16	
05/08/05 11:15	15/09/05 12:00	<7	4	12	12	<6	7
05/08/05 11:15	15/09/05 12:00	<7		883 [c]		7	
Mean			***12***		***13***	***7***	***5***

Table 8b. Concentrations of benzene, toluene and ethyl benzene measured at the nine sites from February 2007 until August 2008. Concentrations are in ppt. Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration. Results marked with c are considered to be contaminated and were not used to produce averages.

Date/time On	Date/time Off	Benzene (ppt)	Benzene Mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene Mean
Site 1							
04/05/07 11:15	14/06/07 09:37	21	18	5	27	1	1
04/05/07 11:15	14/06/07 09:37	15		49		1	
14/06/07 09:46	02/08/07 11:05	10	11	13	9	4	3
14/06/07 09:46	02/08/07 11:05	12		5		2	
02/08/07 11:10	09/09/07 10:30	13	15	12	13	3	3
02/08/07 11:10	09/09/07 10:30	17		13		3	
09/09/07 10:35	25/10/07 16:10	203[c]	192[c]	824[c]	1154[c]	76[c]	103[c]
09/09/07 10:35	25/10/07 16:10	181[c]		1485		130[c]	
25/10/07 16:20	09/11/07 09:17	19	17	15	19	4	4
25/10/07 16:20	09/11/07 09:17	16		24		<5	
09/11/07 09:18	09/01/08 09:15	12	10	4	5	<5	3
09/11/07 09:18	09/01/08 09:15	8		6		<5	
09/01/08 09:15	08/02/08 12:20	17	20	8	9	<5	3
09/01/08 09:15	08/02/08 12:20	23		11		<5	
08/02/08 12:30	120/3/08 13:15	11	10	4	3	<5	3
08/02/08 12:30	120/3/08 13:15	10		2		<5	
12/03/08 13:15	27/04/08 10:50	8	11	7	22	<5	6
12/03/08 13:15	27/04/08 10:50	13		36		6	
27/04/08 11:25	04/06/08 10:13						
27/04/08 11:25	04/06/08 10:13						
04/06/08 10:30	17/07/08 09:45						
04/06/08 10:30	17/07/08 09:45						
17/07/08 09:48	14/08/08 11:05						
17/07/08 09:48	14/08/08 11:05						
Mean			***14***		***13***		***4***
Site 3							
29/01/07 11:00	22/02/07 10:51	10	9	12	16	2	1
29/01/07 11:00	22/02/07 10:51	7		21		1	
22/02/07 11:00	20/03/07 08:51	242[c]	16	121[c]	110[c]	16[c]	16[c]
22/02/07 11:00	20/03/07 08:51	16		110[c]		16[c]	
20/03/07 09:00	04/05/07 12:49	25	35	14	31	2	3
20/03/07 09:00	04/05/07 12:49	46		48		4	
04/05/07 12:59	14/06/07 08:24	29	27	40	41	2	2
04/05/07 12:59	14/06/07 08:24	25		43		1	
14/06/07 08:30	02/08/07 11:05	13	14	5	9	2	3
14/06/07 08:30	02/08/07 11:05	15		13		4	
02/08/07 13:25	09/09/07 12:30	37	40	20	22	4	3
02/08/07 13:25	09/09/07 12:30	42		25		2	
09/09/07 12:35	25/10/07 14:10	35	30	18	19	3	3
09/09/07 12:35	25/10/07 14:10	25		21		3	
25/10/07 14:20	09/11/07 10:30	33	30	7	16	3	4
25/10/07 14:20	09/11/07 10:30	27		24		5	
09/11/07 10:40	09/01/08 10:46	11	10	11	10	3	3
09/11/07 10:40	09/01/08 10:46	9		9		3	
09/01/08 10:50	08/02/08 14:00	16	14	7	10	3	3
09/01/08 10:50	08/02/08 14:00	12		12		2	

Table 8b cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
08/02/08 14:15	12/03/08 11:20	12	13	9	6	6	6
08/02/08 14:15	12/03/08 11:20	15		4		7	
12/03/08 11:30	27/04/08 14:03	12	12	8	8	3	4
12/03/08 11:30	27/04/08 14:03	12		7		5	
27/04/08 15:03	04/06/08 12:20						
27/04/08 15:03	04/06/08 12:20						
04/06/08 12:30	17/07/08 11:17						
04/06/08 12:30	17/07/08 11:17						
17/07/08 11:25	14/08/08 09:00						
17/07/08 11:25	14/08/08 09:00						
Mean			***21***		***17***		***3***
Site 4							
03/05/07 10:12	07/06/07 09:12	27	19	50	48	2	2
03/05/07 10:12	07/06/07 09:12	11		45		1	
07/06/07 09:15	04/08/07 08:22	20	19	21	19	5	5
07/06/07 09:15	04/08/07 08:22	18		18		5	
04/08/07 08:30	12/09/07 09:19	39	26	27	24	11	8
04/08/07 08:30	12/09/07 09:19	13		21		4	
12/09/07 09:26	16/10/07 14:07	33	31	25	23	6	6
12/09/07 09:26	16/10/07 14:07	29		21		7	
16/10/07 14:11	08/11/07 09:36	16	22	27	22	7	8
16/10/07 14:11	08/11/07 09:36	29		17		8	
08/11/07 09:46	08/01/08 09:35	20	22	29	24	7	7
08/11/07 09:46	08/01/08 09:35	24		19		8	
08/01/08 09:45	07/02/08 11:00	33	38	68	65	7	8
08/01/08 09:45	07/02/08 11:00	44		61		9	
07/02/08 11:15	11/03/08 08:55	40	37	48	49	12	10
07/02/08 11:15	11/03/08 08:55	34		50		8	
11/03/08 09:05	21/04/08 07:55	12	13	8	17	5	5
11/03/08 09:05	21/04/08 07:55	14		26		6	
21/04/08 07:55	03/06/08 11:16						
21/04/08 07:55	03/06/08 11:16						
23/06/08 08:30	14/07/08 09:50						
23/06/08 08:30	14/07/08 09:50						
14/07/08 09:55	13/08/08 09:00						
14/07/08 09:55	13/08/08 09:00						
Mean			***25***		***32***		***7***
Site 5							
03/05/07 10:53	07/06/07 09:50	19	21	97	106	6	12
03/05/07 10:53	07/06/07 09:50	23		115		19	
07/06/07 09:55	04/08/07 09:50	24	22	25	21	10	9
07/06/07 09:55	04/08/07 09:50	19		17		8	
04/08/07 10:00	12/09/07 10:04	20	24	21	18	7	7
04/08/07 10:00	12/09/07 10:04	27		14		7	
12/09/07 10:07	16/10/07 15:30	24	25	18	16	8	10
12/09/07 10:07	16/10/07 15:30	27		15		12	
16/10/07 15:31	08/11/07 10:37	15	33	6	16	6	7
16/10/07 15:31	08/11/07 10:37	52		26		9	
08/11/07 10:37	08/01/08 10:45	16	12	13	11	7	7
08/11/07 10:37	08/01/08 10:45	8		9		<5	

Table 8b cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
08/01/08 10:45	07/02/08 13:50	20	25	16	16	5	5
08/01/08 10:45	07/02/08 13:50	30		16		5	
07/02/08 13:50	11/03/08 10:05	14	11	21	24	5	7
07/02/08 13:50	11/03/08 10:05	8		27		9	
11/03/08 10:16	21/04/08 08:26	23	18	45	37	10	8
11/03/08 10:16	21/04/08 08:26	14		29		7	
21/04/08 08:30	03/06/08 12:58						
21/04/08 08:30	03/06/08 12:58						
23/06/08 08:50	14/07/08 11:09						
23/06/08 08:50	14/07/08 11:09						
14/07/08 11:15	13/08/08 09:55						
14/07/08 11:15	13/08/08 09:55						
Mean			***21***		***29***		***8***
Site 6							
03/05/07 11:16	07/06/07 10:21	32	24	72	55	4	6
03/05/07 11:16	07/06/07 10:21	16		38		8	
07/06/07 10:30	04/08/07 09:10	12	13	8	6	4	4
07/06/07 10:30	04/08/07 09:10	13		4		4	
04/08/07 09:15	12/09/07 10:27	16	20	18	19	3	4
04/08/07 09:15	12/09/07 10:27	25		20		4	
12/09/07 10:30	16/10/07 14:54	24	25	18	16	8	10
12/09/07 10:30	16/10/07 14:54	27		15		12	
16/10/07 15:00	08/11/07 10:07	15	33	6	16	6	7
16/10/07 15:00	08/11/07 10:07	52		26		9	
08/11/07 10:17	08/01/08 10:15	16	12	13	11	7	7
08/11/07 10:17	08/01/08 10:15	8		9		<5	
08/01/08 10:25	07/02/08 12:06	21	17	16	14	5	5
08/01/08 10:25	07/02/08 12:06	12		12		<5	
07/02/08 12:25	11/03/08 09:43	12	10	11	14	7	5
07/02/08 12:25	11/03/08 09:43	7		17		3	
11/03/08 09:59	21/04/08 09:20	11	11	16	14	4	4
11/03/08 09:59	21/04/08 09:20	10		12		4	
21/04/08 09:31	03/06/08 12:25						
21/04/08 09:31	03/06/08 12:25						
23/06/08 09:30	14/07/08 11:59						
23/06/08 09:30	14/07/08 11:59						
14/07/08 12:05	13/08/08 10:49						
14/07/08 12:05	13/08/08 10:49						
Mean			***18***		***18***		***6***
Site 7							
03/05/07 11:43	07/06/07 11:05	<7	4	8	10	1	1
03/05/07 11:43	07/06/07 11:05	<7		12		2	
07/06/07 11:23	03/08/07 11:10	8	9	11	9	2	2
07/06/07 11:23	03/08/07 11:10	11		8		3	
03/08/07 11:10	12/09/07 11:05	13	15	16	23	4	8
03/08/07 11:10	12/09/07 11:05	16		31		12	
12/09/07 11:10	16/10/07 17:05	25	30	12	17	7	7
12/09/07 11:10	16/10/07 17:05	35		21		7	
16/10/07 15:15	08/11/07 10:57	19	22	20	17	<5	8
16/10/07 15:15	08/11/07 10:57	25		14		8	

Table 8b cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
08/11/07 10:59	08/01/08 12:05	25	21	32	23	12	9
08/11/07 10:59	08/01/08 12:05	16		14		7	
08/01/08 12:20	07/02/08 14:34	35	26	25	25	15	15
08/01/08 12:20	07/02/08 14:34	16		25		<5	
07/02/08 14:45	11/03/08 10:58	46	40	2004[c]	112	26	27
07/02/08 14:45	11/03/08 10:58	33		112		28	
11/03/08 11:05	21/04/08 10:05	6	9	12	17	3	4
11/03/08 11:05	21/04/08 10:05	12		22		5	
21/04/08 10:25	03/06/08 14:15						
21/04/08 10:25	03/06/08 14:15						
23/06/ 10:1508	14/07/08 13:01						
23/06/ 10:1508	14/07/08 13:01						
14/07/08 13:10	13/08/08 11:40						
14/07/08 13:10	13/08/08 11:40						
Mean			***19***		***28***		***9***
Site 8							
24/01/07 15:00	22/02/07 09:15	16	17	92	93	8	7
24/01/07 15:00	22/02/07 09:15	17		94		7	
22/02/07 09:20	20/03/07 12:22	14	10	105	107	17	13
22/02/07 09:20	20/03/07 12:22	6		108		10	
20/03/07 12:35	03/05/07 13:49	28	27	49	33	6	5
20/03/07 12:35	03/05/07 13:49	25		17		5	
03/05/07 14:00	07/06/07 12:00	13	13	60	41	4	3
03/05/07 14:00	07/06/07 12:00	13		22		2	
07/06/07 12:26	03/08/07 10:01	22	15	15	14	7	7
07/06/07 12:26	03/08/07 10:01	8		13		6	
03/08/07 10:15	12/09/07 12:11	32	30	16	24	11	8
03/08/07 10:15	12/09/07 12:11	29		32		6	
12/09/07 12:18	16/10/07 10:59	28	19	6	18	6	8
12/09/07 12:18	16/10/07 10:59	11		30		10	
16/10/07 11:07	08/11/07 11:38	25	17	16	15	11	8
16/10/07 11:07	08/11/07 11:38	8		15		5	
08/11/07 11:55	08/01/08 14:50	12	11	16	16	5	4
08/11/07 11:55	08/01/08 14:50	10		17		4	
08/01/08 14:55	07/02/08 15:00	18	18	15	15	6	6
08/01/08 14:55	07/02/08 15:00	17		15		5	
07/02/08 15:37	11/03/08 11:50	16	18	10	24	<5	11
07/02/08 15:37	11/03/08 11:50	19		37		11	
11/03/08 12:00	21/04/08 10:57	6	9	14	14	<5	3
11/03/08 12:00	21/04/08 10:57	12		14		<5	
21/04/08 11:08	03/06/08 14:50						
21/04/08 11:08	03/06/08 14:50						
23/06/08 11:00	14/07/08 14:00						
23/06/08 11:00	14/07/08 14:00						
14/07/08 14:02	13/08/08 13:09						
14/07/08 14:02	13/08/08 13:09						
Mean			***17***		***35***		***7***
Site 9							
04/05/07 17:20	07/06/07 13:00	43	60	527	513	40	56
04/05/07 17:20	07/06/07 13:00	78		498		72	

Table 8b cont

Date/time On	Date/time Off	Benzene (ppt)	Benzene mean	Toluene (ppt)	Toluene mean	Ethyl benzene (ppt)	Ethyl benzene mean
07/06/07 13:15	06/08/07 17:30	32	38	307	371	<5	38
07/06/07 13:15	06/08/07 17:30	44		434		38	
06/08/07 17:40	11/09/07 17:36	53	49	405	403	50	50
06/08/07 17:40	11/09/07 17:36	46		401		51	
11/09/07 17:43	22/10/07 17:45	<7	94	<6	1073	<5	115
11/09/07 17:43	22/10/07 17:45	94		1073		115	
25/10/07 16:20	09/11/07 09:17	47	43	425	447	32	33
25/10/07 16:20	09/11/07 09:17	39		470		34	
09/11/07 17:50	08/01/08 16:00	21	22	289	298	28	28
09/11/07 17:50	08/01/08 16:00	22		307		29	
08/01/08 18:00	10/02/08 18:15	39	38	304	305	29	29
08/01/08 18:00	10/02/08 18:15	37		306		29	
10/02/08 18:20	16/03/08 12:00						
10/02/08 18:20	16/03/08 12:00						
16/03/08 12:10	21/04/08 18:00	26	29	389	386	37	38
16/03/08 12:10	21/04/08 18:00	32		382		38	
21/04/08 18:15	12/06/08 17:00						
21/04/08 18:15	12/06/08 17:00						
23/06/08 12:30	18/07/08 10:20						
23/06/08 12:30	18/07/08 10:20						
18/07/08 10:30	13/08/08 17:51						
18/07/08 10:30	13/08/08 17:51						
Mean			***47***		***389***		***39***
Site 10							
07/06/07 13:20	12/07/07 16:30	26	26	7	5	<5	5
07/06/07 13:20	12/07/07 16:30	27		2		5	
12/07/07 16:30	03/08/07 09:20	10	10	16	21	3	6
12/07/07 16:30	03/08/07 09:20	<7		26		9	
03/08/07 09:30	16/09/07 14:00	20	16	21	16	2	2
03/08/07 09:30	16/09/07 14:00	13		12		2	
16/09/07 14:00	04/10/07 18:00	47	38	5	5	<5	3
16/09/07 14:00	04/10/07 18:00	30		4		<5	
04/10/07 18:00	05/11/07 11:00	5	5	3	5	2	1
04/10/07 18:00	05/11/07 11:00	4		6		1	
05/11/07 11:20	19/01/08 13:00	7	8	4	2	2	3
05/11/07 11:20	19/01/08 13:00	8		1		3	
08/02/08 18:20	16/03/08 12:00	22	24	382[c]	412[c]	37[c]	33[c]
08/02/08 18:20	16/03/08 12:00	27		441[c]		30[c]	
07/02/08 16:30	14/03/08 09:30	10	12	11	18	<5	10
07/02/08 16:30	14/03/08 09:30	15		24		10	
19/01/08 13:00	07/02/08 16:30	16	26	25	30	4	6
19/01/08 13:00	07/02/08 16:30	35		36		7	
07/02/08 16:30	14/03/08 21:30						
07/02/08 16:30	14/03/08 21:30						
14/03/08 13:00	03/05/08 15:30						
14/03/08 13:00	03/05/08 15:30						
Mean			***18***		***13***		***4***

Figure 13 shows the temporal variation of benzene at each of the sites. It shows that Site 9, Karratha generally has the highest benzene concentrations, presumably due to the increased emissions of benzene from motor vehicles. There is little enhancement of benzene at the lower Burrup sites compared to concentrations measured at the local background, at sites 1, 3 and 10, the high result at site 10 is due to a contaminated sample.

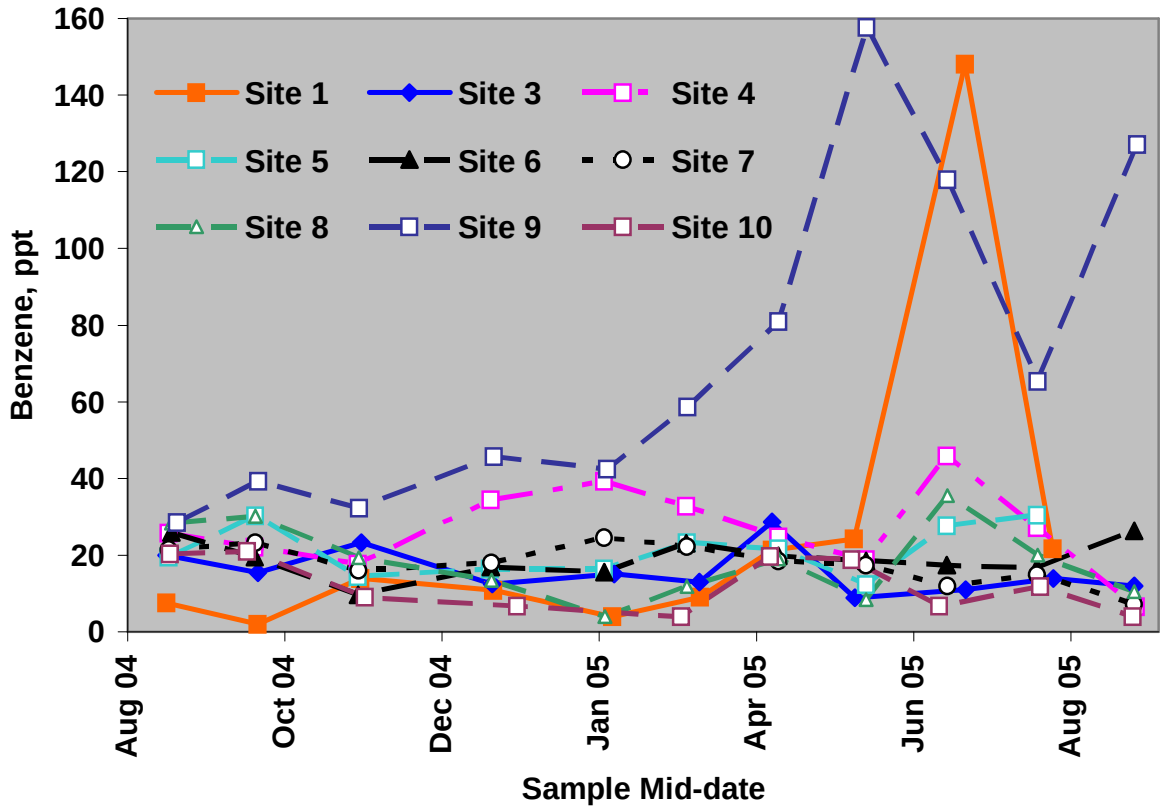


Figure 13a. Benzene concentrations at each site plotted against the sample mid-date for the 2004/2005 period.

The temporal distribution of benzene concentrations, measured during 2007/2007, are presented in Figure 13b. The concentration of 192 ppt at site 1 is the result of contamination during transport of the samples from Karratha to CMAR, Aspendale.

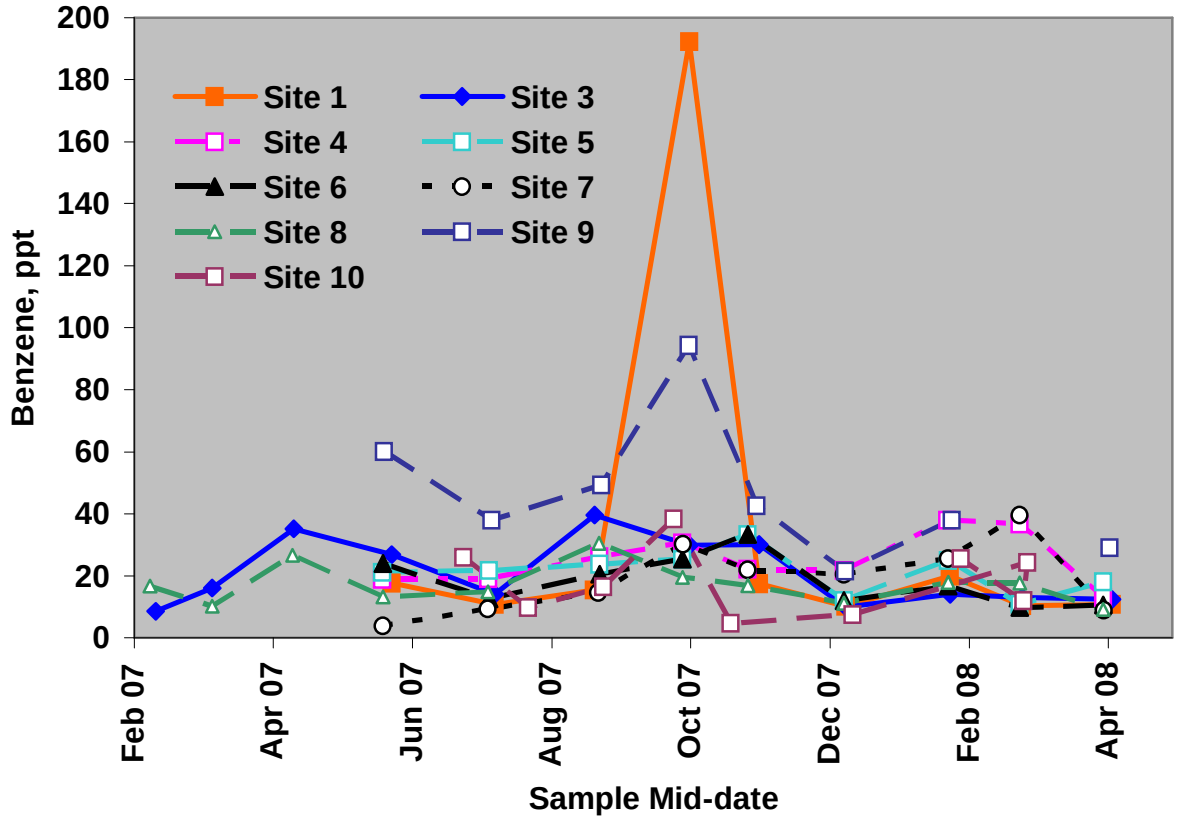


Figure 13b. Benzene concentrations at each site plotted against the sample mid-date for the 2007/2008 period.

Table 9a. Concentrations of p-xylene, m-xylene and o-xylene measured at the nine sites from the beginning of August 2004 until the September 2005. Concentrations are in ppt. Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration. Samples which are believed to have been contaminated during transport are marked with a [c]. These samples have not been used to produce averages.

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene Mean	o-Xylene (ppt)	o-Xylene mean
Site 1					
29/07/04 11:50	02/09/04 15:35	18	18	<2	1
29/07/04 11:50	02/09/04 15:35	<2		<2	
02/09/04 15:35	08/10/04 09:40	242 [c]	1	92 [c]	2
02/09/04 15:35	08/10/04 09:40	<1		<3	
08/10/04 09:45	21/11/04 12:05	7	8	<3	5
08/10/04 09:45	21/11/04 12:05	10		5	
21/11/04 12:05	19/01/05 13:05	8	7	<3	3
21/11/04 12:05	19/01/05 13:05	7		3	
19/01/05 13:05	21/02/05 12:55	7	6	3	3
19/01/05 13:05	21/02/05 12:55	5		3	
21/02/05 12:58	28/03/05 11:15	12	9	20	15
21/02/05 12:58	28/03/05 11:15	7		10	
21/03/05 13:12	18/04/05 11:15	<2	7	4	4
21/03/05 13:12	18/04/05 11:15	7		<3	
18/04/05 11:18	31/05/05 11:15	11	11	9	7
18/04/05 11:18	31/05/05 11:15	11		5	
31/05/05 11:19	13/07/05 11:45	2	2	<3	2
31/05/05 11:19	13/07/05 11:45	3		<3	
13/07/05 11:47	07/08/05 11:43	<3	2	<1	1
13/07/05 11:47	07/08/05 11:43	<3		<1	
17/08/05 11:45	14/09/05 09:53	66 [c]	73 [c]	31 [c]	48 [c]
17/08/05 11:45	14/09/05 09:53	79 [c]		64 [c]	
Mean			***7***		***4***
Site 3					
29/07/04 16:00	02/09/04 13:10	18	17	14	13
29/07/04 16:00	02/09/04 13:10	15		13	
02/09/04 13:15	08/10/04 11:30	<3	8	<3	6
02/09/04 13:15	08/10/04 11:30	8		6	
08/10/04 11:30	21/11/04 15:40	16	15	<3	4
08/10/04 11:30	21/11/04 15:40	14		4	
21/11/04 15:40	18/01/05 10:02	17	14	8	6
21/11/04 15:40	18/01/05 10:02	12		4	
21/01/05 10:28	21/02/05 09:44	8	9	5	5
21/01/05 10:28	21/02/05 09:44	9		<3	
21/02/05 09:48	28/03/05 12:28	9	9	9	8
21/02/05 09:48	28/03/05 12:28	9		8	
28/03/05 12:30	18/04/05 14:36	<6	7	<3	7
28/03/05 12:30	18/04/05 14:36	7		7	
18/04/05 14:40	31/05/05 13:15	13	13	<4	6
18/04/05 14:40	31/05/05 13:15	13		6	
31/05/05 13:20	13/07/05 15:46	<3	2	<3	2
31/05/05 13:20	13/07/05 15:46	<3		<3	
13/07/05 15:50	07/08/05 15:07	16	13	1	1
13/07/05 15:50	07/08/05 15:07	10		2	

Table 9a cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
07/08/05 15:10	14/09/05 13:00	21	21	<1	1
07/08/05 15:10	14/09/05 13:00	<7		<1	
Mean			***12***		***6***
Site 4					
01/08/04 12:09	01/09/04 09:17	16	18	4	4
01/08/04 12:09	01/09/04 09:17	20		4	
01/09/04 09:32	07/10/04 09:15	42	44	13	19
01/09/04 09:32	07/10/04 09:15	46		24	
07/10/04 09:15	20/11/04 08:20	38	37	12	12
07/10/04 09:15	20/11/04 08:20	37		12	
20/11/04 08:20	18/01/05 10:20	55	55	17	16
20/11/04 08:20	18/01/05 10:20	54		14	
18/01/05 10:07	16/02/05 06:40	39	43	19	15
18/01/05 10:07	16/02/05 06:40	46		11	
16/02/05 06:30	23/03/05 09:45	43	47	15	17
16/02/05 06:30	23/03/05 09:45	50		19	
23/03/05 09:50	28/04/05 08:44	43	43	11	10
23/03/05 09:50	28/04/05 08:44	43		8	
28/04/05 08:45	30/05/05 10:36	22	23	11	10
28/04/05 08:45	30/05/05 10:36	24		8	
30/05/05 10:39	30/06/05 08:48	<3	6	<3	2
30/05/05 10:39	30/06/05 08:48	6		<3	
30/06/05 08:50	08/08/05 09:30	16	14	7	6
30/06/05 08:50	08/08/05 09:30	12		6	
08/08/05 08:47	15/09/05 08:43	11	13	16	9
08/08/05 08:47	15/09/05 08:43	14		2	
Mean			***31***		***11***
Site 5					
01/08/04 16:04	01/09/04 12:00	61	61	23	22
01/08/04 16:04	01/09/04 12:00	60		21	
01/09/04 12:00	07/10/04 11:15	105	70	42	29
01/09/04 12:00	07/10/04 11:15	35		16	
07/10/04 11:21	20/11/04 12:20	75	73	24	24
07/10/04 11:21	20/11/04 12:20	72		25	
20/11/04 12:40	18/01/05 00:00	52	52	17	18
20/11/04 12:40	18/01/05 00:00	53		19	
18/01/05 12:44	16/02/05 08:07	52	51	17	17
18/01/05 12:44	16/02/05 08:07	51		16	
16/02/05 08:10	23/03/05 11:55	95	80	37	31
16/02/05 08:10	23/03/05 11:55	65		25	
23/03/05 11:50	28/04/05 10:18	84	68	28	28
23/03/05 11:50	28/04/05 10:18	51		<3	
28/04/05 10:17	30/05/05 10:43	61	59	26	23
28/04/05 10:17	30/05/05 10:43	57		20	
30/05/05 11:45	30/06/05 09:20	25	25	8	8
30/05/05 11:45	30/06/05 09:20	24		<3	
30/06/05 09:22	08/08/05 10:25	69	63	23	24
30/06/05 09:22	08/08/05 10:25	57		24	
08/08/05 09:30	13/09/05 10:32	434 [c]	438 [c]	168 [c]	103 [c]
08/08/05 09:30	13/09/05 10:32	442 [c]		37 [c]	
Mean			***57***		***21***

Table 9a cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
Site 6					
03/08/04 12:09	01/09/04 11:15	32	32	12	10
03/08/04 12:09	01/09/04 11:15	31		8	
01/09/04 11:15	07/10/04 10:30	36	37	24	19
01/09/04 11:15	07/10/04 10:30	37		14	
07/10/04 10:35	20/11/04 12:20	48	48	15	15
07/10/04 10:35	20/11/04 12:20	<4		<3	
20/11/04 10:40	18/01/05 11:20	33	43	14	17
20/11/04 10:40	18/01/05 11:20	53		19	
18/01/05 11:25	16/02/05 07:20	33	33	19	16
18/01/05 11:25	16/02/05 07:20	34		13	
16/02/05 07:25	23/03/05 10:52	35	33	15	14
16/02/05 07:25	23/03/05 10:52	31		13	
23/03/05 10:52	28/04/05 09:36	21	28	12	12
23/03/05 10:52	28/04/05 09:36	35		12	
28/04/05 09:33	30/05/05 12:50	31	29	14	15
28/04/05 09:33	30/05/05 12:50	27		16	
30/05/05 12:56	30/06/05 10:15	9	8	<3	2
30/05/05 12:56	30/06/05 10:15	7		<3	
30/06/05 10:15	08/08/05 10:25	10	10	3	3
30/06/05 10:15	08/08/05 10:25	10		3	
08/08/05 10:25	13/09/05 14:35	24	17	3	5
08/08/05 10:25	13/09/05 14:35	10		6	
Mean			***29***		***12***
Site 7					
01/08/04 15:01	01/09/04 13:34	18	18	4	6
01/08/04 15:01	01/09/04 13:34	19		8	
01/09/04 13:34	07/10/04 13:35	195 [c]	25	84 [c]	9
01/09/04 13:34	07/10/04 13:35	25		9	
07/10/04 13:25	20/11/04 14:45	<4	24	<3	9
07/10/04 13:25	20/11/04 14:45	24		9	
20/11/04 15:00	18/01/05 15:12	27	28	9	10
20/11/04 15:00	18/01/05 15:12	29		12	
18/01/05 15:16	16/02/05 09:04	34	35	10	9
18/01/05 15:16	16/02/05 09:04	35		9	
16/02/05 09:38	23/03/05 13:05	27	27	15	14
16/02/05 09:38	23/03/05 13:05	27		13	
23/03/05 13:12	28/04/05 11:05	33	27	20	12
23/03/05 13:12	28/04/05 11:05	21		5	
28/04/05 11:20	30/05/05 14:10	18	16	8	11
28/04/05 11:20	30/05/05 14:10	14		15	
30/05/05 14:45	30/06/05 11:23	5	4	<3	2
30/05/05 14:45	30/06/05 11:23	4		<3	
30/06/05 11:25	08/08/05 11:27	10	10	2	2
30/06/05 11:25	08/08/05 11:27	10		2	
08/08/05 11:25	13/09/05 11:41	18	16	5	3
08/08/05 11:25	13/09/05 11:41	14		1	
Mean			***21***		***8***
Site 8					
03/08/04 09:07	01/09/04 15:43	30	29	7	7

03/08/04 09:07	01/09/04 15:43	28		6	

Table 9a cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
01/09/04 15:43	07/10/04 15:00	88	71	44	32
01/09/04 15:43	07/10/04 15:00	55		20	
07/10/04 15:10	20/11/04 16:20	41	41	18	17
07/10/04 15:10	20/11/04 16:20	41		16	
20/11/04 16:30	18/01/05 17:17	37	35	14	13
20/11/04 16:30	18/01/05 17:17	34		12	
18/01/05 17:25	16/02/05 10:20	39	38	17	16
18/01/05 17:25	16/02/05 10:20	37		14	
16/02/05 11:10	23/03/05 14:34	20	25	14	16
16/02/05 11:10	23/03/05 14:34	29		17	
23/03/05 14:35	28/04/05 11:50	31	31	12	11
23/03/05 14:35	28/04/05 11:50	31		10	
28/04/05 12:34	30/05/05 16:00	208	26	248	17
28/04/05 12:34	30/05/05 16:00	26		17	
30/05/05 16:01	30/06/05 12:35	10	9	<3	2
30/05/05 16:01	30/06/05 12:35	7		<3	
30/06/05 13:25	08/08/05 17:33	14	13	3	3
30/06/05 13:25	08/08/05 17:33	11		4	
08/08/05 12:36	13/09/05 15:50	34	22	9	8
08/08/05 12:36	13/09/05 15:50	10		7	
Mean			***29***		***12***
Site 9					
05/08/04 15:00	03/09/04 18:00	20	20	8	8
05/08/04 15:00	03/09/04 18:00	<2		<2	
03/09/04 15:30	07/10/04 20:30	296	271	109	104
03/09/04 15:30	07/10/04 20:30	246		98	
07/10/04 20:40	20/11/04 18:00	164	164	63	63
07/10/04 20:40	20/11/04 18:00	<4		4	
20/11/04 18:00	20/01/05 10:26	299	261	112	96
20/11/04 18:00	20/01/05 10:26	222		79	
20/01/05 10:45	16/02/05 18:00	174	182	61	65
20/01/05 10:45	16/02/05 18:00	190		68	
16/02/05 18:00	23/03/05 15:22	212	221	94	98
16/02/05 18:00	23/03/05 15:22	230		102	
23/03/05 15:26	28/04/05 13:45	312	316	120	120
23/03/05 15:26	28/04/05 13:45	320		120	
28/04/05 13:45	30/05/05 18:04	1241	1262	483	492
28/04/05 13:45	30/05/05 18:04	1283		502	
30/05/05 18:06	30/06/05 13:25	273	256	95	94
30/05/05 18:06	30/06/05 13:25	238		94	
30/06/05 13:25	08/08/05 17:33	204	199	73	72
30/06/05 13:25	08/08/05 17:33	195		71	
08/08/05 17:45	15/09/05 18:00	473	464	190	191
08/08/05 17:45	15/09/05 18:00	455		191	
Mean			***329***		***128***
Site 10					
02/08/04 15:00	01/09/04 10:45	5	5	4	4
02/08/04 15:00	01/09/04 10:45	83		159	
01/09/04 10:50	01/10/04 12:35	23	19	15	9
01/09/04 10:50	01/10/04 12:35	15		9	
01/10/04 12:35	01/12/04 10:30	5	5	4	3

Table 9a cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
01/10/04 12:35	01/12/04 10:30	5		3	
01/12/04 12:00	27/01/05 14:00	6	6	7	7
01/12/04 12:00	27/01/05 14:00	<5		<3	
18/02/05 09:30	17/03/05 11:30	4	4	10	7
18/02/05 09:30	17/03/05 11:30	<3		4	
17/03/05 11:30	28/04/05 08:00	17	17	10	9
17/03/05 11:30	28/04/05 08:00	16		8	
28/04/05 08:00	19/05/05 10:00	13	12	10	11
28/04/05 08:00	19/05/05 10:00	11		13	
19/05/05 10:15	05/07/05 11:05	<1	2	<4	2
19/05/05 10:15	05/07/05 11:05	2		<4	
05/07/05 11:15	05/08/05 13:20	5	5	<3	3
05/07/05 11:15	05/08/05 13:20	14		3	
05/08/05 11:15	15/09/05 12:00	<3	2	<1	3
05/08/05 11:15	15/09/05 12:00	17		3	
Mean			***8***		***6***

Table 9b. Concentrations of p-xylene, m-xylene and o-xylene measured at the nine sites from February 2007 until August 2008. Concentrations are in ppt. Where both samples of the pair are below the limit of detection the average concentration is set at half the limit of detection. If only one sample is above the limit of detection that value is entered as the average concentration. Samples which are believed to have been contaminated during transport are marked with a [c]. These samples have not been used to produce averages.

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene Mean
Site 1					
04/05/07 11:15	14/06/07 09:37	5	5	2	2
04/05/07 11:15	14/06/07 09:37	5		2	
14/06/07 09:46	02/08/07 11:05	10	6	3	3
14/06/07 09:46	02/08/07 11:05	2		2	
02/08/07 11:10	09/09/07 10:30	13	7	5	3
02/08/07 11:10	09/09/07 10:30	2		1	
09/09/07 10:35	25/10/07 16:10	122[c]	159[c]	48[c]	65[c]
09/09/07 10:35	25/10/07 16:10	196[c]		82[c]	
25/10/07 16:20	09/11/07 09:17	1	1	<2	1
25/10/07 16:20	09/11/07 09:17	2		<2	
09/11/07 09:18	09/01/08 09:15	2	2	<2	1
09/11/07 09:18	09/01/08 09:15	2		<2	
09/01/08 09:15	08/02/08 12:20	3	5	2	2
09/01/08 09:15	08/02/08 12:20	6		<2	
08/02/08 12:30	120/3/08 13:15	2	2	<2	1
08/02/08 12:30	120/3/08 13:15	1		<2	
12/03/08 13:15	27/04/08 10:50	2	2	<2	1
12/03/08 13:15	27/04/08 10:50	3		<2	
27/04/08 11:25	04/06/08 10:13				
27/04/08 11:25	04/06/08 10:13				
27/04/08 11:10	04/06/08 10:30				
27/04/08 11:10	04/06/08 10:30				
04/06/08 10:30	17/07/08 09:45				
04/06/08 10:30	17/07/08 09:45				
17/07/08 09:48	14/08/08 11:05				
17/07/08 09:48	14/08/08 11:05				
Mean			***4***		***1***
Site 3					
29/01/07 11:00	22/02/07 10:51	9	10	4	4
29/01/07 11:00	22/02/07 10:51	11		4	
22/02/07 11:00	20/03/07 08:51	78[c]	66[c]	28[c]	27[c]
22/02/07 11:00	20/03/07 08:51	66[c]		27[c]	
20/03/07 09:00	04/05/07 12:49	8	9	3	4
20/03/07 09:00	04/05/07 12:49	10		6	
04/05/07 12:59	14/06/07 08:24	5	5	2	2
04/05/07 12:59	14/06/07 08:24	5		2	
14/06/07 08:30	02/08/07 11:05	3	4	2	2
14/06/07 08:30	02/08/07 11:05	5		2	
02/08/07 13:25	09/09/07 12:30	10	8	5	4
02/08/07 13:25	09/09/07 12:30	6		3	
09/09/07 12:35	25/10/07 14:10	3	3	<1	1
09/09/07 12:35	25/10/07 14:10	3		1	
25/10/07 14:20	09/11/07 10:30	2	3	<1	1
25/10/07 14:20	09/11/07 10:30	3		<1	
09/11/07 10:40	09/01/08 10:46	9	6	1	1
09/11/07 10:40	09/01/08 10:46	2		1	
09/01/08 10:50	08/02/08 14:00	4	6	1	1

09/01/08 10:50	08/02/08 14:00	8	2

Table 9b cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene Mean
08/02/08 14:15	12/03/08 11:20	6	5	2	2
08/02/08 14:15	12/03/08 11:20	5		1	
12/03/08 11:30	27/04/08 14:03	3	4	1	1
12/03/08 11:30	27/04/08 14:03	5		1	
27/04/08 15:03	04/06/08 12:20				
27/04/08 15:03	04/06/08 12:20				
04/06/08 12:30	17/07/08 11:17				
04/06/08 12:30	17/07/08 11:17				
17/07/08 11:25	14/08/08 09:00				
17/07/08 11:25	14/08/08 09:00				
Mean			**5**		**2**
Site 4					
03/05/07 10:12	07/06/07 09:12	10	9	4	4
03/05/07 10:12	07/06/07 09:12	9		4	
07/06/07 09:15	04/08/07 08:22	13	12	5	5
07/06/07 09:15	04/08/07 08:22	11		5	
04/08/07 08:30	12/09/07 09:19	20	14	4	3
04/08/07 08:30	12/09/07 09:19	8		3	
12/09/07 09:26	16/10/07 14:07	12	16	4	3
12/09/07 09:26	16/10/07 14:07	20		3	
16/10/07 14:11	08/11/07 09:36	21	23	5	6
16/10/07 14:11	08/11/07 09:36	26		6	
08/11/07 09:46	08/01/08 09:35	25	25	6	6
08/11/07 09:46	08/01/08 09:35	25		6	
08/01/08 09:45	07/02/08 11:00	39	41	12	13
08/01/08 09:45	07/02/08 11:00	42		13	
07/02/08 11:15	11/03/08 08:55	31	33	9	9
07/02/08 11:15	11/03/08 08:55	34		9	
11/03/08 09:05	21/04/08 07:55	3	10	1	3
11/03/08 09:05	21/04/08 07:55	18		5	
21/04/08 07:55	03/06/08 11:16				
21/04/08 07:55	03/06/08 11:16				
23/06/08 08:30	14/07/08 09:50				
23/06/08 08:30	14/07/08 09:50				
14/07/08 09:55	13/08/08 09:00				
14/07/08 09:55	13/08/08 09:00				
Mean			***20***		***6***
Site 5					
03/05/07 10:53	07/06/07 09:50	22	48	8	21
03/05/07 10:53	07/06/07 09:50	73		33	
07/06/07 09:55	04/08/07 09:50	25	21	10	8
07/06/07 09:55	04/08/07 09:50	16		6	
04/08/07 10:00	12/09/07 10:04	20	17	5	5
04/08/07 10:00	12/09/07 10:04	14		5	
12/09/07 10:07	16/10/07 15:30	20	24	6	7
12/09/07 10:07	16/10/07 15:30	27		8	
16/10/07 15:31	08/11/07 10:37	17	22	5	6
16/10/07 15:31	08/11/07 10:37	27		8	
08/11/07 10:37	08/01/08 10:45	10	10	3	1
08/11/07 10:37	08/01/08 10:45	<2		0	

Table 9b cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
08/01/08 10:45	07/02/08 13:50	10	11	3	4
08/01/08 10:45	07/02/08 13:50	11		4	
07/02/08 13:50	11/03/08 10:05	11	13	4	4
07/02/08 13:50	11/03/08 10:05	15		3	
11/03/08 10:16	21/04/08 08:26	18	18	6	7
11/03/08 10:16	21/04/08 08:26	18		7	
21/04/08 08:30	03/06/08 12:58				
21/04/08 08:30	03/06/08 12:58				
23/06/08 08:50	14/07/08 11:09				
23/06/08 08:50	14/07/08 11:09				
14/07/08 11:15	13/08/08 09:55				
14/07/08 11:15	13/08/08 09:55				
Mean			***20***		***7***
Site 6					
03/05/07 11:16	07/06/07 10:21	13	16	7	6
03/05/07 11:16	07/06/07 10:21	19		5	
07/06/07 10:30	04/08/07 09:10	5	6	1	2
07/06/07 10:30	04/08/07 09:10	7		3	
04/08/07 09:15	12/09/07 10:27	6	7	2	2
04/08/07 09:15	12/09/07 10:27	8		2	
12/09/07 10:30	16/10/07 14:54	20	24	6	7
12/09/07 10:30	16/10/07 14:54	27		8	
16/10/07 15:00	08/11/07 10:07	17	22	5	6
16/10/07 15:00	08/11/07 10:07	27		8	
08/11/07 10:17	08/01/08 10:15	10	5	3	3
08/11/07 10:17	08/01/08 10:15	0		<1	
08/01/08 10:25	07/02/08 12:06	11	11	2	2
08/01/08 10:25	07/02/08 12:06	<2		<1	
07/02/08 12:25	11/03/08 09:43	10	9	2	2
07/02/08 12:25	11/03/08 09:43	7		2	
11/03/08 09:59	21/04/08 09:20	9	9	3	2
11/03/08 09:59	21/04/08 09:20	9		2	
21/04/08 09:31	03/06/08 12:25				
21/04/08 09:31	03/06/08 12:25				
23/06/08 09:30	14/07/08 11:59				
23/06/08 09:30	14/07/08 11:59				
14/07/08 12:05	13/08/08 10:49				
14/07/08 12:05	13/08/08 10:49				
Mean			***12***		***4***
Site 7					
03/05/07 11:43	07/06/07 11:05	7	8	2	3
03/05/07 11:43	07/06/07 11:05	10		4	
07/06/07 11:23	03/08/07 11:10	3	3	3	2
07/06/07 11:23	03/08/07 11:10	3		1	
03/08/07 11:10	12/09/07 11:05	8	16	5	4
03/08/07 11:10	12/09/07 11:05	24		4	
12/09/07 11:10	16/10/07 17:05	13	12	3	3
12/09/07 11:10	16/10/07 17:05	11		3	
16/10/07 15:15	08/11/07 10:57	5	6	1	2
16/10/07 15:15	08/11/07 10:57	7		3	

Table 9b cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
08/11/07 10:59	08/01/08 12:05	21	15	7	5
08/11/07 10:59	08/01/08 12:05	9		3	
08/01/08 12:20	07/02/08 14:34	7	7	2	3
08/01/08 12:20	07/02/08 14:34	7		3	
07/02/08 14:45	11/03/08 10:58	29	23	11	8
07/02/08 14:45	11/03/08 10:58	16		5	
11/03/08 11:05	21/04/08 10:05	7	6	4	3
11/03/08 11:05	21/04/08 10:05	6		2	
21/04/08 10:25	03/06/08 14:15				
21/04/08 10:25	03/06/08 14:15				
23/06/ 10:1508	14/07/08 13:01				
23/06/ 10:1508	14/07/08 13:01				
14/07/08 12:05	13/08/08 10:49				
14/07/08 12:05	13/08/08 10:49				
Mean			***11***		***4***
Site 8					
24/01/07 15:00	22/02/07 09:15	28	27	10	10
24/01/07 15:00	22/02/07 09:15	26		10	
22/02/07 09:20	20/03/07 12:22	65	63	24	25
22/02/07 09:20	20/03/07 12:22	61		25	
20/03/07 12:35	03/05/07 13:49	14	14	6	6
20/03/07 12:35	03/05/07 13:49	14		6	
03/05/07 14:00	07/06/07 12:00	16	13	4	5
03/05/07 14:00	07/06/07 12:00	11		5	
07/06/07 12:26	03/08/07 10:01	8	10	3	5
07/06/07 12:26	03/08/07 10:01	12		7	
03/08/07 10:15	12/09/07 12:11	10	12	5	5
03/08/07 10:15	12/09/07 12:11	13		4	
12/09/07 12:18	16/10/07 10:59	6	12	3	2
12/09/07 12:18	16/10/07 10:59	19		2	
16/10/07 11:07	08/11/07 11:38	9	8	2	2
16/10/07 11:07	08/11/07 11:38	6		2	
08/11/07 11:55	08/01/08 14:50	9	9	3	3
08/11/07 11:55	08/01/08 14:50	10		3	
08/01/08 14:55	07/02/08 15:00	10	10	3	3
08/01/08 14:55	07/02/08 15:00	10		3	
07/02/08 15:37	11/03/08 11:50	4	11	2	4
07/02/08 15:37	11/03/08 11:50	18		6	
11/03/08 12:00	21/04/08 10:57	7	7	3	3
11/03/08 12:00	21/04/08 10:57	7		3	
21/04/08 11:08	03/06/08 14:50				
21/04/08 11:08	03/06/08 14:50				
23/06/08 11:00	14/07/08 14:00				
23/06/08 11:00	14/07/08 14:00				
14/07/08 13:10	13/08/08 11:40				
14/07/08 13:10	13/08/08 11:40				
Mean			***16***		***6***
Site 9					
04/05/07 17:20	07/06/07 13:00	137[c]	147[c]	52[c]	64[c]
04/05/07 17:20	07/06/07 13:00	157[c]		77[c]	

Table 9b cont

Date/time On	Date/time Off	p+m-Xylene (ppt)	p+m-Xylene mean	o-Xylene (ppt)	o-Xylene mean
07/06/07 13:15	06/08/07 17:30	2	59	0	17
07/06/07 13:15	06/08/07 17:30	115		34	
06/08/07 17:40	11/09/07 17:36	181	184	107	108
06/08/07 17:40	11/09/07 17:36	187		109	
11/09/07 17:43	22/10/07 17:45	<2	356	<1	148
11/09/07 17:43	22/10/07 17:45	356		148	
25/10/07 16:20	09/11/07 09:17	3	37	19	23
25/10/07 16:20	09/11/07 09:17	70		26	
09/11/07 17:50	08/01/08 16:00	74	73	30	29
09/11/07 17:50	08/01/08 16:00	71		29	
08/01/08 18:00	10/02/08 18:15	55	56	21	22
08/01/08 18:00	10/02/08 18:15	57		23	
10/02/08 18:20	16/03/08 12:00				
10/02/08 18:20	16/03/08 12:00				
16/03/08 12:10	21/04/08 18:00	92	93	35	36
16/03/08 12:10	21/04/08 18:00	93		37	
21/04/08 18:15	12/06/08 17:00				
21/04/08 18:15	12/06/08 17:00				
23/06/08 12:30	18/07/08 10:20				
23/06/08 12:30	18/07/08 10:20				
18/07/08 10:30	13/08/08 17:51				
18/07/08 10:30	13/08/08 17:51				
Mean			***93***		***44***
Site 10					
07/06/07 13:20	12/07/07 16:30	2	1	<1	2
07/06/07 13:20	12/07/07 16:30	1		2	
12/07/07 16:30	03/08/07 09:20	6	8	<1	1
12/07/07 16:30	03/08/07 09:20	10		1	
03/08/07 09:30	16/09/07 14:00	<2	1	2	1
03/08/07 09:30	16/09/07 14:00	<2		1	
16/09/07 14:00	04/10/07 18:00	<2	1	<1	1
16/09/07 14:00	04/10/07 18:00	<2		<1	
04/10/07 18:00	05/11/07 11:20	<2	1	1	1
04/10/07 18:00	05/11/07 11:20	<2		1	
05/11/07 11:20	19/01/08 13:00	1	1	1	1
05/11/07 11:20	19/01/08 13:00	1		<1	
19/01/08 13:00	07/02/08 16:30	2	3	1	1
19/01/08 13:00	07/02/08 16:30	5		1	
07/02/08 16:30	14/03/08 21:30	<2	11	<1	1
07/02/08 16:30	14/03/08 21:30	11		1	
14/03/08 13:00	03/05/08 15:30	70	67	29	29
14/03/08 13:00	03/05/08 15:30	64		28	
Mean			***3***		***1***

Table 9a lists the concentrations of the three xylene isomers measured at the sampling sites. Monthly average p+m xylene concentrations range from 20 ppt to 1262 ppt at site 9 (Karratha). The average annual concentration of xylenes over the 12 sampling periods for Sites 1 and 3 is about 7 ppt compared to about 23 ppt for sites 4 – 8. As expected, there is only a small enhancement of xylene at Sites 4 – 8 over the local background concentrations. The average at site 9 is higher than any other site probably due to the influence of motor vehicles.

The p+m xylene and o-xylene concentrations measured during 2007/2008 are presented in Table 9b. The monthly average concentrations range from 1 ppt at site 10 to 356 ppt at site 9, in Karratha and 1 ppt to 148 ppt at site 9 for p+m xylene and o-xylene respectively. The annual average p+m xylene concentrations range from 4 ppt at site 1 to 329 ppt at site 9 while o-xylene concentrations ranged from 1 ppt to 44 ppt at sites 1 and 9 respectively. These are very similar to the concentrations recorded during 2004/2005. The annual average concentrations at the background sites are about 4 ppt and 1 ppt for p+m xylene and o-xylene respectively while the concentrations increase to about 16ppt and 5 ppt at sites 4 – 8. Site 9 in Karratha have the highest p+m xylene and o-xylene concentrations and this is most likely due to the BTEX gas emissions from motor vehicles.

Table 10. Summary of annual average gas concentrations measured at the Burrup peninsular sites during the periods of 2004/005 and 2007/2008. Concentrations of NH_3 and NO_2 are in ppb while SO_2 and HNO_3 are in ppt.

Site	NH_3 04/05	NH_3 07/08	NO_2 04/05	NO_2 07/08	SO_2 04/05	SO_2 07/08	HNO_3 04/05	HNO_3 07/08
1	0.3	0.3	0.6	0.6	101	112	144	158
3	0.3	0.3	0.7	0.8	139	152	162	157
4	0.4	0.5	1.8	2.0	178	191	198	217
5	0.4	0.7	2.4	2.8	215	223	240	272
6	0.5	0.9	1.8	1.7	176	167	241	203
7	0.4	0.6	1.4	1.3	141	145	210	176
8	0.4	0.6	2.1	2.1	164	177	250	243
9	2.6	2.4	2.2	2.4	89	105	276	280
10	0.8	0.6	0.5	0.8	83	115	160	173

5.2 Particulate Measurements

5.2.1 TSP and PM_{10} Measurements

Concentrations of TSP measured at sites 1 – 8 and PM_{10}, measured at sites 8 and 8 HI with conditional sampling are presented in Table 11a. The average for sites 1 and 3, considered to represent background levels, is about 22 µg m^{-3} over the period from August 2004 until mid September 2005. The maximum monthly averaged TSP concentrations are 136 µg m^{-3} at Site 7, during January/February 2005 and 135µg m^{-3} at Site 8, during January/February 2005, and the average for sites 4 – 8 is about 34 µg m^{-3}. This shows that TSP concentrations, probably due to anthropogenic activities, are enhanced on the lower Burrup Peninsula, at sites 4 – 8. This is particularly true at Site 8, which had an annual average TSP concentration of 51.1 µg m^{-3}.

Conditional sampling to measure PM_{10} was carried out at Site 8HI, about 0.5 km to 1 km east of the Hamersley Iron loading facilities at Parker Point, and at Site 8 which is located about 3 km east of Parker Point; (Figure 1). Site 8HI was located in order to sample PM_{10} originating from Parker Point, and the sampler operated when the wind direction was between 225º and 315º. At Site 8 the conditional sampler operated when the wind direction was between 180º and 360º, also to collect PM_{10} from Parker Point. Table 8 shows that at 116.6 µg m^{-3} and 19.8 µg m^{-3} at 8HI and Site 8 respectively, there is a large difference in PM_{10} mass concentration between the two sites. Filters from these sites have been analysed for a range of

elements and soluble ionic species to seek a fingerprint for particulate originating from the Parker Point iron ore loading facilities.

The TSP mass concentrations measured at sites 1 -8 and at site 8 conditional (site 8C) and at a site adjacent to the iron ore stockpile (site 8HI) are presented in Table 11b. Site 8HI was located about 500 metres east of the ore stockpile at parker Point. At this site sampling was conditional and the Microvol turned on when the wind direction was between 225^{o} and 315^{o}. This was to sample TSP which was emitted as a result of the ore loading operations at Parker Point. The chemical composition of the TSP samples collected at this site will be used to compare with the chemical composition of TSP at the other sites on the Burrup Peninsula to assess the proportion of TSP emanating from the ore loading operations.

The two background sites 1 and 3 had concentrations of 15.4 µg m^{-3} and 20.0 µg m^{-3} respectively, indicating that the background TSP concentration for the area is about 18 µg m^{-3}. This compares closely with the background level of 22 µg m-3 estimated during 2004/2005. The TSP mass concentrations vary from 25.9 µg m^{-3} at site 6 to 38.7 µg m^{-3} at site 7. The annual average TSP mass concentration at sites 4 – 8 is about 32 µg m^{-3}, and this is significantly higher than that measured at the background sites. Sites 7 and 8 have the highest TSP concentrations similar to the observations during 2004/2005, probably because they are more often downwind of Parker Point. The magnitude of the TSP concentrations is largely a factor of the wind direction, especially for sites 7 and 8. For example, the highest monthly concentrations are observed during January/February 2007 and November 2007/January 2008 at site 8C and these are period when the wind direction has a large west to south westerly component. Conversely the periods with the lowest TSP concentrations at sites 7 and 8 occurred when the wind direction had a significant north-easterly component. As expected site 8HI had the highest TSP concentration, averaging 112 µg m^{-3} compared with 117 µg m^{-3} measured during 2004/2005. Concentrations at this site ranged from 52 µg m^{-3} to 176 µg m^{-3}.

Table 11a. Concentrations of TSP at sites 1 – 8 and PM_{10} conditionally sampled at sites 8 and 8HI from the end of August 2004 until September 2005. Concentrations are in $\mu g\ m^{-3}$.

Date/time on	Date/time Off	TSP $\mu g\ m^{-3}$	Date/time on	Date/time Off	TSP $\mu g\ m^{-3}$	PM_{10} $\mu g\ m^{-3}$
Site 1			Site 3			
29/07/04 11:55	02/09/04 15:34	11.6	29/07/04 16:00	02/09/04 13:10	11.0	
02/09/04 15:34	08/10/04 09:50	14.0	02/09/04 13:10	08/10/04 11:30	19.2	
08/10/04 09:45	21/11/04 11:25	24.3	08/10/04 11:20	21/11/04 15:35	11.6	
21/11/04 11:55	17/12/04 12:00	32.4	21/11/04 15:35	17/12/04 14:00	31.5	
17/12/04 12:39	19/01/05 12:40	35.0	17/12/04 14:20	19/01/05 16:12	43.7	
19/01/05 13:10	21/02/05 13:05	36.6	19/01/05 16:45	21/02/05 09:44	41.7	
21/02/05 13:06	28/03/05 10:27	25.1	21/02/05 09:48	28/03/05 12:13	25.0	
28/03/05 11:09	18/04/05 09:09	13.6	28/03/05 12:25	18/04/05 14:31	15.7	
18/04/05 09:44	31/05/05 10:36	25.0	18/04/05 14:32	31/05/05 12:38	9.7	
31/05/05 10:58	13/07/05 11:30	33.6	31/05/05 13:14	not used		
13/07/05 11:41	07/08/05 11:32	8.8	13/07/05 15:33	07/08/05 14:41	8.62	
07/08/05 11:32	14/09/05 08:05	11.4	not working			
Mean		***22.6***	***Mean***		***21.8***	
Site 4			Site 5			
01/08/04 12:00	01/09/04 08:49	15.3	01/08/04 16:00	01/09/04 11:38	17.1	
01/09/04 08:49	07/10/04 08:51	12.1	01/09/04 12:00	07/10/04 11:20	12.4	
07/10/04 09:04	20/11/04 08:30	42.6	07/10/04 11:00	20/11/04 12:15	32.0	
20/11/04 09:20	18/12/04 06:20	60.3	20/11/04 12:40	18/12/04 07:30	33.4	
18/12/04 06:30	18/01/05 09:40	60.6	18/12/04 07:40	18/01/05 12:36	48.6	
18/01/05 09:50	16/02/05 06:25	55.2	18/01/05 12:37	16/02/05 07:57	36.4	
16/02/05 06:45	23/03/05 09:23	47.6	16/02/05 08:20	23/03/05 11:29	30.7	
23/03/05 10:16	28/04/05 08:30	28.5	23/03/05 11:29	28/04/05 09:57	17.8	
28/04/05 08:30	30/05/05 10:11	22.6	28/04/05 10:10	30/05/05 11:17	15.5	
30/05/05 10:31	30/06/05 08:30	17.6	30/05/05 11:40	30/06/05 09:08	16.2	
30/06/05 08:40	08/08/05 08:25	15.6	30/06/05 09:15	08/08/05 09:11	12.6	
08/08/05 08:40	13/09/05 08:40	33.2	08/08/05 09:15	13/09/05 10:31	17.0	
Mean		***34.3***	***Mean***		***24.1***	
Site 6			Site 7			
03/08/04 13:02	01/09/04 10:35	16.4	01/08/04 14:57	01/09/04 13:25	19.2	
01/09/04 10:35	07/10/04 10:46	21.3	01/09/04 13:34	07/10/04 13:00	21.8	
07/10/04 10:06	20/11/04 10:30	18.7	07/10/04 13:00	20/11/04 14:30	46.6	
20/11/04 11:20	18/12/04 08:30	38.4	20/11/04 14:30	18/12/04 09:30	58.4	
18/12/04 08:45	18/01/05 11:15	47.1	18/12/04 09:50	18/01/05 15:00	42.4	
18/01/05 11:30	16/02/05 07:15	50.0	18/01/05 15:14	16/02/05 09:00	136.0	
16/02/05 07:25	23/03/05 10:32	31.6	16/02/05 09:15	23/03/05 12:42	34.7	
23/03/05 11:32	28/04/05 09:11	18.1	23/03/05 12:50	28/04/05 10:52	21.3	
28/04/05 09:20	30/05/05 12:34	13.3	28/04/05 10:57	30/05/05 13:49	15.0	
30/05/05 12:51	30/06/05 10:03	14.1	30/05/05 13:59	30/06/05 11:15	15.1	
30/06/05 10:10	08/08/05 10:03	11.5	30/06/05 11:20	08/08/05 11:08	11.4	
08/08/05 10:10	13/09/05 14:26	15.9	08/08/05 11:15	13/09/05 11:38	16.8	
Mean		***24.7***	***Mean***		***36.6***	

Table 11a cont

Date/time on	Date/time Off	TSP µg m^{-3}	Date/time on	Date/time Off	TSP µg m^{-3}	PM_{10} µg m^{-3}
Site 8			Site 8 Conditional			
03/08/04 09:19	01/09/04 15:55	22.9	04/08/04 15:20	01/09/04 15:59		10.3
01/09/04 16:00	07/10/04 14:35	28.2	01/09/04 16:05	07/10/04 15:25		13.2
07/10/04 15:00	20/11/04 15:30	52.7	07/10/04 15:15	20/11/04 16:10		21.4
20/11/04 15:30	18/12/04 11:10	53.4	20/11/04 16:10	18/12/04 11:30		31.0
18/12/04 11:30	18/01/05 16:15	61.7	18/12/04 11:20	18/01/05 16:24		42.9
18/01/05 17:31	16/02/05 10:11	94.6	18/01/05 17:37	16/02/05 10:15		32.0
16/02/05 10:25	23/03/05 13:53	29.3	16/02/05 10:28	23/03/05 14:05		24.1
23/03/05 13:58	28/04/05 11:52	135.2	23/03/05 14:05	28/04/05 11:50		13.0
28/04/05 11:54	30/05/05 15:55	65.9	28/04/05 12:10	30/05/05 15:30		16.1
30/05/05 15:57	30/06/05 12:00	23.3	30/05/05 15:45	30/06/05 12:05		10.6
30/06/05 12:01	08/08/05 12:25	16.1	30/06/05 12:20	08/08/05 12:09		8.8
08/08/05 12:30	13/09/05 15:39	30.5	08/08/05 12:20	13/09/05 15:39		13.6
Mean		***51.1***	***Mean***			***19.8***
Site 8 HI	Conditional					
04/08/04 11:15	02/09/04 09:00	86.4				
02/09/04 09:00	08/10/04 15:05	64.8				
08/10/04 15:05	30/11/04 08:40	96.6				
30/11/04 13:00	20/12/04 08:30	79.0				
20/12/04 08:40	20/01/05 08:32	53.0				
20/01/05 08:46	23/02/05 08:30	560.9				
23/02/05 08:40	31/03/05 07:26	49.3				
31/03/05 07:30	02/05/05 08:49	81.1				
02/05/05 09:00	09/06/05 08:36	81.4				
09/06/05 10:17	01/07/05 08:50	49.7				
01/07/05 09:00	09/08/05 08:38	82.0				
09/08/05 08:45	16/09/05 00:00	115.2				
Mean		***116.6***				

Table 11b. Concentrations of TSP at sites 1 – 8 and PM_{10} conditionally sampled at sites 8 and 8HI from February 2007 until August 2008. Concentrations are in $\mu g\ m^{-3}$.

Date/time on	Date/time Off	TSP $\mu g\ m^{-3}$	Date/time on	Date/time Off	TSP $\mu g\ m^{-3}$
Site 1			Site 3		
04/05/07 12:45	14/06/07 09:29	12.1	29/01/07 11:07	22/02/07 10:41	45.4
14/06/07 09:31	02/08/07 10:30	11.6	22/02/07 11:00	20/03/07 09:55	27.7
02/08/07 10:40	09/09/07 10:02	14.6	20/03/07 10:00	04/05/07 12:50	14.8
09/09/07 10:11	25/10/07 15:54	21.6	04/05/07 12:50	14/06/07 08:12	12.6
25/10/07 16:10	09/11/07 09:11	26.2	14/06/07 08:16	02/08/07 13:07	12.1
09/11/07 09:15	09/01/08 09:00	26.9	02/08/07 13:15	09/09/07 12:30	17.1
09/01/08 09:20	08/02/08 13:55	4.4	09/09/07 12:35	25/10/07 13:54	24.1
08/02/08 12:30	12/03/08 13:10	14.0	25/10/07 14:10	09/11/07 10:50	7.3
12/03/08 12:20	27/04/08 10:49	14.6	09/11/07 10:44	09/01/08 10:37	11.0
27/04/08 11:25	04/06/08 10:20	11.8	09/01/08 10:40	08/02/08 13:55	41.7
04/06/08 10:30	17/07/08 09:41	12.2	08/02/08 14:04	12/03/08 11:20	29.8
17/07/08 09:41	14/08/08 11:02	14.7	12/03/08 11:35	27/04/08 10:52	16.6
			27/04/08 10:52	04/06/08 12:20	19.4
			04/06/08 12:00	17/07/08 11:17	10.8
			17/07/08 11:17	14/08/08 09:00	9.7
Mean		***15.4***	***Mean***		***20.0***
Site 4			Site 5		
03/05/07 10:07	07/06/07 08:49	20.0	03/05/07 10:53	07/06/07 10:09	17.5
07/06/07 09:00	04/08/07 08:08	17.8	07/06/07 09:48	04/08/07 09:43	15.0
04/08/07 08:20	12/09/07 08:55	28.1	04/08/07 09:55	12/09/07 09:48	24.0
12/09/07 09:22	16/10/07 13:58	40.5	12/09/07 09:55	16/10/07 15:20	33.6
16/10/07 14:11	08/11/07 09:37	33.9	16/10/07 15:22	08/11/07 10:32	37.3
08/11/07 09:44	08/01/08 09:25	49.3	08/11/07 10:38	08/01/08 10:42	41.1
08/01/08 09:43	07/02/08 10:54	44.8	08/01/08 10:42	07/02/08 13:38	53.3
07/02/08 11:08	11/03/08 08:48	30.8	07/02/08 13:50	11/03/08 10:05	28.7
11/03/08 09:10	21/04/08 07:39	13.8	11/03/08 10:13	21/04/08 08:03	26.4
21/04/08 08:10	03/06/08 11:12		21/04/08 08:15	03/06/08 12:50	26.6
03/06/08 11:12	14/07/08 11:04	16.6	03/06/08 12:55	14/07/08 10:26	17.2
14/07/08 11:04	13/08/08 08:45	23.7	14/07/08 10:26	13/08/08 09:50	26.3
Mean		***29.0***	***Mean***		***28.9***
Site 6			Site 7		
03/05/07 11:08	07/06/07 10:09	18.7	03/05/07 11:38	07/06/07 10:53	16.7
07/06/07 10:25	04/08/07 09:00	15.6	07/06/07 11:04	03/08/07 10:40	10.3
04/08/07 09:14	12/09/07 10:18	24.0	03/08/07 11:06	12/09/07 10:49	24.7
12/09/07 10:20	16/10/07 14:40	32.6	02/09/07 10:52	16/10/07 15:52	44.4
16/10/07 14:51	08/11/07 10:07	39.5	16/10/07 16:11	08/11/07 10:57	46.2
08/11/07 10:07	08/01/08 10:08	37.8	08/11/07 10:57	08/01/08 12:00	49.1
08/01/08 10:56	07/02/08 12:00	36.0	08/01/08 12:20	07/02/08 14:21	36.7
07/02/08 12:10	11/03/08 09:35	28.7	07/02/08 14:26	11/03/08 10:55	35.2
11/03/08 09:40	21/04/08 09:23	21.7	11/03/08 11:10	21/04/08 10:00	29.4
21/04/08 09:35	03/06/08 12:06	12.3	21/04/08 10:10	03/06/08 14:10	51.6
03/06/08 12:30	14/07/08 11:47	19.5	03/06/08 14:21	14/07/08 12:45	107.5
14/07/08 12:00	13/08/08 10:49	24.4	14/07/08 13:00	13/08/08 11:35	12.3
Mean		***25.9***	***Mean***		***38.7***

Table 11b cont

Date/time on	Date/time Off	TSP µg m^{-3}	Date/time On	Date/time Off	TSP µg m^{-3}
Site 8			Site 8 Conditional		
24/01/07 15:04	22/02/07 08:16	88.1	24/01/07 15:04	22/02/07 08:36	109.7
22/02/07 08:30	20/03/07 12:05	43.2	22/02/07 08:30	20/03/07 12:07	57.4
20/03/07 12:20	03/05/07 13:21	22.0	20/03/07 12:20	03/05/07 14:00	30.8
03/05/07 13:39	07/06/07 12:00	17.0	03/05/07 14:00	07/06/07 12:11	33.1
07/06/07 12:07	03/08/07 09:20	16.3	07/06/07 12:13	03/08/07 09:21	34.4
03/08/07 10:10	12/09/07 11:52	21.2	03/08/07 10:10	12/09/07 11:52	51.9
12/09/07 12:13	16/10/07 09:56	66.0	12/09/07 12:16	16/10/07 10:10	65.1
16/10/07 10:57	08/11/07 11:38	55.6	16/10/07 10:56	08/11/07 11:52	75.5
08/11/07 12:05	08/01/08 14:13	82.6	08/11/07 12:05	08/01/08 14:20	132.0
08/01/08 14:40	07/02/08 15:17	49.8	08/01/08 14:40	07/02/08 15:21	79.3
07/02/08 15:35	11/03/08 11:45	34.4	07/02/08 15:36	11/03/08 12:00	43.5
11/03/08 11:55	21/04/08 10:54	22.6	11/03/08 12:10	21/04/08 11:00	31.9
21/04/08 11:15	03/06/08 14:54	25.1	21/04/08 11:15	03/06/08 14:55	31.5
03/06/08 16:00	14/07/08 14:05	6.5	03/06/08 15:20	14/07/08 14:10	20.4
14/07/08 14:05	13/08/08 12:58	20.8	14/07/08 14:10	13/08/08 13:23	26.6
Mean		***38.1***	***Mean***		***54.9***
Site 8 HI	Conditional				
21/05/07 09:37	25/06/07 09:36	90.4			
25/06/07 09:39	04/08/07 10:27	82.1			
04/08/07 10:50	12/09/07 12:43	99.9			
12/09/07 12:55	08/11/07 12:35	172.1			
08/11/07 12:35	08/01/08 14:20	112.4			
08/01/08 15:30	07/02/08 16:10	176.2			
07/02/08 16:12	11/03/08 13:00	104.8			
11/03/08 13:05	21/04/08 12:00	102.0			
21/04/08 12:00	04/06/08 10:24	171.2			
04/06/08 10:25	14/07/08 14:30	51.8			
14/07/08 14:30	13/08/08 14:08	67.4			
Mean		***111.9***			

After gravimetric mass was determined on each particulate sample a sub-set was chosen for PIXE analysis. These were sent to ANSTO where they were analysed as described previously in a non-destructive manner. After PIXE analysis was complete they were extracted and analysed by ion chromatography to determine the concentrations of the soluble cations and anions.

The detailed results of the PIXE analysis are given in the Appendix in Table A1. Table 12 presents the results of the gravimetric mass concentrations, the estimated chemical mass (ECM) concentration, the iron concentration, the sea-salt fraction of the total mass and the iron to sea-salt ratio. The ECM was reconstructed by adding the elements, as their ores, measured by PIXE plus SO_4^{2-}, NO_3^-, NH_4^+ Mg^{2+}, HOOC-COOH, HCOOH and CH_3COOH, as suggested by Brook et al. (1997).

$$ECM = SO_4^{2-} + NO_3^- + NH_4^+ + 1.79V + 1.24Zn + Pb + Br + Cl + Na + soil + remainder \quad (11)$$

Where:

$$Soil = 3.48Si + 1.63Ca + 1.58Fe + 1.94Ti + 1.41K \quad (12)$$

$$Remainder = HOOC\text{-}COOH + HCOOH + CH_3COOH + Mg^{2+} \quad (13)$$

Values of ECM are given in Table 12, and are compared with gravimetric mass in Figure 14. Figure 14 shows a straight line fitted to the gravimetric data and the ECM values with a reduced major axis regression. The slope of the line is 0.73, indicating that most of the gravimetric mass is accounted for by the ECM; the remainder is probably due contributions of combustion derived organic and elemental carbon, which were not measured in this study and residual water associated with the gravimetric mass measurement.

Site 8HI was located close to the ore loading facilities at Parker Point and the Microvol sampler was programmed to begin sampling only when the wind direction was from the ore loading area. In this case iron is used as an indicator of soil dust which originates from ore the loading processes or transport of the ore to the loading facilities. The data show that the iron content of the particulate material at Site 8Hi varies from 17 % to 56 %, with an average of 31.5 %. The fraction of sea-salt at each site was estimated from composition of seawater provided by Millero (1974), using Mg^{2+} as an indicator of sea-salt. The results given in Table 12 show that Site 8Hi had an average sea-salt fraction of 9.5 %, the lowest fraction of sea-salt at any of the sites. The particulate samples at this site were composed largely of particulate associated from the ore loading operations.

Table 12 also shows the concentration of iron varies substantially from Site 1, the background site, to Site 8. For example, on average iron contributed 3.5 % and sea-salt 37.6 % of the TSP particulate loading at Site 1. This compares with contributions of 23.4 % and 19.6 % for iron and sea-salt respectively at Site 8. The TSP samples at Sites 5 and 7 had average iron contents of 11.7 % – 11.1 % and sea-salt loadings of about 26 %, which are intermediate between Site 1 and Site 8. This suggests that the increase in TSP observed between Site 1 and Site 8 may be due to dust which originates from the ore loading and transport processes. This point is emphasized by the increasing iron to sea-salt ratios proceeding from Site 1 to Site 8 given in Table 12.

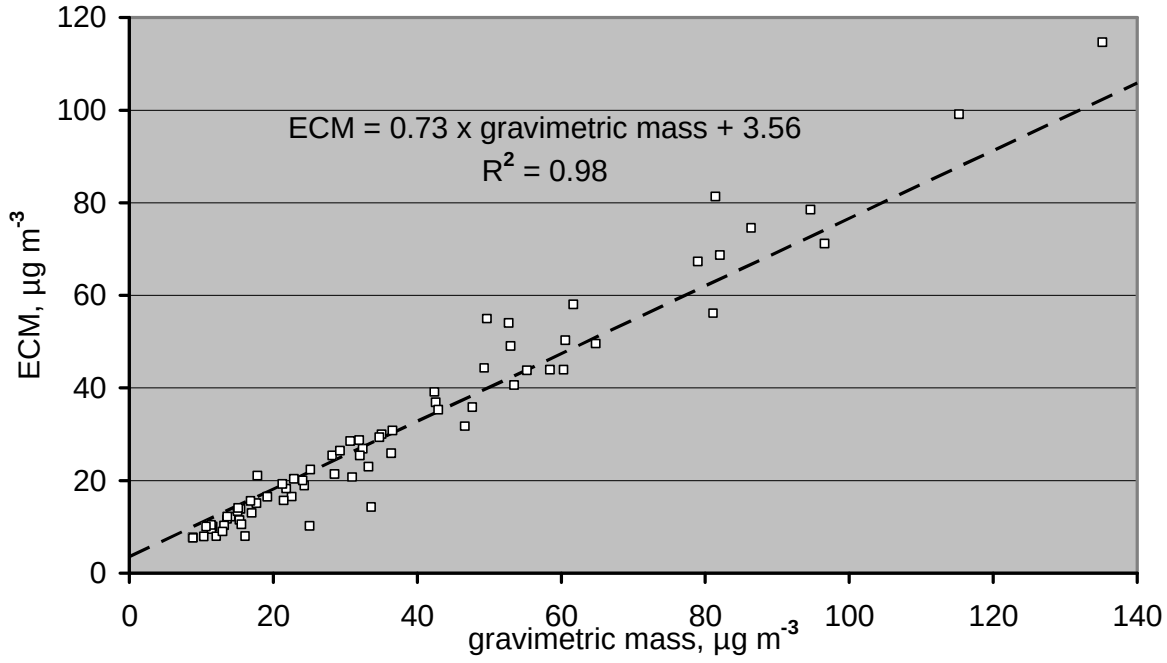


Figure 14. ECM as a function of gravimetric mass for all sites.

Table 12. Concentrations of gravimetric mass (Grav mass), (estimated chemical mass) ECM and iron, fraction of ECM to gravimetric mass (%) and the fraction of iron and sea-salt in TSP and PM_{10} samples collected at various sites.

Site	Date on	Date off	Grav Mass µg m^{-3}	ECM µg m^{-3}	% Total mass	Fe µg m^{-3}	% Fe	% Sea salt	Fe : Sea-salt
1	29/07/04	02/09/04	11.6	10.1	87.2	0.649	6.6	36.1	0.18
1	02/09/04	08/10/04	14.0	12.2	86.9	0.519	4.4	47.2	0.09
1	08/10/04	21/11/04	24.3	18.9	77.8	0.736	3.6	42.9	0.08
1	21/11/04	17/12/04	32.4	26.9	82.9	0.545	2.0	43.3	0.05
1	17/12/04	19/01/05	35.0	30.0	85.6	0.635	2.2	48.1	0.04
1	19/01/05	21/02/05	36.6	30.8	84.2	0.380	1.2	54.4	0.02
1	21/02/05	28/03/05	25.1	22.4	89.1	0.853	4.0	33.6	0.12
1	28/03/05	18/04/05	13.6	11.7	86.2	0.452	4.0	34.9	0.11
1	18/04/05	31/05/05	25.0	10.2	40.7	0.397	1.9	16.5	0.11
1	31/05/05	13/07/05	33.6	14.3	42.6	0.493	1.7	14.3	0.12
1	13/07/05	07/08/05	8.8	7.7	87.4	0.422	5.7	34.2	0.17
1	07/08/05	14/09/05	11.4	9.5	83.2	0.406	4.2	45.2	0.09
			22.6	***17.1***	***77.8***	***0.542***	***3.5***	***37.6***	***0.10***
4	01/08/04	01/09/04	15.3	11.5	75.1	0.945	6.2	25.3	0.24
4	01/09/04	07/10/04	12.1	8.0	66.0	0.826	6.8	24.3	0.28
4	07/10/04	20/11/04	42.6	36.9	86.7	4.319	10.2	16.3	0.62
4	20/11/04	18/12/04	60.3	43.9	72.8	2.366	3.9	19.7	0.20
4	18/12/04	18/01/05	60.6	50.3	83.0	2.766	4.6	24.3	0.19
4	18/01/05	16/02/05	55.2	43.8	79.4	2.234	4.0	30.6	0.13
4	16/02/05	23/03/05	47.6	35.9	75.2	2.920	6.1	24.2	0.25
4	23/03/05	28/04/05	28.5	21.4	75.1	1.867	6.6	19.1	0.34
4	28/04/05	30/05/05	22.6	16.5	73.3	1.264	5.6	14.8	0.38
4	30/05/05	30/06/05	17.6	15.1	85.4	0.896	5.1	34.7	0.15
4	30/06/05	08/08/05	15.6	10.6	67.8	0.975	6.3	15.6	0.40
4	08/08/05	13/09/05	33.2	23.0	69.2	1.743	5.2	15.1	0.35
			34.3	***26.4***	***75.8***	***1.927***	***5.9***	***22.0***	***0.29***
5	07/10/04	20/11/04	32.0	25.4	79.5	4.080	12.7	27.9	0.46
5	18/01/05	16/02/05	36.4	25.9	71.2	1.707	4.7	38.1	0.12
5	16/02/05	23/03/05	30.7	28.5	92.9	2.967	9.7	25.1	0.39
5	23/03/05	28/04/05	17.8	21.0	118.3	2.559	14.4	20.6	0.70
5	28/04/05	30/05/05	15.5	13.9	89.7	1.968	12.7	18.5	0.69
5	08/08/05	13/09/05	17.0	13.0	76.6	2.710	15.9	26.8	0.59
			24.9	***21.3***	***88.0***	***2.665***	***11.7***	***26.2***	***0.49***
7	01/08/04	01/09/04	19.2	16.5	86.1	2.696	14.1	20.7	0.68
7	01/09/04	07/10/04	21.8	18.3	83.9	3.094	14.2	24.5	0.58
7	07/10/04	20/11/04	46.6	31.8	68.1	5.118	11.0	20.5	0.53
7	20/11/04	18/12/04	58.4	43.9	75.2	5.864	10.0	19.8	0.51
7	18/12/04	18/01/05	42.4	39.2	92.4	4.047	9.6	29.8	0.32
7	18/01/05	16/02/05	136.0	120.9	88.9	12.602	9.3	33.3	0.28
7	16/02/05	23/03/05	34.7	29.3	84.6	3.164	9.12	23.9	0.38
7	23/03/05	28/04/05	21.3	19.3	90.7	2.788	13.1	19.3	0.68
7	28/04/05	30/05/05	15.0	13.3	88.8	1.809	12.0	23.5	0.51
7	30/05/05	30/06/05	15.1	14.1	93.1	1.155	7.6	41.1	0.19
7	30/06/05	08/08/05	11.4	10.4	91.9	0.976	8.6	26.3	0.33
7	08/08/05	13/09/05	16.8	15.6	92.7	2.495	14.8	29.1	0.51
			36.6	***31.1***	***86.4***	***3.817***	***11.1***	***26.0***	***0.46***

Table 12 cont

Site	Date on	Date off	Grav Mass µg m^{-3}	ECM µg m^{-3}	% Total mass	Fe µg m^{-3}	% Fe	% Sea salt	Fe : Sea-salt
8	03/08/04	01/09/04	22.9	20.4	89.3	6.107	26.7	15.2	1.76
8	01/09/04	07/10/04	28.2	25.4	90.2	7.565	26.9	19.6	1.37
8	07/10/04	20/11/04	52.7	54.1	102.6	19.292	36.6	16.6	2.21
8	20/11/04	18/12/04	53.4	40.6	76.0	7.920	14.8	20.7	0.72
8	18/12/04	18/01/05	61.7	58.1	94.2	13.210	21.4	25.0	0.86
8	18/01/05	16/02/05	94.6	78.5	83.0	19.678	20.8	20.3	1.02
8	16/02/05	23/03/05	29.3	26.4	90.3	5.275	18.0	21.7	0.83
8	23/03/05	28/04/05	135.2	114.7	84.8	29.294	21.7	17.6	1.23
			59.7	***52.3***	***88.8***	***13.543***	***23.4***	***19.6***	***1.25***
8 Cond	04/08/04	01/09/04	10.3	7.9	76.3	0.726	7.0	15.6	0.45
8 Cond	01/09/04	07/10/04	13.2	10.3	78.1	1.186	9.0	20.1	0.45
8 Cond	07/10/04	20/11/04	21.4	15.7	73.1	2.883	13.4	10.4	1.29
8 Cond	20/11/04	18/12/04	31.0	20.8	67.0	1.638	5.3	13.1	0.40
8 Cond	18/12/04	18/01/05	42.9	35.3	82.3	4.166	9.7	16.5	0.59
8 Cond	18/01/05	16/02/05	32.0	28.8	90.0	1.586	5.0	21.4	0.23
8 Cond	16/02/05	23/03/05	24.1	20.0	83.2	1.614	6.7	18.9	0.35
8 Cond	23/03/05	28/04/05	13.0	9.0	69.5	1.398	10.8	9.7	1.11
8 Cond	28/04/05	30/05/05	16.1	8.0	49.7	0.690	4.3	13.3	0.32
8 Cond	30/05/05	30/06/05	10.6	10.1	94.5	0.569	5.3	33.6	0.16
8 Cond	30/06/05	08/08/05	8.8	7.6	85.9	0.836	9.5	17.3	0.55
8 Cond	08/08/05	13/09/05	13.6	12.2	89.7	1.978	14.5	17.7	0.82
			19.8	***15.5***	***78.3***	***1.606***	***8.4***	***17.3***	***0.6***
8Hi	04/08/04	02/09/04	86.4	74.6	86.3	29.857	34.6	5.0	6.95
8Hi	02/09/04	08/10/04	64.8	49.6	76.5	16.905	26.1	10.0	2.61
8Hi	08/10/04	30/11/04	96.6	71.2	73.7	24.653	25.5	10.6	2.40
8Hi	30/11/04	20/12/04	79.0	67.3	85.3	19.797	25.1	14.4	1.74
8Hi	20/12/04	20/01/05	53.0	49.0	92.6	12.067	22.8	24.0	0.95
8Hi	20/01/05	23/02/05	560.9	395.4	70.5	94.333	16.8	16.7	1.01
8Hi	23/02/05	31/03/05	49.3	44.3	89.9	12.535	25.4	13.4	1.90
8Hi	31/03/05	02/05/05	81.1	56.2	69.3	17.493	21.6	6.9	3.12
8Hi	02/05/05	09/06/05	81.4	81.3	99.9	34.902	42.9	3.2	13.46
8Hi	09/06/05	01/07/05	49.7	55.0	110.7	27.673	55.7	2.1	26.47
8Hi	01/07/05	09/08/05	82.0	68.7	83.7	34.789	42.4	1.3	32.80
8Hi	09/08/05	16/09/05	115.2	99.1	86.0	45.562	39.5	6.5	6.09
			116.6	***92.6***	***85.4***	***30.880***	***31.5***	***9.5***	***8.3***

5.2.2 DustTrak Measurements

Figures 15, 16, 17 and 18 show PM_{10} concentrations measured using the DustTrak instrument at site 8 during 2004/2005 for four periods throughout the study plotted as a function of wind direction. Figures 15 and 17 were plotted using wind directions measured at Site 8 collected at a frequency of 2 minutes, while Figures 16 and 18 employed 30 minute averaged wind direction data from Karratha Airport. The Figures show that background PM_{10} concentration at site 8 appears to be about 10 µg m^{-3}, based on the concentration envelope observed in wind directions about 150º and about 15º. Site 8 is only about 2 – 3 km east of the iron ore loading facilities at Parker Point and it is evident from the Figures, that the activities at Parker Point have a large influence on PM_{10} concentrations at Site 8. The plot shows a large increase in PM_{10} over background concentrations in wind directions ranging from about 220º to 280º and this is directly downwind of Parker Point. The other influence on PM_{10} concentrations at site 8 is vehicle traffic travelling along

Burrup Road. This can be seen as increased PM_{10} concentrations, particularly in wind directions from about 43º to 105º.

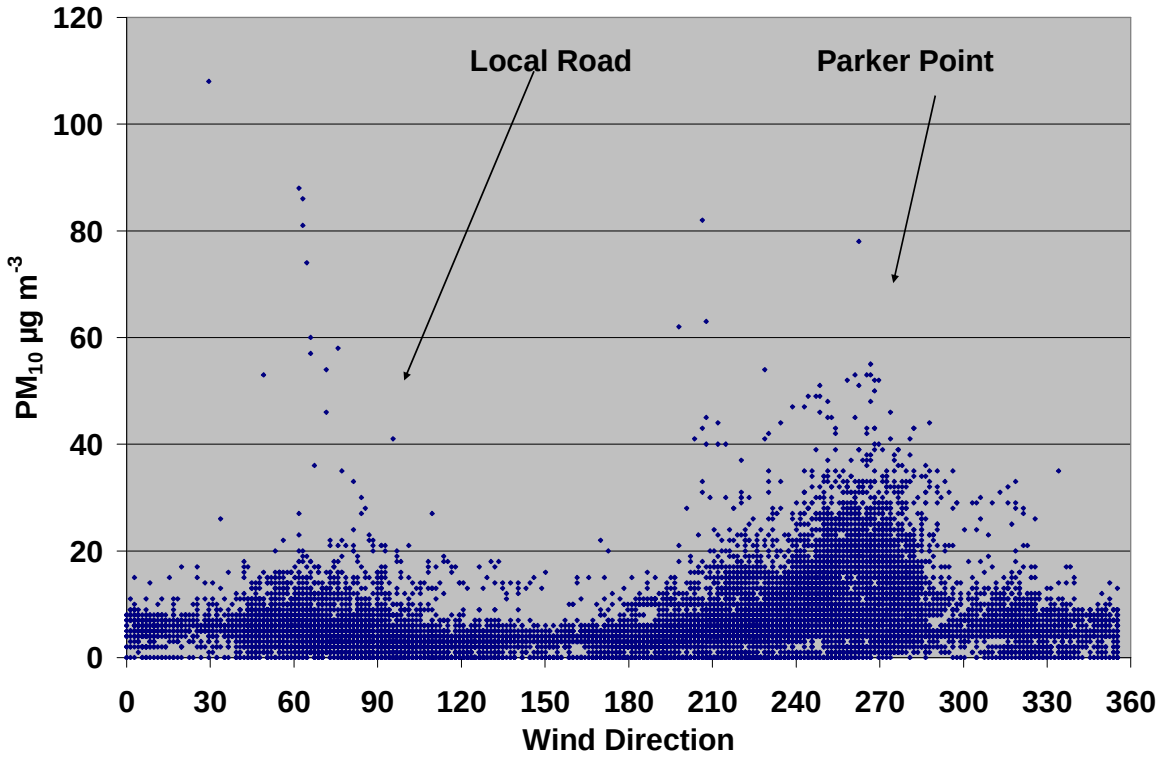


Figure 15. PM_{10} concentrations measured by DustTrak at site 8 from4th August 2004 until 1st September 2004, and plotted against wind direction measured at Site 8 at a frequency of two minutes. The average PM_{10} concentration was 6.6 µg m^{-3} during that period.

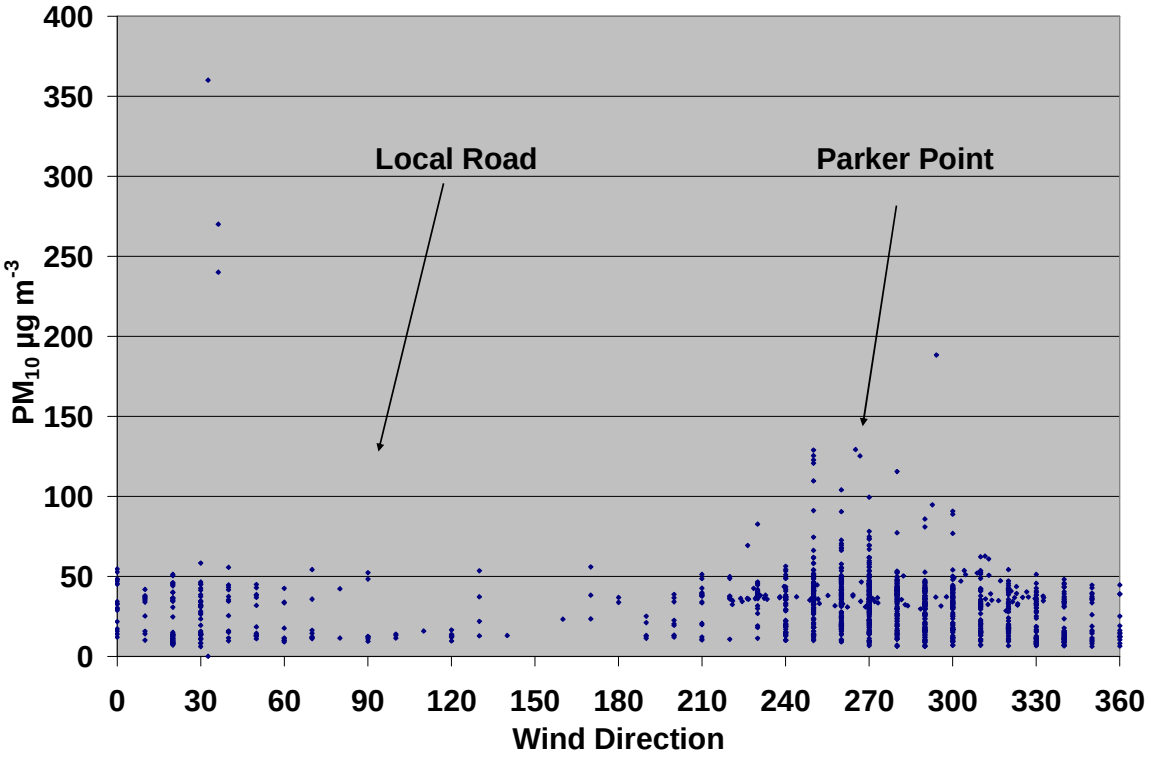


Figure 16. PM_{10} concentration measured at Site 8 measured with DustTrak from 18th January 2005 until 16th February 2005, and plotted against wind direction measured at Karratha Airport at a frequency of thirty minutes. The average PM_{10} concentration was 31.6 µg m^{-3} during that period.

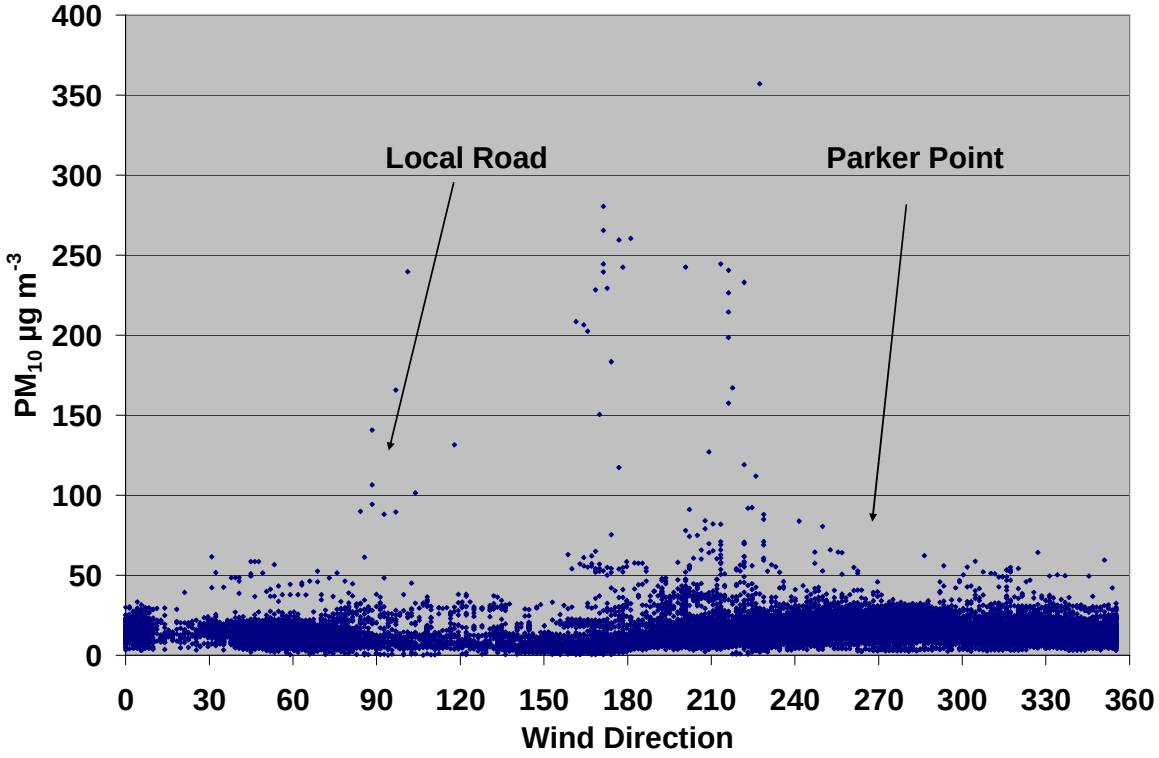


Figure 17. PM_{10} concentration measured at Site 8 measured with DustTrak from 23rd February 2005 until 23rd March 2005, and plotted against wind direction measured at Site 8 at a frequency of two minutes. The average PM_{10} concentration was15.3 µg m^{-3} during that period.

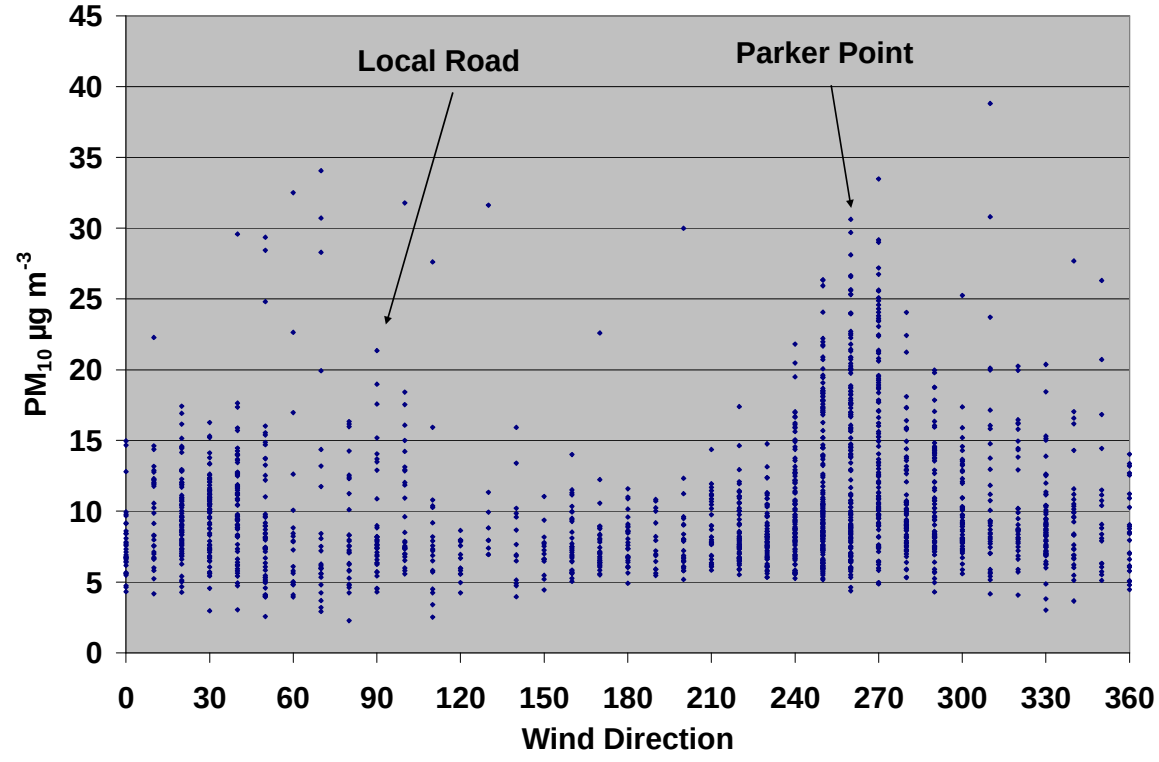


Figure 18. PM_{10} concentration measured at Site 8 measured with DustTrak from 23rd March 2005 until 28th April 2005, and plotted against wind direction measured at Karratha Airport at a frequency of thirty minutes. The average PM_{10} concentration was10.4 µg m^{-3} during that period.

Figures 19 and 20 are plots of PM_{10} concentrations measured at site 8 during 2007/2008. They are included here to represent two periods of high and low TSP concentrations. The data in Figure 19 is compiled from TSP and wind direction data collected at site 8 from October 16th 2007 to November 8th 2007. The average PM_{10}concentration during this period was 27.2 µg m^{-3}. The Figure shows that the concentrations were highest when the wind direction was from about 210° to 300°, and this is downwind of Parker Point, indicating that the ore loading operations have a major impact on the TSP and PM_{10} concentrations at site 8. The other wind direction with increased PM_{10} concentrations is from 60° to 90°, and this is most likely the results from TSP and PM_{10} emissions from motor vehicles travelling along Burrup Road which is adjacent to site 8. Figure 20 shows the PM_{10} concentrations plotted against wind directions from June/July 2008. The PM_{10} concentrations during this period averaged only about 4 µg m^{-3}, much lower than the October/November 2007 period. During this period there was a significant fraction of the time when the wind direction was from east to north east and the site was upwind of Parker Point.

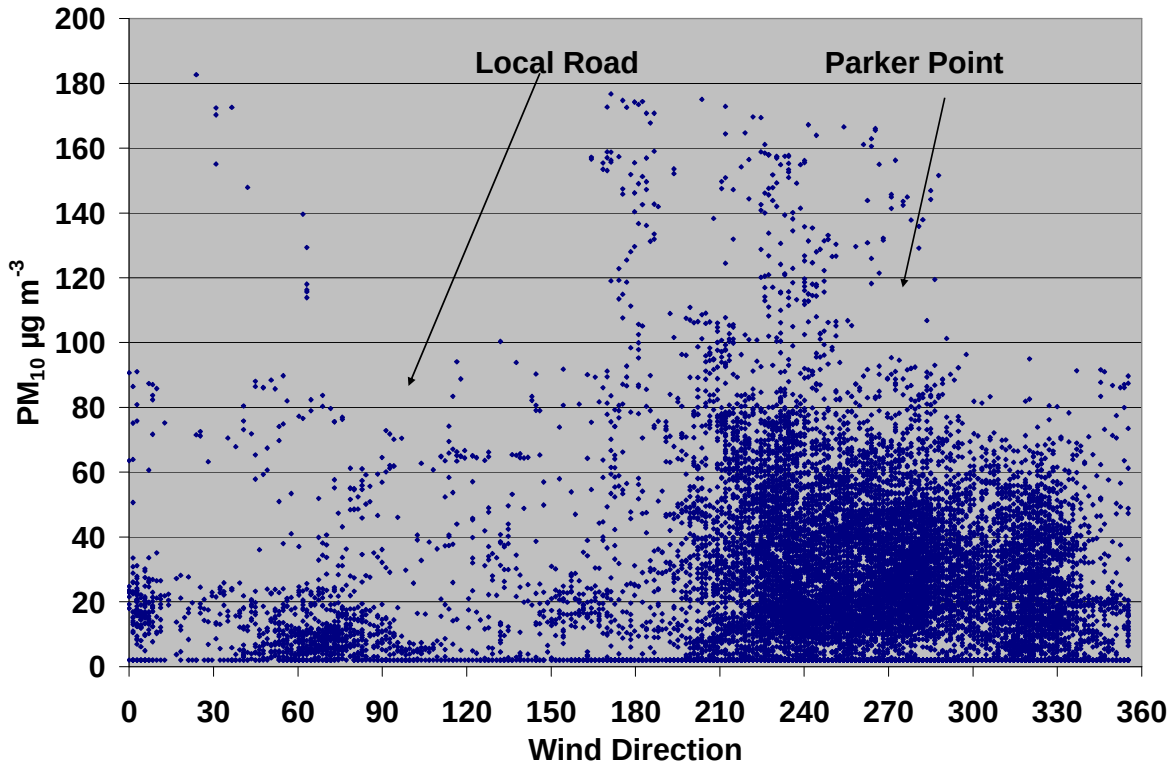


Figure 19. PM_{10} concentrations plotted against wind direction at Site 8 from October 16th 2007 to November 8th 2007. The average PM_{10} concentration for this period was 27.2 µg m^{-3}.

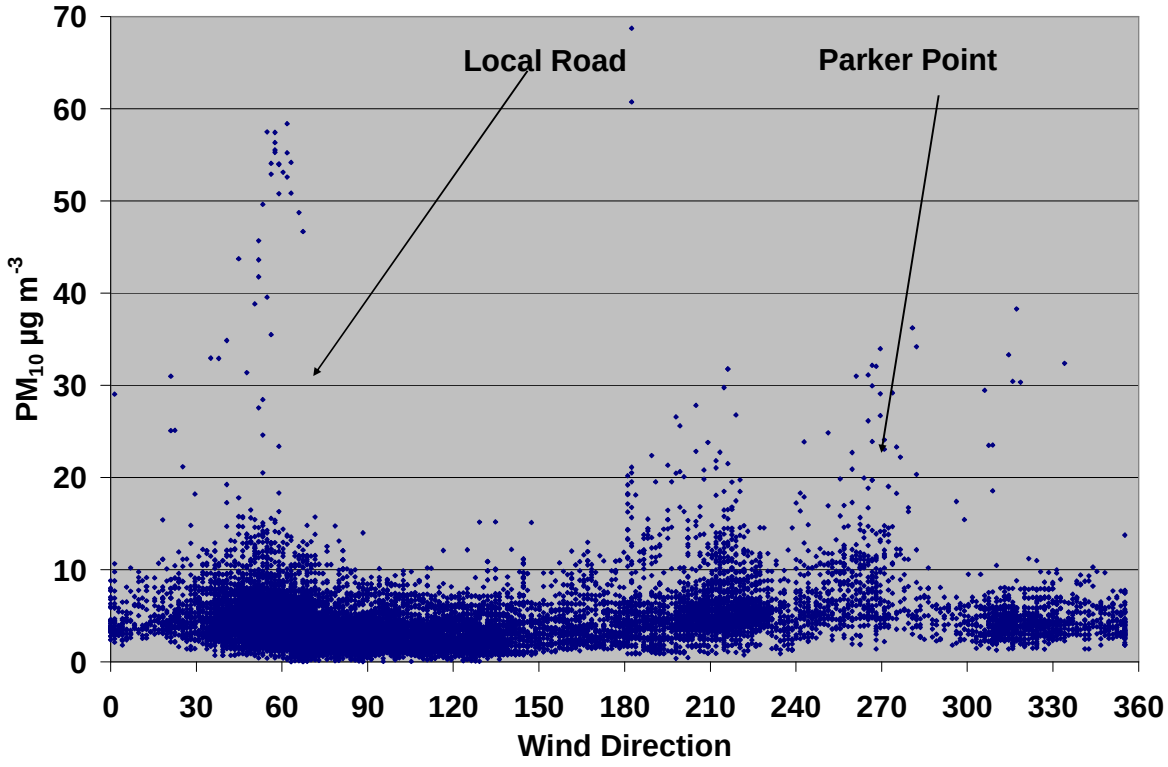


Figure 20. PM_{10} concentrations plotted against wind direction at Site 8 from June 16th 2008 to July 14th 2008. The average PM_{10} concentration for this period was 4.4 µg m^{-3}.

5.3 Dust Deposition

5.3.1 Dust Deposition using passive dry Frisbee-type dust deposit gauges

In the Six Monthly Report an initial evaluation of dust deposition flux measurements was included. Since that report 3-monthly samples were collected at Sites 1, 4, 5, 6, 7 and 8 for periods 3 and 4. The results of these samples have been inconsistent at all sites during those periods. It was found that the dust mass on the foam pads was often less than that found on the blank foam pads, which were sent to the Burrup Peninsula, and treated in the same manner, except they were not exposed. Moreover, repeated weighing of the foam pads showed an unacceptably large range of dust mass on individual foam pads. Despite repeated weighing these inconsistencies could not be overcome. For these reasons the results of all the dust depositions cannot be reported in this final report. The only available estimates dust deposition fluxes are those from an aerosol spectrometer discussed in the next section.

5.3.2 Dust Deposition using GRIMM Aerosol Spectrometer.

During a visit to the sites in September 2005 a GRIMM aerosol spectrometer was used to measure the number size distribution of particles at each site. The GRIMM instrument is battery powered and weighs only 2.5 kg, so it presented an opportunity to measure particle size distribution. Although measurements were taken for only for a short period at each site, it nevertheless provides valuable size distribution data which can be converted to particle concentration, and then to dust deposition.

Size distributions were measured over a size range from 0.3 µm – 20 µm in 15 steps at each site over periods of 1 minute. The data were stored on a removable data logger card and then transferred to a notebook computer. The size distributions showed that no particles measured were greater than 10 µm diameter, but this could be due to losses in the inlet or to counting statistics (the sample flow rate is relatively low; about 2

l min^{-1}) . The distributions were then converted to mass concentrations by assuming the particles were spherical and had a density of 2.1 kg l^{-1}. The density was chosen to represent a soil having an iron ore content of about 23 %. This gives a short record of particle concentrations at the sites. The particle distributions were then converted to deposition in mg m^{-2} day^{-1} using particle deposition velocities as a function of particle diameter, as suggested by Nho-Kim et al. (2004).

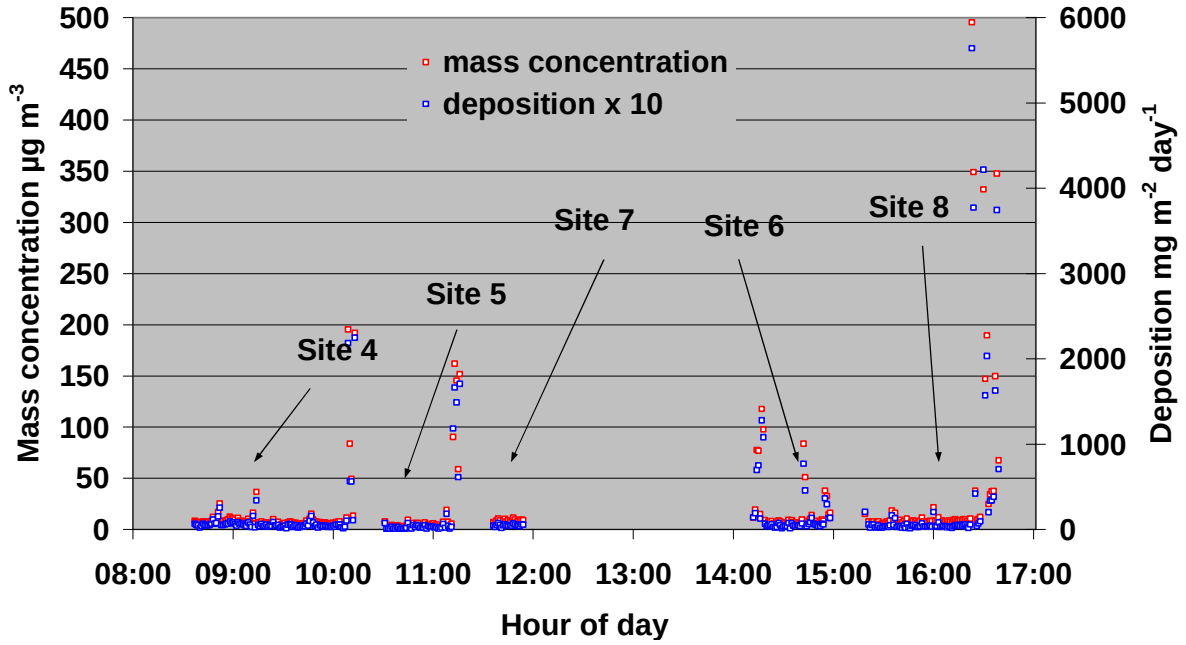


Figure 21. Mass concentration and dust deposition measured with GRIMM aerosol spectrometer at sites 4, 5, 6, 7 and 8 during a short period on 13th September 2005. The deposition fluxes have been multiplied by 10 for display purposes.

The results of the mass concentrations and dust deposition measurements are shown in Figure 21 for sites on the lower Burrup, and in Figure 22 for sites 1 and 3 on northern Burrup area. They appear consistent with PM_{10} results measured with the DustTrak at Site 8, for example. The average TSP concentration measured at Site 8 with the GRIMM was about 40 µg m^{-3}, which is in the range of the DustTrak results shown in Figures 15 – 18. The average TSP loading for sites 1 and 3 was about 9 µg m^{-3} compared with about 40 µg m^{-3} at Site 8, and about 30 µg m^{-3} at sites 4, 5, 6 and 7. These results are of the same order as the averages presented in Table 11, and indicate that higher TSP concentrations exist at the lower Burrup sites compared to the "background" at sites 1 and 3. The high mass concentrations and depositions observed in Figures 21 and 22, at the start and end of the sampling periods, coincided with site visits, and are probably artefacts caused by people moving about the site.

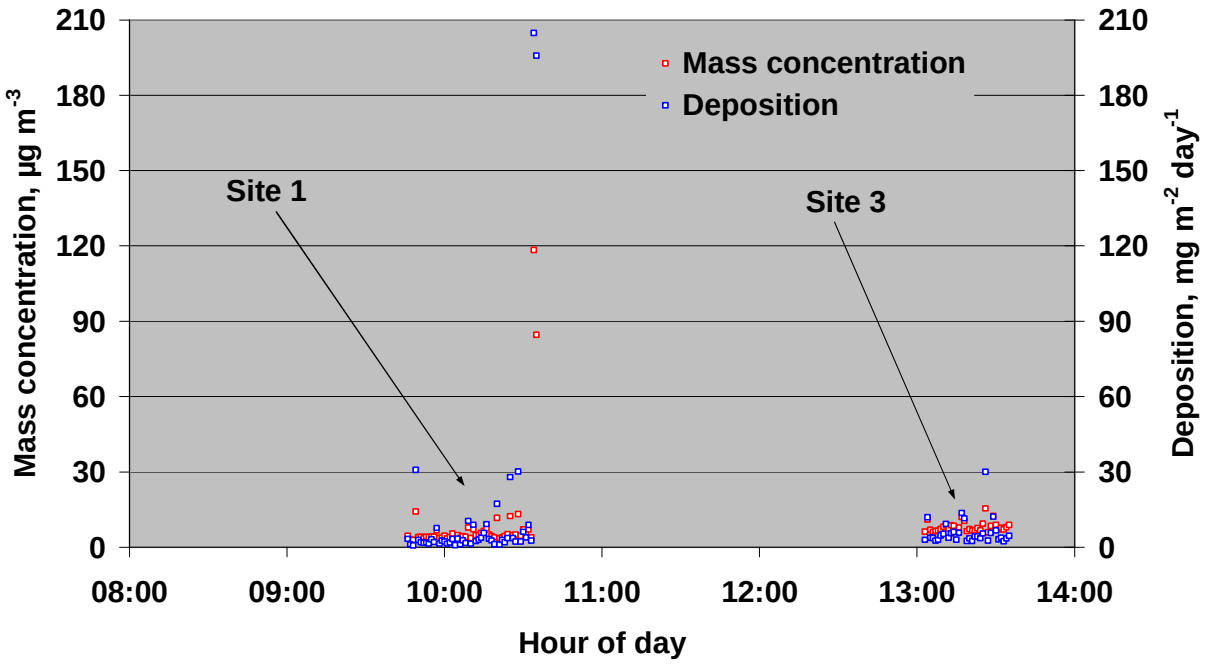


Figure 22. Mass concentration and dust deposition measured with GRIMM aerosol spectrometer at sites 1 and 3 during a short period on 14th September 2005.

The results of the dust deposition calculations for Sites 4, 5, 6, 7 and 8 are presented in Figure 21 and for Sites 1 and 3 in Figure 22. These data show that dust deposition values average about 10 mg m^{-2} day^{-1} at Sites 1 and 3 compared to about 68 mg m^{-2} day^{-1} at Site 8 and 32 mg m^{-2} day^{-1} for sites 4, 5, 6 7, and 8. These depositions indicate that over this short sample period the more industrial area of the Burrup experienced higher dust deposition than the background sites. However, it should be noted that the absolute values of the dust deposition at any of the Burrup sites is quite low. In comparison, Vallack, (1995), using the frisbee type foam pad samplers to measure dust deposition fluxes at two villages in north Yorkshire. One was located near a power station for 17 months in an area known to have relatively high dust fluxes and a maximum of about 120 mg m^{-2} day^{-1} was measured with an average of about 63 mg m^{-2} day^{-1}. The second site was in a rural area known to have lower deposition fluxes and the flux was 23 mg m^{-2} day^{-1}, using a dry frisbee without an insert. The dust fluxes measured at the lower Burrup sites are generally lower than those measured at the high deposition site in north Yorkshire, except at site 8 which is closest to the ore loading facilities at Parker Point.

5.4 Meteorological Measurements

Figure 23 displays wind directions observed at site 8 from August 2004 and December 2004. No data were collected at site 8 during January 2005 so the rose for that period was compiled using data from Karratha Airport. The Figure shows that during August wind directions were from about 200º to about 250º, with a smaller component from about 70º. From September wind directions generally veered more to the north until November, when they were from about 250º to 290º.

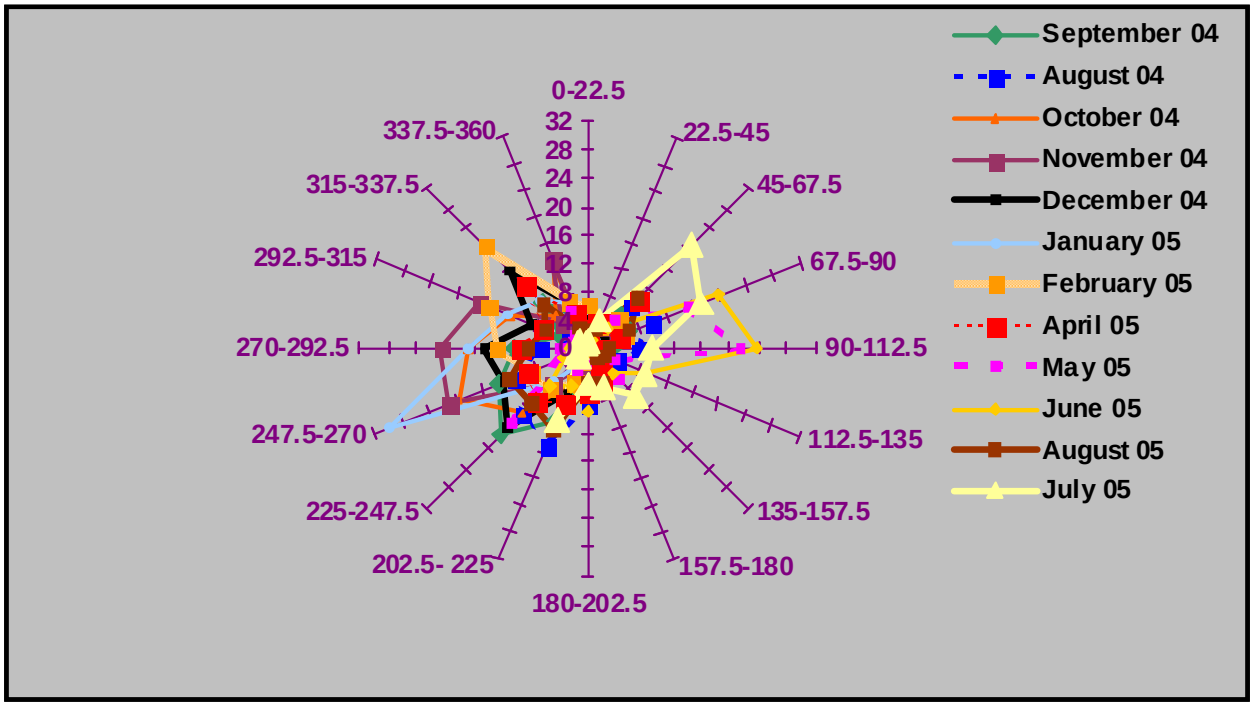


Figure 23. Wind roses recorded at site 8 from August 2004 to August 2005. The data for January 2005 is compiled from data recorded at Karratha airport.

Figures 24 to 27 show the wind directions measured at site 8 over the 2007/2008 sampling period. The wind direction data was collected at 2 minute intervals, along with wind speed and gust speed and was used to construct the plot in Figures 19 and 20. The wind directions at site 8 vary during the year from about west to south west during January to March and west south west in march/April. During may to September there is a large north easterly component with a smaller contribution from the south west to west south west. During the last part of the year, from about October to December, the wind direction changes back around from about west to south west.

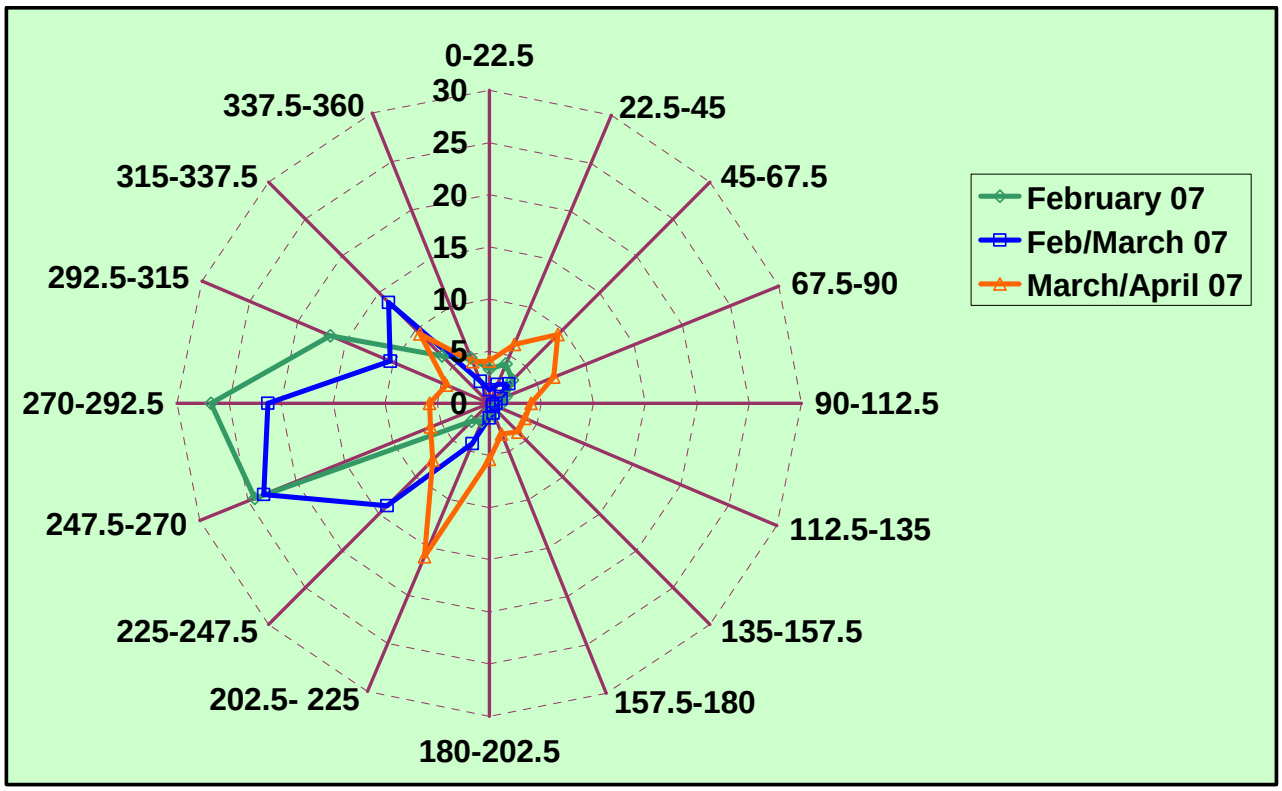


Figure 24. Wind roses recorded at site 8 for three periods from 24th January 2007 – 22nd February 2007, February 2007 – 20th March 2007 and 20th March 2007 – 3rd May 2007.

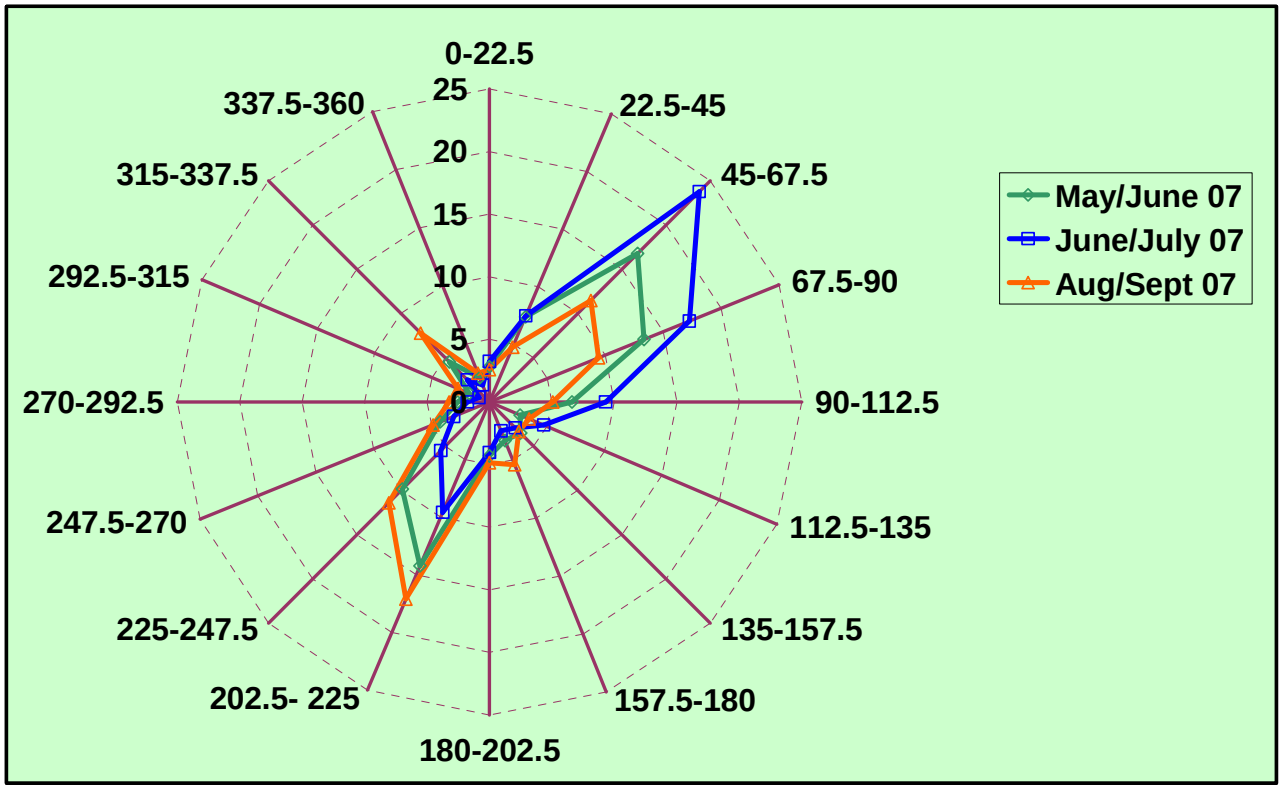


Figure 25. Wind roses recorded at site 8 for three periods from 3rd May 2007– 7th June 2007, 7th June 2007– 3rd August 2007 and 3rd August 2007 – 12th September 2007.

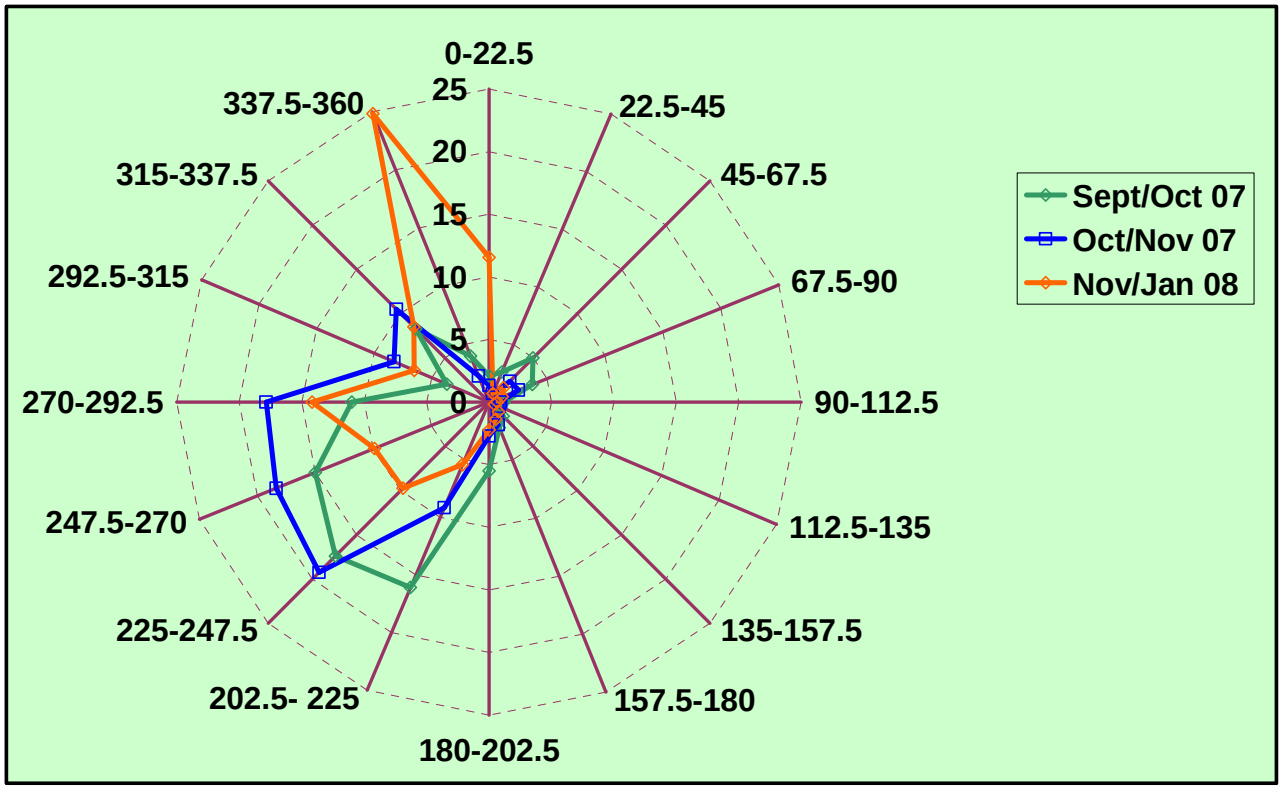


Figure 26. Wind roses recorded at site 8 for three periods from 12th September 2007 – 16th October 2007, 16th October 2007 – 8th November 2007 and 8th November 2007 – 8th January 2008.

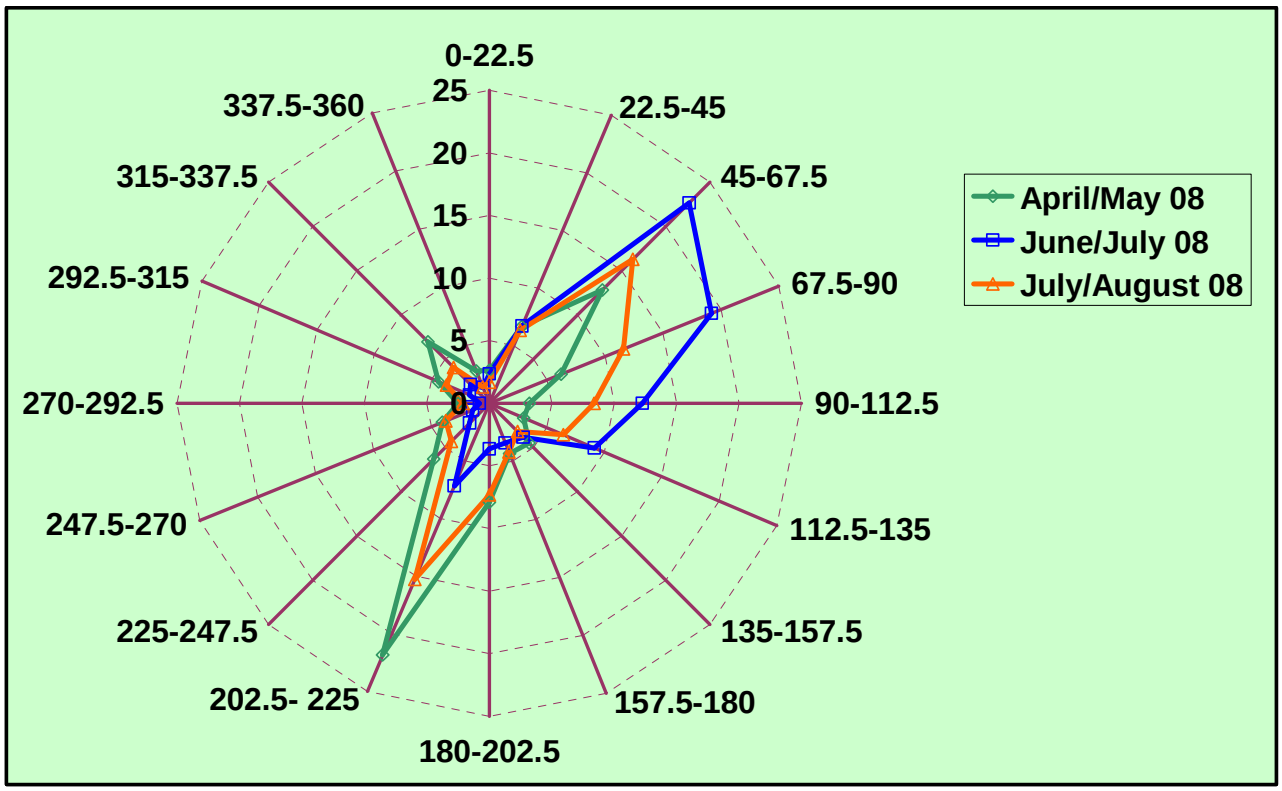


Figure 27. Wind roses recorded at site 8 for three periods from 21st April 2008 – 3rd June 2008, 3rd June 2008– 14th July 2008 and 14th July 2008 – 13th August 2008.

Table 13 shows average, maximum and minimum temperature measurements at sites 1, 3, 4, 5, 6, 7 and 8 from August 2004 until March 2005, and from May 2007 until September 2008. Temperatures measured at the sites were used to calculate concentrations of gaseous species measured in the study. The temperatures will assist in interpretation if seasonal cycles are found in any of the gas, particulate matter or dust measurements. The average temperatures show only small variations from site to site and the variation is generally only a fraction of a degree Celsius. Relative humidity data is also presented in Table 13, they show that humidity is more variable from site to site than temperature. Low humidity values can be as low as 10% to 20%, and that maximum humidities can vary from 85% to 100%.

Table 13. Average, maximum and minimum temperature (^{o}C), and relative humidity (%) measurements at sites 1, 3, 4, 5, 6, 7 and 8. MF indicates an equipment malfunction.

Date on	Date off	Temp Mean	Temp max	Temp Min	Humidity mean	Humidity max	Humidity Min
Site 1							
2004/2005							
02/09/04 15:46	08/10/04 09:16	23.6	35.2	17.4	61.4	97.5	10.9
08/10/04 09:22	21/11/04 11:34	28.7	40.3	21.2	53.9	94.9	9.5
21/11/04 11:34	17/12/04 12:01	29.4	37.6	23.9	63.6	92.2	17.8
17/12/04 12:12	19/01/05 12:51	30.6	40.3	24.8	68.7	93.7	6.9
19/01/05 12:52	21/02/05 12:52	30.5	36.7	26.3	72.2	92.6	4.5
23/02/05 09:57	28/03/05 10:36	31.7	40.9	25.2	30.1	85.3	0
28/03/05 10:46	18/04/05 09:31	30.3	38.2	23.5	MF	MF	MF
18/04/05 09:36	31/05/05 10:48	27.6	38.4	20.5	MF	MF	MF
31/05/05 11:28	13/07/05 11:37	21.2	27.0	15.3	MF	MF	MF
13/07/05 11:35	07/08/05 11:29	22.0	28.8	16.2	MF	MF	MF
07/08/05 11:23	14/09/05 09:59	21.8	27.9	16.0	MF	MF	MF
2007/2008							
04/05/07 09:30	14/06/07 09:30	24.99	33.22	17.92	53.4	93.7	17.4
14/06/07 09:35	29/07/07 17:41	20.95	29.00	15.11	62.9	98.1	23.9
02/08/07 10:58	09/09/07 10:16	23.39	32.91	17.07	50.2	96.0	8.8
09/09/07 12:21	24/10/07 20:27	25.91	36.29	18.95	59.0	96.7	9.1
25/10/07 18:04	09/11/07 10:31	25.53	34.77	20.57	63.0	89.6	15.0
09/11/07 11:37	24/12/07 19:43	29.24	41.57	22.07	61.5	96.0	7.8
09/01/08 11:16	08/02/08 14:40	31.15	43.45	25.08	70.9	96.7	8.1
08/02/08 14:42	12/03/08 15:24	30.34	38.82	24.21	73.0	96.3	-1.6
12/03/08 15:25	26/04/08 23:31	29.00	38.13	22.62	67.0	97.4	-1.6
27/04/08 13:03	04/06/08 12:36	25.95	34.29	19.71	MF	MF	MF
04/06/08 12:40	17/07/08 12:01	21.72	28.36	15.83	MF	MF	MF
17/07/08 12:06	14/08/08 13:06	21.08	29.28	15.26	MF	MF	MF
Site 3							
2004/2005							
02/09/04 13:07	08/10/04 11:34	23.8	35.3	17.3	59.8	98.2	12.7
08/10/04 11:36	21/11/04 15:40	28.8	40.2	21.7	54.6	94.1	10.9
21/11/04 15:40	17/12/04 14:01	29.6	40.0	24.2	62.8	88.8	15.4
19/01/05 16:19	21/02/05 09:52	30.6	37.7	27.0	74.6	91.8	29.9
21/02/05 09:58	28/03/05 12:13	31.9	41.0	27.3	61.7	90.1	16.2
28/03/05 12:15	18/04/05 14:18	30.5	39.2	23.5	54.9	87.6	10.5
18/04/05 14:26	31/05/05 12:50	27.6	38.4	20.8	MF	MF	MF
31/05/05 13:30	13/07/05 13:40	21.2	27.0	15.3	MF	MF	MF
13/07/05 16:02	07/08/05 14:41	22.1	28.3	16.8	MF	MF	MF
07/08/05 14:55	14/09/05 13:19	22.1	33.2	16.0	MF	MF	MF
2007/2008							
07/01/08 17:47	08/02/08 15:50	31.04	43.81	19.16	70.0	97.5	12.0
08/02/08 15:53	12/03/08 13:17	30.60	40.56	24.11	72.7	96.4	19.1
12/03/08 13:20	26/04/08 21:26	29.26	37.57	22.62	68.3	98.2	18.7
27/04/08 16:49	04/06/08 14:13	25.85	34.35	18.52	55.1	94.9	14.2
04/06/08 14:14	17/07/08 13:32	21.58	28.75	15.11	56.4	97.9	9.5
17/07/08 13:33	14/08/08 11:03	20.91	28.90	13.53	55.8	99.3	13.5

Table 13 cont

Date on	Date off	Temp mean	Temp max	Temp Min	Humidity mean	Humidity max	Humidity Min
Site 4							
2004/2005							
01/08/04 11:22	01/09/04 08:22	21.5	29.0	15.4	44.2	91.4	8.8
01/09/04 08:28	07/10/04 08:43	23.6	32.4	16.0	55.6	98.3	6.2
07/10/04 08:50	20/11/04 08:38	29.1	41.6	20.9	48.6	94.6	10.9
20/11/04 08:42	18/12/04 06:36	29.8	40.0	23.3	58.5	89.8	11.3
18/12/04 06:38	18/01/05 09:29	31.1	41.8	24.3	63.7	91.0	13.1
18/01/05 09:32	16/02/05 06:29	30.7	38.2	26.9	72.7	92.3	20.4
16/02/05 06:55	23/03/05 09:49	32.1	42.9	27.8	62.0	89.8	16.2
23/03/05 09:37	28/04/05 08:03	30.7	40.0	23.2	55.3	91.0	9.5
28/04/05 08:10	30/05/05 10:07	27.1	36.6	20.9	62.0	99.3	9.5
30/05/05 10:12	30/06/05 08:21	21.4	28.2	15.8	57.1	99.0	20.8
30/06/05 08:25	08/08/05 08:28	21.8	29.2	15.0	48.9	100.0	11.6
08/08/05 08:34	13/09/05 08:52	22.0	28.7	15.2	58.7	98.0	13.5
2007/2008							
04/05/07 14:41	07/06/07 08:50	25.77	32.93	19.9	47.1	87.8	11.2
07/06/07 08:53	22/07/07 16:59	21.16	28.06	14.92	52.4	97.0	10.2
No data							
05/08/07 09:27	12/09/07 08:45	24.04	35.97	16.78	43.4	94.0	8.1
12/09/07 10:52	16/10/07 15:52	25.82	37.22	18.52	53.1	98.1	5.3
08/11/07 11:37	23/12/07 19:43	29.55	42.52	21.88	50.9	90.0	-1.6
08/01/98 11:23	07/02/98 12:47	31.42	43.45	24.91	27.5	81.1	-1.6
07/02/08 12:53	11/03/08 10:44	30.62	41.22	24.35	MF	MF	MF
11/03/08 10:46	21/04/08 10:28	29.57	40.04	22.26	MF	MF	MF
21/04/08 09:33	03/06/08 13:00	26.95	36.89	18.40	MF	MF	MF
03/06/08 13:03	14/07/08 11:09	22.13	30.08	15.26	MF	MF	MF
14/07/08 11:14	13/08/08 10:44	21.28	29.80	14.80	MF	MF	MF
Site 5							
2004/2005							
01/08/04 15:44	01/09/04 11:38	21.0	28.3	14.7	13.3	35.1	1.34
01/09/04 11:41	07/10/04 10:59	23.3	35.7	15.5	57.6	98.5	6.2
20/11/04 12:27	18/12/04 07:42	29.4	41.3	23.1	60.7	89.6	11.6
18/12/04 07:45	18/01/05 12:15	30.9	43.2	24.1	65.1	92.1	13.1
18/01/05 12:23	16/02/05 08:08	30.5	37.1	26.8	74.0	92.9	24.8
16/02/05 08:30	22/03/05 11:33	32.0	43.1	27.5	63.4	91.7	16.2
23/03/05 11:40	28/04/05 10:04	30.4	40.1	22.9	57.2	94.1	10.9
28/04/05 10:05	30/05/05 11:20	26.3	34.3	20.0	65.0	100.5	11.2
30/05/05 11:32	30/06/05 09:11	20.9	27.6	14.9	59.5	99.2	19.1
30/06/05 09:16	08/08/05 09:16	21.2	28.3	15.0	51.7	101.2	13.5
08/08/05 09:21	13/09/05 10:42	21.6	28.5	15.0	61.2	99.9	15.8

Table 13 cont

Date on	Date off	Temp mean	Temp max	Temp min	Humidity mean	Humidity max	Humidity Min
Site 6							
2004/2005							
03/08/04 12:51	01/09/04 10:21	21.2	28.4	13.8	45.1	91.7	9.5
01/09/04 10:25	07/10/04 10:04	23.7	34.6	15.7	54.9	98.1	6.5
07/10/04 10:14	29/10/04 10:17	29.5	41.8	20.7	45.8	92.9	8.8
20/11/04 10:33	18/12/04 08:45	30.0	41.3	23.0	56.6	88.3	9.5
18/12/04 08:50	18/01/05 11:08	31.4	43.0	24.2	61.2	90.4	12.0
18/01/05 11:13	16/02/05 07:19	31.0	38.9	26.7	70.7	91.3	20.8
16/02/05 07:35	23/03/05 10:47	32.3	43.8	27.3	60.1	90.0	14.2
23/03/05 10:41	28/04/05 09:17	30.8	40.2	23.0	53.3	92.1	7.5
28/04/05 09:20	30/05/05 12:38	26.5	34.6	19.7	67.3	103.8	11.2
30/05/05 12:43	30/06/05 10:04	20.9	27.8	13.8	72.5	103.8	17.8
30/06/05 10:11	08/08/05 10:05	21.2	28.5	14.9	54.7	103.8	11.2
08/08/05 10:12	13/09/05 14:33	21.7	29.5	14.6	68.3	103.8	8.5
23/03/05 10:41	28/04/05 09:17	30.8	40.2	23.0	53.3	92.1	7.5
Site 7							
2004/2005							
01/08/04 14:18	01/09/04 13:21	21.6	29.0	14.6	43.1	94.1	10.5
01/09/04 13:28	07/10/04 13:10	23.8	36.9	15.5	54.1	99.5	6.5
07/10/04 13:16	20/11/04 14:16	29.7	41.4	21.2	44.3	93.7	8.1
18/12/04 10:15	18/01/05 15:09	31.5	42.5	24.2	60.8	92.9	12.3
18/01/05 15:07	16/02/05 09:13	31.0	39.9	26.5	71.0	92.1	23
16/02/05 09:25	23/03/05 12:55	32.5	42.3	26.8	59.9	92.5	15
23/03/05 12:59	28/04/05 10:59	31.4	42.4	23.7	51.5	90.9	7.5
28/04/05 10:59	30/05/05 13:56	26.5	35.4	20.1	63.0	98.2	10.5
30/05/05 14:04	30/06/05 11:13	21.1	27.4	14.6	57.7	96.7	17.8
30/06/05 11:15	08/08/05 11:12	21.5	28.2	15.0	49.1	98.2	12.7
08/08/05 11:15	13/09/05 11:45	21.8	29.0	13.7	57.1	97.8	12.3
2007/2008							
03/05/07 11:49	07/06/07 10:55	25.61	33.98	18.99	MF	MF	MF
07/06/07 10:57	22/07/07 19:03	20.68	27.96	13.77	MF	MF	MF
No data							
03/08/07 10:43	12/09/07 10:52	23.62	35.30	13.70	MF	MF	MF
12/09/07 12:55	16/10/07 17:52	26.14	38.04	17.73	MF	MF	MF
08/11/07 13:00	23/12/07 21:06	29.91	42.73	21.78	MF	MF	MF
07/01/08 17:55	07/02/08 16:16	31.52	45.86	20.97	64.7	95.8	10.9
07/02/08 16:19	11/03/08 12:55	30.43	40.64	24.54	70.0	97.6	8.5
11/03/08 13:02	21/04/08 12:59	29.48	38.66	19.64	60.7	98.0	8.5
21/04/08 12:02	03/06/08 16:05	26.22	35.38	16.93	44.1	95.4	2.9
03/06/08 16:07	14/07/08 14:46	21.84	29.55	13.48	43.9	98.3	1.0
14/07/08 14:50	13/08/08 13:32	21.04	30.35	11.41	35.5	100.1	-1.6

Table 13 cont

Date on	Date off	Temp mean	Temp max	Temp min	Humidity mean	Humidity max	Humidity Min
Site 8							
2004/2005							
04/08/04 13:28	01/09/04 15:40	21.1	29.7	13.6	45.6	93.9	8.2
01/09/04 15:45	07/10/04 14:36	23.4	36.4	15.0	56.7	99.7	5.3
07/10/04 14:42	20/11/04 15:45	28.9	41.4	19.3	48.6	94.7	10.6
20/11/04 15:46	18/12/04 10:40	29.5	40.6	22.7	59.7	90.7	10.6
18/12/04 10:50	18/01/05 16:35	31.0	43.1	23.8	64.7	92.3	10.9
18/01/05 16:38	16/02/05 10:20	30.7	38.4	26.5	73.9	92.3	23.1
16/02/05 10:38	23/03/05 14:02	32.1	44.3	26.3	62.7	91.9	13.5
23/03/05 13:58	28/04/05 11:52	30.5	40.0	23.2	57.2	94.3	9.2
28/04/05 11:56	30/05/05 15:17	26.4	34.8	19.1	64.4	99.4	9.5
30/05/05 15:23	30/06/05 11:59	21.0	27.8	14.7	57.6	99.0	12.7
30/06/05 12:04	08/08/05 11:58	21.3	29.5	14.2	49.8	100.4	9.5
08/08/05 12:01	13/09/05 15:22	21.5	30.1	13.7	59.6	99.7	10.2
2007/2008							
24/01/07 14:38	22/02/07 07:50	30.02	42.79	23.27	72.0	95.5	11.2
22/02/07 08:01	20/03/07 11:07	31.06	42.61	24.57	67.4	99.1	15.4
No data							
03/05/07 13:14	07/06/07 11:38	25.34	32.99	18.76	47.53	92.00	9.8
07/06/07 11:41	22/07/07 19:47	20.58	27.93	13.84	51.8	99.8	8.8
No data							
03/08/07 09:33	12/09/07 11:36	23.17	36.48	13.75	45.3	99.4	5.6
12/09/07 13:39	16/10/07 11:36	25.36	38.13	17.00	54.6	99.4	4.5
16/10/07 11:43	08/11/07 12:37	26.68	39.30	18.12	53.4	87.4	6.2
08/11/07 13:41	23/12/07 21:47	29.38	43.03	21.23	56.2	94.8	4.7
08/01/08 16:11	07/02/08 17:11	31.28	45.32	24.45	70.3	98.4	8.1
07/02/08 17:12	11/03/08 13:39	30.37	42.34	24.28	75.1	98.1	9.8
11/03/08 13:42	21/04/08 12:45	29.11	39.61	20.09	70.2	101.7	13.8
21/04/08 12:48	03/06/08 16:45	25.64	36.08	16.54	56.6	99.4	8.4
03/06/08 16:47	14/07/08 15:35	21.63	30.63	12.88	54.1	100.8	8.4
14/07/08 15:44	13/08/08 14:26	20.59	29.20	11.79	50.3	103.8	5.3

5.5 Rainwater Composition

Tables 14a and 14b present concentrations of cations, anions, rainfall amount and pH measured in rainwater collected at Sites 3, 5, 6, 7 and 8. The results in the Tables show that the rainwater composition is dominated by sodium and chloride ions since most of the sites are in close proximity to the ocean. The focus of this study will be on the non sea-salt sulfate and nitrate concentrations and deposition in rainwater since they are indicative of the total concentration (neutralised and unneutralised) of sulfuric acid and nitric acid in rainwater. Sulfate in rainwater has a sea-salt source as well as a non sea-salt source. The non sea-salt fraction of the sulfate in rainwater was estimated by assuming magnesium had a predominately marine source. Ionic ratios provided by Millero, (1974) were then used to calculate the non sea-salt fraction of sulfate in the rainwater samples.

The concentrations of cations and anions measured in rainwater at sites 1, 3, 4, 6, 7 and 8 are presented in Tables 15a and 15b. The ion concentrations in 14a, 14b, 15a and 15b Tables were produced by the ion chromatographic techniques described above under accreditation from (NATA). As noted above for the 2004/2005 rainwater data the ion concentrations are again dominated by sodium and chloride since the sites are relatively close to the ocean.

The volume-weighted mean concentrations are given in bold italics in Tables 14a and 14b. These results show a slight increase in non sea-salt sulfate concentrations, from a local background of 4.8 µeq l^{-1} at Site 3, to 15.6 µeq l^{-1} at site 7.

Tables 15a and 15b give the volume weighted mean concentration of rainwater measured during 2007/2008 at sites 1, 3, 4, 6, 7 and 8. The non sea-salt sulfate concentrations at the background sites averaged about 2.9 µeq l^{-1} compared to about 4.8 µeq l^{-1} during the last sampling period. This is similar to the non sea-salt sulfate concentrations measured at site 6, but less than those measured at sites 4, 7 and 8. Taking an average of sites 4, 6, 7 and 8 show that the non sea-salt sulfate concentrations at the lower Burrup Peninsula sites is about 6.5 µeq l^{-1}, this is less than that observed during 2004/2005 and shows only a small enhancement over the background levels.

These results can be compared with previous studies, using similar sampling and analytical procedures, carried out in Malaysia and Indonesia. Non sea-salt concentrations were measured at several sites covering a range of pollution regimes in Indonesia (Gillett et al., 2000). At the heavily polluted sites in Jakarta and Bogor non sea-salt concentrations were 29 µeq l^{-1} – 38 µeq l^{-1}, whereas it was about 13 µeq l^{-1} at the relatively unpolluted GAW station at Bukit Koto Tabang, in west Sumatra. At Petaling Jaya, near Kuala Lumpur annual VWM non sea-salt sulfate concentrations in rainwater ranged from approximately 40 µeq l^{-1} – 70 µeq l^{-1} over 5 annual periods, (Ayers et al., 2000) and from about 30 µeq l^{-1} – 60 µeq l^{-1} at other polluted Malaysian sites (Ayers et al., 2002). Even at the relatively unpolluted Malaysian site in the Cameron Highlands, north of Kuala Lumpur, non sea-salt concentration VWM was 11.4 µeq l^{-1}. The non sea-salt sulfate concentrations at unpolluted sites in Malaysia and Indonesia exceeded those measured at the local back ground site on the Burrup Peninsula, and were similar to the concentrations at the lower sites on the Burrup.

Table 14a. Rainfall amount, pH, concentrations of cations, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+} cation sum and anion sum for the 2004/2005 period. Ion concentrations are μeq l^{-1}. VWM is the volume weighted mean concentrations at each site. The VWM anions are in bold. Total is the total rainfall for the sample period.

Sample	Sample (mm)	pH	H^+	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	∑Cat	∑An
Site 3										
18/04/05 – 06/05/05	14.2	4.586	25.9	71.0	6.6	4.6	13.4	18.1	139.7	139.8
06/05/05 – 24/05/05	79.0	5.172	6.7	16.2	1.4	0.6	1.4	0.9	27.3	26.1
31/05/05 – 13/07/05	71.0	4.733	18.5	39.0	7.0	1.2	6.6	3.7	76.1	74.0
VWM			***14.6***	***33.8***	***4.7***	***1.4***	***5.4***	***4.4***		
Total	***164.2***									
Site 5										
14/11/04 – 06/03/05	0.8	4.341	45.6	169.4	94.5	25.4	39.6	89.2	463.7	457.5
16/03/05 – 23/03/05	5.8	5.345	4.5	214.1	7.8	6.6	40.4	56.2	329.6	338.4
24/03/05 – 28/04/05	3.4	5.215	6.1	85.5	16.7	5.2	13.8	25.1	152.3	157.3
28/04/05 – 16/05/05	18.2	4.818	15.2	49.9	5.4	1.6	9.5	5.8	87.4	81.0
16/05/05 – 30/05/05	85.4	4.988	10.3	19.3	1.5	0.7	2.3	1.0	35.1	31.7
30/06/05 – 08/08/05	71.0	4.944	11.4	39.4	5.9	1.1	6.0	3.7	67.5	64.1
VWM			***11.2***	***38.5***	***4.8***	***1.4***	***6.1***	***5.3***		
Total	***184.6***									
Site 6										
16/03/05 – 23/03/05	5.8			944.9	537.5	107.5	291.1	571.3		
23/03/05 – 28/04/05	3.4	4.698	20.0	123.5	7.4	6.2	24.8	30.5	212.4	222.1
28/04/05 – 16/05/05	14.1	4.736	18.4	46.1	9.9	1.9	9.7	6.7	92.8	84.9
16/05/05 – 30/05/05	60.0	4.830	14.8	30.8	4.4	1.2	4.8	1.8	57.8	54.7
30/06/05 – 08/08/05	71.0	4.762	17.3	31.0	1.4	0.8	4.6	2.9	58.0	46.6
VWM			***15.7***	***63.0***	***20.7***	***4.5***	***12.5***	***21.2***		
Total	***154.3***									
Site 7										
16/03/05 – 23/03/05	5.8			1095.3	208.5	91.4	248.7	693.4		
24/03/05 – 28/04/05	3.4	4.732	18.5	92.1	6.5	4.9	17.1	21.4	160.6	165.2
16/05/05 – 30/05/05	76.5	5.059	8.7	29.7	2.6	1.2	4.1	1.4	47.6	48.0
30/06/05 – 08/08/05	71.0	4.835	14.6	43.4	3.2	2.0	6.7	2.4	72.4	68.1
VWM			***11.2***	***74.2***	***10.1***	***4.8***	***14.0***	***26.5***		
Total	***156.7***									
Site 8										
16/03/05 – 23/03/05	5.8	7.541	0.03	721.8	27.7	34.3	216.4	759.2	1759.5	1234.8
24/03/05 – 28/04/05	3.4	5.851	1.4	345.4	26.3	21.8	105.9	352.1	853.0	550.3
28/04/05 – 16/05/05	15.0	4.794	16.1	127.9	4.5	15.4	22.9	51.3	238.0	204.0
16/05/05 – 13/05/05	61.8	4.949	11.2	36.3	2.3	1.8	6.9	8.4	66.9	55.0
05/06/05 – 17/06/05	21.4			239.2	30.0	22.4	78.8	221.3		
VWM			***9.4***	***118.5***	***8.7***	***8.8***	***32.0***	***89.4***		
Total	***107.4***									

Background nitrate concentrations varied from about 4.2 μeq l^{-1} at Site 3 to 11.5 μeq l^{-1} and 10.8 μeq l^{-1} at Sites 6 and 7 respectively during 2004/2005 giving an average of about 8.6 μeq l^{-1} at the lower Burrup sites. During 2007/2008 background nitrate concentrations were about 3.2 μeq l^{-1} and about 7.8 μeq l^{-1} at the lower background sites. In both cases, during 2004/2005 and 2007/2008, there was a small enhancement above the background showing a geographical gradient in concentration from the local background sites to the lower Burrup sites, and this is probably due a similar geographical gradient in nitrogen dioxide concentrations from the local background to the lower Burrup sites. . During 2004/2004 the average nitrate concentrations on the lower Burrup Peninsula sites was about 8.6 μeq l^{-1} in 2004/2005 and about 7.8 μeq l^{-1} in 2007/2008.

In contrast to these results, the unpolluted sites in Tanah rata and Bukit Koto Tabang have nitrate concentrations of around 4.7 μeq l^{-1} and 0.8 μeq l^{-1} respectively, (Ayers et al., 1996; Gillett et. al., 2000) which is similar to the concentrations at Site 3. However the more polluted sites in Asia have substantially higher nitrate concentrations than any of the Burrup sites. Concentrations at various sites in Malaysia range

from approximately 15 µeq l^{-1} – 30 µeq l^{-1} and from 13 µeq l^{-1} – about 38 µeq l^{-1} in Jakarta (Ayers et al., 1996; Gillett et. al., 2000).

Table 14b. Concentrations of anions in rainwater samples for the 2004/2005 period. All concentrations are μeq l^{-1}. *SO_4^{2-} indicates non sea-salt sulfate. Volume weighted mean concentrations are given in bold italics.

Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	*SO_4^{2-}	$C_2O_4^{2-}$	PO_4^{3-}	F^-	CH_3COO^-	$HCOO^-$	$CH_3SO_3^-$	HCO_3^-
Site 3											
75.6	0.03	11.5	14.2	6.4	2.2	9.8	1.07	4.4	21.7	0.14	0.2
18.6	0.08	1.2	3.3	1.4	0.1	1.5	0.06	0.4	0.3		0.8
43.2	0.04	4.9	12.0	7.5	0.5	2.9	0.36	2.5	7.8	0.04	0.3
37.3	***0.06***	***4.2***	***8.7***	***4.8***	***0.6***	***3.2***	***0.33***	***4.0***	***7.3***	***0.04***	***0.5***
Site 5											
174.6	0.16	73.4	62.4	44.4	22.3	10.5		19.0	95.2		0.1
235.6	0.20	12.9	59.4	35.0	5.3	7.6	0.79	4.2	12.1	0.16	1.1
78.3	0.22	7.9	17.5	9.4	6.8	28.5	3.19	5.4	11.8	0.12	0.8
55.6	0.02	8.8	9.7	3.9	0.3	5.2	0.35	0.7	0.4		0.3
21.9	0.04	1.5	4.8	2.5	0.02	2.5	0.04	0.3	0.3		0.5
42.4	0.01	5.4	7.7	3.3	0.6	2.5	0.10	1.5	3.7	0.02	0.4
42.0	***0.04***	***4.7***	***8.7***	***4.4***	***0.7***	***3.4***	***0.17***	***1.1***	***2.9***	***0.01***	***0.5***
Site 6											
1026.7	2.30	240.0	323.6	217.4	55.6	18.8				6.49	
131.9	0.10	14.2	27.3	13.7	3.3	22.8	1.2	4.6	17.5	0.05	0.2
52.6	0.02	10.4	13.5	8.0	0.02	6.0	0.7	0.5	0.7	0.77	0.3
34.2	0.03	2.7	6.8	3.3	0.6	2.3	0.2	2.2	5.7		0.3
35.0	0.03	3.5	5.5	1.9		2.0	0.05	0.02	0.2		0.3
69.4	***0.10***	***11.5***	***17.3***	***10.2***	***2.1***	***3.5***	***0.21***	***1.1***	***3.1***	***0.28***	***0.3***
Site 7											
1289.3		165.1	466.0	332.7	56.3	18.9				6.28	
96.6	0.08	10.0	16.9	6.9	2.9	17.2	1.6	5.0	16.3	0.05	0.3
35.0	0.06	2.4	7.0	3.4	0.04	2.3	0.04	0.4	0.3		0.6
47.9	0.03	8.4	9.7	4.8	0.04	1.5	0.08	0.12	0.09	0.03	0.4
85.7	***0.05***	***10.8***	***24.5***	***15.6***	***2.1***	***2.8***	***0.09***	***0.3***	***0.5***	***0.23***	***0.5***
Site 8											
785.7	1.80	73.9	79.2	0.0	52.0	4.6	14.3	33.7	27.7	0.79	177.2
385.8	6.60	4.2	75.8	35.9	44.1	26.3	8.9	9.2	1.4		3.6
136.3	0.94	7.5	18.9	4.8	4.0	0.9		12.6	23.2	0.36	0.3
40.7	0.54	0.01	11.0	6.8	0.1	1.0	0.6	1.0	0.7		0.4
320.0	12.31	18.5	47.9	13.9	7.0	36.5	38.8			1.88	
139.1	***2.68***	***7.3***	***22.4***	***8.1***	***5.1***	***7.4***	***7.40***	***4.1***	***4.8***	***0.38***	***8.1***

Table 15a. Rainfall amount, pH, concentrations of cations, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+} cation sum and anion sum for the 2004/2005 period. Ion concentrations are μeq l^{-1}. VWM is the volume weighted mean concentrations at each site. The VWM anions are in bold. Total is the total rainfall for the sample period.

Sample	Sample (mm)	pH	H^+	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	∑Cat	∑An
Site 1										
02/07/07 – 29/07/07	23.8	5.504	3.1	79.0	5.89	3.5	17.6	10.4	119.5	106.8
09/01/08 – 07/02/08	70.4	5.321	4.8	48.4	0.22	2.2	11.1	11.5	78.2	69.0
08/02/08 – 31/03/08	267.2	5.827	1.5	109.7	11.56	4.8	24.0	9.3	160.8	145.3
VWM			***2.2***	***95.7***	***9.0***	***4.2***	***21.1***	***9.8***		
Total	***361.4***									
Site 3										
22/02/07 – 20/03/07	104.0	5.120	7.6	142.4	2.0	4.2	33.2	12.2	201.7	194.5
14/06/07 – 02/07/07	3.2	5.180	6.6	68.1	2.5	1.6	16.0	4.6	99.3	92.1
03/07/07 – 02/08/07	20.6	4.894	12.8	154.0	5.0	4.7	36.5	21.2	234.2	226.2
09/01/08 – 07/02/08	70.4	5.092	8.1	111.7	8.1	3.8	25.5	10.3	167.5	157.1
08/02/08 – 26/02/08	80.2	6.102	0.8	152.0	28.3	6.1	31.9	8.6	227.6	207.8
12/03/08 – 30/03/08	186.4	4.896	12.7	42.2	2.6	2.3	9.9	4.9	74.5	69.7
VWM			***8.8***	***73.0***	***7.8***	***3.7***	***22.5***	***8.7***		
Total	***464.8***									
Site 4										
25/06/07 – 04/08/07	23.8	5.241	5.7	65.8	9.3	5.4	17.4	50.4	154.1	113.3
05/02/08 – 06/06/08	362.4	5.241	5.7	65.8	9.3	5.4	17.4	50.4	154.1	113.3
VWM			***5.7***	***65.8***	***9.3***	***5.4***	***17.4***	***50.4***		
Total	***386.2***									
Site 6										
26/01/08 – 07/02/08	65.6	5.192	6.4	12.4	5.2	0.3	3.3	6.4	34.1	25.6
08/02/08 – 25/02/08	80.2	5.115	7.7	85.5	5.3	2.2	20.1	7.4	128.1	111.3
11/03/08 – 29/03/08	182.0	5.120	7.6	15.9	2.0	0.6	3.8	2.4	32.1	28.0
30/03/08 – 21/04/08	4.8	4.818	15.2	36.0	1.0	0.7	8.6	4.4	65.9	56.5
VWM			***7.5***	***32.3***	***3.4***	***0.9***	***7.7***	***4.4***		
Total	***332.6***									
Site 7										
26/01/08 – 07/02/08	65.2	5.500	3.16	14.9	1.6	0.5	3.9	4.4	28.4	25.9
08/02/08 – 25/02/08	80.2	5.513	3.07	52.3	11.5	2.0	12.0	4.5	85.4	70.4
26/03/08 – 16/06/08	212.0	5.506	3.12	33.6	6.6	1.3	7.9	4.4	56.9	48.2
VWM			***3.1***	***34.4***	***6.8***	***1.3***	***8.1***	***4.4***		
Total	***357.4***									
Site 8										
22/02/07 – 20/03/07	104	4.998	10.0	49.1	2.0	3.4	12.9	7.9	85.3	73.2
25/06/07 – 03/08/07	23.8	6.579	0.3	928.7	39.7	58.0	264.8	572.0	1863.5	1729.5
26/01/08 – 07/02/08	65.6	4.938	11.5	21.3	0.3	1.3	4.6	3.5	42.5	33.5
08/02/08 – 25/02/08	80.2	5.536	2.9	72.3	32.2	5.1	16.7	10.7	140.0	109.0
11/03/08 – 29/03/08	182.0	4.776	16.7	65.5	3.0	1.6	20.3	8.9	116.0	111.3
30/03/08 – 21/04/08	4.8	5.141	7.2	22.4	1.0	0.5	5.2	4.1	40.4	35.1
VWM			***11.1***	***100.8***	***9.3***	***5.5***	***28.2***	***37.3***		
Total	***460.4***									

Table 15b. Concentrations of anions in rainwater samples for the 2004/2005 period. All concentrations are μeq l^{-1}. $*SO_4^{2-}$ indicates non sea-salt sulfate. Volume weighted mean concentrations are given in bold italics.

Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	$*SO_4^{2-}$	$C_2O_4^{2-}$	PO_4^{3-}	F^-	CH_3COO^-	$HCOO^-$	$CH_3SO_3^-$	HCO_3^-
Site 1											
85.3	0.1	3.2	12.5	3.2	0.2	1.9	0.4	0.8	0.5	0.1	1.6
51.0		5.1	9.7	3.8	0.2	0.7		0.6	0.5		1.1
119.7	0.1	1.3	15.4	2.6	0.2	3.1	0.4	1.0	0.5	0.1	3.4
104.0	***0.3***	***2.2***	***14.1***	***2.9***	***0.2***	***2.5***	***0.3***	***1.0***	***0.5***	***0.1***	***1.8***
Site 3											
162.2		2.4	18.6	1.0	1.1	0.5	0.2	2.6	5.7	0.2	0.7
77.0		1.7	8.5	0.03	0.4	0.3	0.1	1.1	2.2		0.8
170.9		10.2	28.5	9.1	2.3	0.9	0.3	3.1	9.2	0.3	0.4
169.5	0.20	4.0	20.4	3.5	0.5	4.8	0.2	1.4	0.4		6.4
45.0		4.5	8.1	2.9	0.9	1.5		2.1	7.0	0.1	0.4
124.9	0.20	4.5	16.8	3.3	1.0	1.6	0.2	2.0	4.9	0.2	0.6
110.6	***0.1***	***4.1***	***14.8***	***2.9***	***1.0***	***1.8***	***0.1***	***2.1***	***5.3***	***0.1***	***1.5***
Site 4											
63.4	0.4	9.2	21.8	12.5	3.0	1.1	0.7	7.4	16.1	0.5	0.9
63.4	0.4	9.2	21.8	12.5	3.0	1.1	0.7	7.4	16.1	0.5	0.9
63.4	***0.4***	***9.2***	***21.8***	***12.5***	***3.0***	***1.1***	***0.7***	***7.4***	***16.1***	***0.5***	***0.9***
Site 6											
13.2		3.7	5.5	3.7	0.5	0.3		1.8	2.6	0.1	0.8
95.4		6.2	13.9	3.3	0.3		0.6	0.7	0.5	0.1	0.7
17.2		1.5	3.9	1.9	0.4	1.0	0.2	2.2	3.1	0.1	0.7
41.1	0.1	2.9	6.1	1.6	0.6			1.8	6.9	0.1	0.3
35.6	***0.0***	***3.1***	***6.7***	***2.6***	***0.4***	***0.6***	***0.2***	***1.7***	***2.3***	***0.1***	***0.7***
Site 7											
15.3		4.6	5.4	3.3	0.2	0.3		0.8	0.4		1.6
56.2	0.1	4.2	11.2	4.9	0.2	1.0	0.1	0.9	0.4		1.7
35.8	0.1	4.4	8.3	4.1	0.2	0.6	0.1	0.8	0.4		1.6
36.6	***0.1***	***4.4***	***8.4***	***4.1***	***0.2***	***0.7***	***0.1***	***0.9***	***0.4***		***1.6***
Site 8											
51.8	0.6	1.8	7.1	0.2	1.0	5.2	0.8	1.5	3.4	0.1	0.5
1211.0	12.5	198.7	236.0	95.6	6.3	5.3	6.7	22.2	20.7	1.7	19.3
21.8	0.5	3.3	5.5	3.1	0.2	0.9		0.9	0.4		0.4
80.6	0.6	6.1	12.5	3.7	1.5	4.8	0.3	1.0	0.4		1.8
72.6		5.7	12.5	1.7	0.8	0.7	0.6	3.6	14.1	0.2	0.3
24.9	0.1	1.4	4.7	2.0	0.4	0.0		1.4	1.6		0.7
120.4	***1.0***	***14.5***	***21.7***	***6.8***	***1.2***	***2.7***	***0.8***	***3.2***	***7.6***	***0.2***	***1.6***

5.6 Deposition of Nitrogen and Sulfur

An aim of this study was to measure the total deposition of acidity to the ground. The strong mineral acidity, resulting from industry is in the form of sulfuric and nitric acids, both as free and neutralised acids. These are formed as the products of the oxidation of nitrogen dioxide and sulfur dioxide, some of which is emitted from industrial sources. Reactions 14 to 18 show the basic steps in the atmospheric oxidation of nitrogen to produce nitric acid and ammonium nitrate, the major neutralised form of nitric acid. Sulfuric acid can also be formed as a result of chemical reactions in the atmosphere. The major oxidation steps are shown in reactions 19 to 23. Reactions 17 and 18 and 22 and 23 show the free acid and neutralised forms of

nitric acid and sulfuric acid respectively. The reactions also show the role of ammonia in the formation of the neutralised species.

Nitrogen oxidation and formation of nitric acid and ammonium nitrate

$N_2 + O_2 \Longrightarrow 2NO$ (14)

$NO + HO_2\bullet \text{ (or } RO_2\bullet) \Longrightarrow NO_2 + OH\bullet$ (15)

$NO + O_3 \Longrightarrow NO_2 + O_2$ (16)

$NO_2 + OH\bullet \Longrightarrow HNO_3$ (17)

$NH_3 + HNO_3 \Longrightarrow NH_4NO_3$ (18)

Gas phase sulfur oxidation and formation of sulfur dioxide and ammonium bisulfate and ammonium sulfate aerosol.

$S + O_2 \Longrightarrow SO_2$ (19)

$2SO_2 + O_2 \Longrightarrow 2SO_3$ *(very slow unless catalysed)* (20)

$SO_2 + O_3 \Longrightarrow SO_3 + O_2$ (20)

$SO_2 + H_2O_2 \Longrightarrow SO_3 + H_2O$ (21)

$SO_2 + \bullet OH + M \Longrightarrow HOSO_2\bullet + M$ (22)

$HOSO_2\bullet + O_2 \Longrightarrow HO_2\bullet + SO_3$ (23)

$SO_3 + H_2O\ M + \Longrightarrow H_2SO_4 + M$ (24)

$NH_3 + H_2SO_4 \Longrightarrow (NH_4)_2SO_4$ (25)

$2NH_3 + H_2SO_4 \Longrightarrow NH_4HSO_4$ (26)

Aqueous phase sulfur oxidation and formation of sulfur dioxide and ammonium bisulfate and ammonium sulfate aerosol.

$$SO_2 + H_2O \Longleftrightarrow SO_2 \bullet H_2O \quad (27)$$

$$SO_2 \bullet H_2O \Longleftrightarrow H^+ + HSO_3^- \quad (28)$$

$$HSO_3^- \Longleftrightarrow H^+ + SO_3^{2-} \quad (29)$$

$$HSO_3^- + H_2O_2 \Longleftrightarrow H_2O + SO_2OOH^- \quad (30)$$

$$SO_2OOH^- + H^+ \Longrightarrow H_2SO_4 \quad (31)$$

Wet deposition fluxes in meq m^{-2} of nitrogen and sulfur were calculated from the rainfall amount in mm and the concentrations of nitrate, sulfate and ammonium in units of µeq l^{-1} in the rainwater samples collected at each site. The results of these deposition fluxes for 2004/2005 and 2007/2008 are shown in Tables 16a and 16b respectively. The totals shown in the Table are the annual fluxes at each site. Since the amount of rain that fell at each site was similar, the range in wet deposition fluxes is similar to the ranges observed in the rainfall composition. The rainfall amounts are given in Tables 14a and 14b respectively, and it is immediately obvious that more rain fell during 2007/2008 than fell during 2004/2005. During 2004/2005 rain fall amounts varied from 107 mm to 185 mm whereas they varied from 332mm to 465 mm during 2007/2008 and the increase in 2007/2008 will directly increase the wet deposition fluxes of nitrate ion, ammonium ion and non sea-salt ion.

Table 16. Wet deposition fluxes of nitrogen and sulfur during the 2005/2005 sampling period. $*SO_4^{2-}$ is the non sea-salt fraction of the sulfate.

Sample	NO_3^- meq m^{-2}	$*SO_4^{2-}$ meq m^{-2}	NH_4^+ meq m^{-2}
Site 3			
18/04/05 – 06/05/05	0.2	0.1	0.1
06/05/05 – 24/05/05	0.1	0.2	0.1
31/05/05 – 13/07/05	0.3	0.6	0.5
total	***0.6***	***0.9***	***0.7***
Site 5			
14/11/04 – 06/03/05	0.1	0.1	0.1
16/03/05 – 23/03/05	0.1	0.2	0.1
24/03/05 – 28/04/05	0.0	0.1	0.1
28/04/05 – 16/05/05	0.1	0.1	0.1
16/05/05 – 30/05/05	0.1	0.3	0.1
30/06/05 – 08/08/05	0.4	0.3	0.4
total	***0.8***	***1.0***	***0.9***
Site 6			
16/03/05 – 23/03/05	1.4	1.2	3.1
23/03/05 – 28/04/05	0.1	0.1	0.0
28/04/05 – 16/05/05	0.1	0.1	0.1
16/05/05 – 30/05/05	0.2	0.2	0.3
30/06/05 – 08/08/05	0.2	0.2	0.1
total	***2.0***	***1.8***	***3.6***
Site 7			
16/03/05 – 23/03/05	1.0	1.9	1.2
24/03/05 – 28/04/05	0.0	0.1	0.1
16/05/05 – 30/05/05	0.2	0.4	0.2
30/06/05 – 08/08/05	0.6	0.4	0.2
total	***1.8***	***2.8***	***1.7***
Site 8			
16/03/05 – 23/03/05	0.4	0.1	0.2
24/03/05 – 28/04/05	0.0	0.1	0.1
28/04/05 – 16/05/05	0.1	0.1	0.1
16/05/05 – 13/05/05	0.0	0.4	0.1
05/06/05 – 17/06/05	0.4	0.1	0.6
total	***1.0***	***0.9***	***1.1***

Table 17. Wet deposition fluxes of nitrogen and sulfur during the 2007/2008 sampling period. $*SO_4^{2-}$ is the non sea-salt fraction of the sulfate.

Sample	NO_3^- meq m^{-2}	$*SO_4^{2-}$ meq m^{-2}	NH_4^+ meq m^{-2}
Site 1			
02/07/07 – 29/07/08	0.1	0.1	0.1
09/01/08 – 07/02/08	0.4	0.3	0.0
08/02/08 – 31/03/08	0.3	0.7	3.1
total	***0.8***	***1.0***	***3.2***
Site 3			
22/02/07 – 20/03/07	0.2	0.1	0.2
14/06/07 – 02/07/07	0.0	0.0	0.0
03/07/07 – 02/08/07	0.2	0.2	0.1
09/01/08 – 07/02/08	0.3	0.2	0.6
08/02/08 – 26/02/08	0.3	0.3	2.3
12/03/08 – 30/03/08	0.8	0.5	0.5
total	***1.9***	***1.4***	***3.6***
Site 4			
25/06/07 – 04/08/07	0.2	0.3	0.2
05/02/08 – 06/06/08	3.3	4.5	3.4
total	***3.5***	***4.8***	***3.6***
Site 6			
26/01/08 – 07/02/08	0.2	0.2	0.3
08/02/08 – 25/02/08	0.5	0.3	0.4
11/03/08 – 29/03/08	0.3	0.3	0.4
30/03/08 – 21/04/08	0.0	0.0	0.0
total	***1.0***	***0.9***	***1.1***
Site 7			
26/01/08 – 07/02/08	0.3	0.4	0.1
08/02/08 – 25/02/08	0.3	0.2	0.9
26/03/08 – 16/06/08	0.9	0.9	1.4
total	***1.6***	***1.5***	***2.4***
Site 8			
22/02/07 – 20/03/07	0.2	0.0	0.1
25/06/07 – 03/08/07	4.7	2.5	1.0
26/01/08 – 07/02/08	0.2	0.2	0.0
08/02/08 – 25/02/08	0.5	0.3	2.5
11/03/08 – 29/03/08	1.0	0.4	0.6
29/03/08 – 21/04/08	0.0	0.3	0.2
total	***6.7***	***3.7***	***4.5***

Tables 16 and 17 display the wet deposition fluxes of ammonium, nitrate and non sea-salt sulfate acid estimated at each site. The fluxes ranged from about 1 meq m^{-2} for background levels of nitrate and non sea-salt and about 2.5 meq m^{-2} for ammonium and the fluxes were higher during 2007/2008, especially for ammonium ion. The fluxes of these wet deposited species, given in Tables 17 and 18, show a general increase at the lower Burrup sites when they are compared to the background sites, and is most markedly seen at site8 during 2007/2008, but this is partly due to the larger rainfall amounts.

Dry deposition fluxes were estimated from the product of the gas concentration, the sampling period and the dry deposition velocity. Deposition velocities for nitrogen dioxide, sulfur dioxide and nitric acid are taken from Manins, (1994). This used an inferential technique to estimate deposition velocities for Malaysian conditions.

The deposition flux, F*d*, to the surface of a gas such as sulfur dioxide may be described in terms of a dry deposition velocity, V*d*:

$$Fd = C \times Vd = \frac{C}{r_t} = \frac{C}{(r_a + r_b + r_c)} \quad (32)$$

Where:
C is the near-surface concentration of the relevant trace gas.
V*d* is inversely proportional to the sum of three resistance terms

$$Vd = (ra + rb + rc)^{-1} \quad (33)$$

These terms characterise the critical factors controlling surface-atmosphere exchange (Hicks et al., 1987).
Where:
ra is aerodynamic resistance,
rb is surface boundary layer resistance, and
rc is surface or canopy resistance (Hicks et al., 1987; Baldocchi et al., 1987).

The annual average values dry deposition velocities were 0.0090 m sec^{-1}, 0.0028 m sec^{-1} and 0.0021 m sec^{-1} for nitric acid, sulfur dioxide and nitrogen dioxide respectively (Manins (1994). The dry deposition flux for ammonia was taken from Puxbaum and Gregorgi, (1998). Inferred deposition velocities from such studies as Meyers et. al. (1991) show annual average deposition velocities can vary by about 10%. Since deposition flux is the product of deposition velocity and gas mixing ratio this variability flows through to the deposition flux so that it has at least a 10% uncertainty.

The dry deposition results, shown in Table 18a, are calculated from the 12 approximately monthly average concentrations of the gases measured at each site. The annual deposition in meq m^{-2} yr^{-1} is the addition of the monthly values for each gas, and the total dry deposition is given in the last column of Table 15. The total deposition values vary from about 8.8 meq m^{-2} yr^{-1} at Site 1 to 40.4 meq m^{-2} yr^{-1} at Site 9, in Karratha. The large value at Site 9 is due largely to the high deposition of ammonia, which most likely has a local source. The local background dry deposition flux is about 12 meq m^{-2} yr^{-1}, as defined by the average of Sites 1, 3 and 10. There is an obvious, although small increase in the dry deposition flux over the background at the lower Burrup sites which range from 14.2 meq m^{-2} yr^{-1} to 17.7 meq m^{-2} yr^{-1}.

Table 18b has the dry deposition fluxes of for nitrogen dioxide, sulfur dioxide, nitric acid and ammonia gases measured over 12 approximately periods during 2007/2008. The gas concentrations were converted to deposition fluxes using the appropriate deposition velocities, as described above.

Tables 18a and 18b give the dry deposition fluxes of the gases for 2004/2005 and 2007/2008 sampling periods respectively. The data in these tables have been collected over two sampling periods that are not of the same length, so they cannot be directly compared. Nevertheless the fluxes do not show much variation between the two sampling years. The fluxes in 2007/2008 are generally higher than those measured during 2004/2005 but this is principally due to the longer sampling period. It should be noted that the high ammonia flux at site 1 is due to the flux during 09/01/08 to 08/02/08, probably due to a dead animal, and this was not included in subsequent tables.

Table 18a. Dry deposition fluxes of nitrogen and sulfur from July 2004 to September 2005. Totals are given in bold italics.

Date on	Date off	NH_3 meq m^{-2}	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	total meq m^{-2}
Site 1						
29/07/04 11:50	02/09/04 15:35	0.2	0.2	0.1	0.1	0.5
02/09/04 15:40	08/10/04 09:35	0.6	0.1	0.0	0.2	0.9
08/10/04 09:45	21/11/04 12:05	0.4	0.3	0.1	0.2	1.0
21/11/04 12:05	17/12/04 12:10	0.7	0.1	0.0	0.1	0.9
17/12/04 12:10	19/01/05 13:02	0.2	0.1	0.1	0.1	0.6
19/01/05 13:07	21/02/05 12:55	0.6	0.1	0.1	0.1	0.9
21/02/05 13:12	28/03/05 11:14	0.5	0.2	0.1	0.2	0.9
28/03/05 11:20	18/04/05 09:55	0.1	0.1	0.1	0.1	0.4
18/04/05 11:17	31/05/05 11:24	0.3	0.3	0.1	0.3	1.0
31/05/05 11:25	13/07/05 11:50	0.2	0.2	0.0	0.1	0.5
13/07/05 11:45	07/08/05 11:40	0.3	0.1	0.0	0.2	0.6
07/08/05 11:50	14/09/05 09:53	0.3	0.1	0.1	0.1	0.6
Total		***4.3***	***1.8***	***0.8***	***1.9***	***8.8***
Site 3						
29/07/04 16:00	02/09/04 13:10	0.6	0.3	0.1	0.1	1.1
02/09/04 13:20	08/10/04 11:25	0.3	0.2	0.1	0.2	0.8
08/10/04 11:30	21/11/04 15:45	1.0	0.3	0.1	0.2	1.7
21/11/04 15:45	17/12/04 14:15	1.4	0.1	0.1	0.1	1.7
17/12/04 14:15	19/01/05 16:40	0.2	0.1	0.1	0.1	0.6
19/01/05 16:40	21/02/05 10:31	0.1	0.1	0.1	0.1	0.4
21/02/05 09:53	28/03/05 12:28	0.8	0.2	0.1	0.2	1.3
28/03/05 12:30	18/04/05 14:41	0.1	0.1	0.0	0.1	0.4
18/04/05 14:41	31/05/05 13:15	1.0	0.4	0.2	0.4	1.9
31/05/05 13:20	13/07/05 16:05	0.3	0.2	0.1	0.2	0.7
13/07/05 15:46	07/08/05 15:05	0.3	0.1	0.1	0.2	0.7
07/08/05 15:10	14/09/05 13:00	0.3	0.2	0.1	0.2	0.7
Total		***6.5***	***2.3***	***1.1***	***2.1***	***12.1***
Site 4						
01/08/04 12:09	01/09/04 09:17	0.1	0.4	0.1	0.1	0.7
01/09/04 09:25	07/10/04 09:15	0.9	0.4	0.2	0.2	1.7
07/10/04 09:20	20/11/04 08:20	0.1	0.7	0.3	0.3	1.5
20/11/04 08:20	18/12/04 06:30	1.4	0.6	0.1	0.2	2.2
18/12/04 06:30	18/01/05 10:02	0.2	0.5	0.1	0.2	1.0
18/01/05 10:07	16/02/05 06:30	0.1	0.3	0.1	0.1	0.6
16/02/05 06:45	23/03/05 09:53	0.4	0.4	0.1	0.3	1.1
23/03/05 09:53	28/04/05 08:48	0.2	0.5	0.3	0.2	1.3
28/04/05 08:49	30/05/05 10:40	0.7	0.5	0.1	0.3	1.6
30/05/05 10:40	30/06/05 08:45	0.1	0.2	0.0	0.1	0.5
30/06/05 08:48	08/08/05 08:47	0.4	0.3	0.0	0.3	1.0
08/08/05 08:47	13/09/05 08:43	0.3	0.4	0.1	0.2	1.1
Total		***4.9***	***5.3***	***1.5***	***2.6***	***14.2***
Site 5						
01/08/04 16:04	01/09/04 13:35	0.3	0.6	0.1	0.1	1.2
01/09/04 13:40	07/10/04 11:15	0.6	0.7	0.2	0.3	1.7
07/10/04 11:20	20/11/04 12:40	0.4	1.0	0.3	0.4	2.0
20/11/04 12:40	18/12/04 07:45	0.7	0.5	0.2	0.2	1.6
18/12/04 07:45	18/01/05 12:38	0.2	0.4	0.1	0.2	0.9

Table 18a Cont

Date on	Date off	NH_3 meq m^{-2}	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	total meq m^{-2}
18/01/05 12:44	16/02/05 08:30	0.1	0.3	0.1	0.2	0.7
16/02/05 08:15	23/03/05 11:56	0.7	0.4	0.2	0.3	1.5
23/03/05 11:56	28/04/05 10:22	0.5	0.7	0.2	0.3	1.7
28/04/05 10:22	30/05/05 11:40	0.8	0.8	0.1	0.4	2.1
30/05/05 11:40	30/06/05 19:15	0.4	0.6	0.1	0.3	1.4
30/06/05 09:20	08/08/05 09:35	0.4	0.8	0.1	0.3	1.6
08/08/05 09:35	13/09/05 10:32	0.3	0.6	0.1	0.3	1.3
Total		***5.5***	***7.3***	***1.7***	***3.1***	***17.7***
Site 6						
03/08/04 12:29	01/09/04 12:00	0.3	0.4	0.1	0.1	0.9
01/09/04 12:10	07/10/04 10:30	0.4	0.5	0.1	0.2	1.2
07/10/04 10:35	20/11/04 10:30	0.3	0.7	0.2	0.3	1.5
20/11/04 10:30	18/12/04 08:45	1.7	0.5	0.1	0.2	2.4
18/12/04 08:45	18/01/05 11:15	0.9	0.4	0.1	0.2	1.6
18/01/05 11:25	16/02/05 07:20	0.1	0.3	0.1	0.1	0.6
16/02/05 07:30	23/03/05 10:52	0.6	0.5	0.2	0.3	1.5
23/03/05 10:52	28/04/05 09:35	0.2	0.5	0.2	0.2	1.2
28/04/05 09:36	30/05/05 13:00	1.2	0.6	0.1	0.5	2.4
30/05/05 13:00	30/06/05 10:20	0.5	0.3	0.1	0.5	1.4
30/06/05 10:15	08/08/05 10:21	0.4	0.4	0.0	0.2	1.1
08/08/05 10:21	13/09/05 14:35	0.3	0.4	0.1	0.3	1.0
Total		***6.9***	***5.5***	***1.4***	***3.1***	***16.9***
Site 7						
01/08/04 15:01	01/09/04 08:24	0.1	0.3	0.1	0.1	0.6
01/09/04 13:45	07/10/04 13:30	0.4	0.4	0.1	0.2	1.2
07/10/04 13:35	20/11/04 14:35	0.1	0.7	0.2	0.4	1.4
20/11/04 14:35	18/12/04 09:40	0.5	0.3	0.1	0.1	1.1
18/12/04 09:40	18/01/05 15:10	1.2	0.3	0.1	0.2	1.8
18/01/05 15:16	16/02/05 09:15	0.3	0.3	0.1	0.1	0.7
16/02/05 09:30	23/03/05 13:05	0.9	0.3	0.1	0.3	1.6
23/03/05 13:12	28/04/05 11:20	0.2	0.4	0.1	0.2	1.0
28/04/05 11:20	30/05/05 14:10	0.7	0.5	0.1	0.4	1.7
30/05/05 14:10	30/06/05 11:25	0.4	0.2	0.0	0.2	0.9
30/06/05 11:23	08/08/05 11:25	0.4	0.3	0.0	0.2	0.9
08/08/05 11:25	13/09/05 11:41	0.3	0.2	0.1	0.2	0.7
Total		***5.7***	***4.2***	***1.1***	***2.6***	***13.7***

Table 18a Cont

Date on	Date off	NH_3 meq m^{-2}	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	total meq m^{-2}
Site 8						
03/08/04 09:07	01/09/04 11:05	0.1	0.4	0.1	0.1	0.8
01/09/04 11:15	07/10/04 15:00	1.0	0.6	0.1	0.3	2.0
07/10/04 15:05	20/11/04 16:30	0.4	0.9	0.2	0.4	1.8
20/11/04 16:30	18/12/04 11:30	0.7	0.5	0.1	0.2	1.5
18/12/04 11:30	18/01/05 17:17	0.2	0.4	0.2	0.2	1.0
18/01/05 17:25	16/02/05 10:40	0.1	0.4	0.1	0.2	0.8
16/02/05 11:15	23/03/05 14:31	1.5	0.4	0.1	0.3	2.4
23/03/05 14:35	28/04/05 11:50	0.2	0.6	0.2	0.3	1.2
28/04/05 11:51	30/05/05 16:00	0.8	0.6	0.1	0.4	1.9
30/05/05 16:01	30/06/05 12:30	0.2	0.3	0.0	0.2	0.8
30/06/05 12:35	08/08/05 12:35	0.4	0.6	0.0	0.3	1.3
08/08/05 12:35	13/09/05 15:50	0.3	0.5	0.1	0.4	1.3
Total		***6.0***	***6.4***	***1.3***	***3.2***	***16.9***
Site 9						
05/08/04 15:00	03/09/04 18:00	1.9	0.5	0.0	0.0	2.5
03/09/04 18:00	07/10/04 20:30	3.0	0.6	0.1	0.1	3.8
07/10/04 20:35	20/11/04 18:00	3.5	0.6	0.1	0.1	4.3
20/11/04 18:00	20/12/04 11:30	3.2	0.4	0.0	0.1	3.6
20/12/04 11:30	20/01/05 10:15		0.3	0.1	0.0	0.4
20/01/05 10:45	16/02/05 18:00	3.2	0.3	0.1	0.1	3.6
16/02/05 18:10	23/03/05 15:20	3.5	0.5	0.0	0.1	4.1
23/03/05 15:26	28/04/05 13:42	2.8	0.6	0.1	0.1	3.6
28/04/05 13:45	30/05/05 18:04	4.7	0.9	0.1	0.2	5.9
30/05/05 18:08	30/06/05 13:30	1.3	0.6	0.0	0.1	2.0
30/06/05 13:25	08/08/05 17:30	2.7	0.8	0.0	0.1	3.7
08/08/05 17:45	15/09/05 18:00	2.1	0.7	0.0	0.2	3.0
Total		***31.9***	***6.7***	***0.7***	***1.1***	***40.4***
Site10						
02/08/04 15:00	01/09/04 10:50	0.3	0.1	0.0	0.0	0.4
01/09/04 10:50	01/10/04 12:35	0.6	0.1	0.0	0.1	0.8
01/10/04 12:35	01/12/04 10:30	0.9	0.1	0.1	0.3	1.4
01/12/04 12:00	27/01/05 14:00	1.1	0.2	0.2	0.3	1.7
27/01/05 14:00	18/02/05 09:30	0.4	0.1	0.1	0.0	0.6
18/02/05 09:30	17/03/05 11:30	1.0	0.1	0.0	0.1	1.3
17/03/05 11:30	28/04/05 08:00	1.6	0.2	0.0	0.3	2.1
28/04/05 08:00	19/05/05 10:00	1.0	0.2	0.1	0.2	1.4
19/05/05 10:15	05/07/05 11:05	1.3	0.2	0.0	0.2	1.7
05/07/05 11:15	05/08/05 13:20	1.0	0.1	0.0	0.3	1.5
05/08/05 13:20	15/09/05 12:00	1.2	0.1	0.0	0.2	1.5
Total		***10.4***	***1.3***	***0.6***	***2.0***	***14.4***

Table 18b. Dry deposition fluxes of nitrogen and sulfur from February 2007 to August 2008. Totals are given in bold italics.

Date on	Date off	NH_3 meq m^{-2}	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	total meq m^{-2}
Site 1						
04/05/07 11:22	14/06/07 09:39	0.3	0.2	0.08	0.2	0.7
14/06/07 09:39	02/08/07 11:05	0.3	0.2	0.11	0.2	0.7
02/08/07 11:10	09/09/07 10:30	0.4	0.2	0.10	0.3	1.0
09/09/07 10:35	25/10/07 16:10	1.1	0.3	0.09	0.2	1.6
25/10/07 16:20	09/11/07 09:22	0.1	0.0	0.04	0.1	0.3
09/11/07 09:18	09/01/08 09:15	0.7	0.2	0.13	0.2	1.3
09/01/08 09:25	08/02/08 12:20	18.9	0.1	0.07	0.1	19.2
08/02/08 12:30	12/03/08 13:15	0.4	0.1	0.07	0.2	0.8
12/03/08 13:15	27/04/08 10:50	0.7	0.2	0.12	0.3	1.4
27/04/08 11:10	04/06/08 10:30	0.3	0.2	0.10	0.3	0.9
04/06/08 10:30	17/07/08 09:45	0.3	0.2	0.06	0.1	0.6
17/07/08 09:48	14/08/08 11:05	0.2	0.1	0.05	0.1	0.4
Total		***23.5***	***2.1***	***1.0***	***2.3***	***28.9***
Site 3						
29/01/07 11:00	22/02/07 10:51	1.0	0.1	0.04	0.1	1.3
22/02/07 11:00	20/03/07 08:51	0.5	0.2	0.06	0.2	0.9
20/03/07 08:55	04/05/07 12:59	0.5	0.3	0.20	0.3	1.3
04/05/07 12:59	14/06/07 08:24	0.3	0.2	0.06	0.1	0.6
14/06/07 08:24	02/08/07 13:20	0.4	0.2	0.16	0.3	1.0
02/08/07 13:23	09/09/07 12:30	0.3	0.3	0.13	0.2	1.0
09/09/07 12:35	25/10/07 14:10	0.3	0.3	0.18	0.3	1.1
25/10/07 14:20	09/11/07 10:42	0.2	0.1	0.05	0.1	0.3
09/11/07 10:46	09/01/08 10:46	0.5	0.3	0.17	0.2	1.2
09/01/08 10:50	08/02/08 13:50	0.2	0.2	0.09	0.1	0.6
08/02/08 14:05	12/03/08 11:25	0.5	0.2	0.10	0.2	1.0
12/03/08 11:30	27/04/08 14:03	0.4	0.3	0.22	0.3	1.3
27/04/08 15:00	04/06/08 12:20	0.2	0.3	0.12	0.3	0.9
04/06/08 12:30	17/07/08 11:17	0.3	0.2	0.07	0.1	0.6
17/07/08 11:25	14/08/08 09:00	0.2	0.1	0.07	0.1	0.5
Total		***5.8***	***3.3***	***1.7***	***2.8***	***13.6***
Site 4						
03/05/07 10:12	07/06/07 09:12	0.2	0.3	0.07	0.1	0.8
07/06/07 09:12	04/08/07 08:05	0.4	0.4	0.15	0.2	1.2
04/08/07 08:25	12/09/07 09:19	0.9	0.6	0.15	0.3	2.0
12/09/07 09:26	16/10/07 14:10	0.9	0.8	0.20	0.2	2.1
16/10/07 14:11	08/11/07 09:40	0.1	0.4	0.11	0.2	0.8
08/11/07 09:36	08/01/08 09:35	0.7	1.0	0.24	0.5	2.4
08/01/08 09:45	07/02/08 11:00	0.4	0.6	0.14	0.2	1.3
07/02/08 11:00	11/03/08 08:55	1.0	0.5	0.13	0.3	1.9
11/03/08 09:05	21/04/08 07:55	0.7	0.7	0.14	0.3	1.9
21/04/08 07:46	03/06/08 11:19	0.6	0.7	0.13	0.4	1.9
04/06/08 11:25	14/07/08 09:50	0.9	0.4	0.10	0.2	1.6
14/07/08 09:55	14/08/08 11:05	0.6	0.4	0.14	0.2	1.3
Total		***7.3***	***6.8***	***1.7***	***3.2***	***19.0***
Site 5						
03/05/07 10:53	07/06/07 09:50	0.8	0.5	0.08	0.1	1.5
07/06/07 09:50	04/08/07 09:50	1.7	0.8	0.19	0.4	3.1

Table 18b Cont

Date on	Date off	NH3 meq m-2	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	total meq m^{-2}
02/08/07 11:10	09/09/07 10:30	0.9	0.9	0.16	0.4	2.4
12/09/07 10:07	16/10/07 15:16	0.3	0.9	0.22	0.3	1.7
16/10/07 15:31	08/11/07 10:37	0.2	0.5	0.10	0.2	1.0
08/11/07 10:45	08/01/08 10:50	0.8	1.1	0.25	0.5	2.6
08/01/08 11:00	07/02/08 13:50	0.2	0.7	0.28	0.3	1.5
07/02/08 11:10	11/03/08 10:10	1.1	0.6	0.10	0.3	2.1
11/03/08 10:16	21/04/08 08:26	0.9	1.0	0.23	0.5	2.7
21/04/08 08:30	03/06/08 12:57	0.7	1.1	0.19	0.5	2.6
03/06/08 13:04	14/07/08 11:10	4.2	0.7	0.09	0.2	5.2
14/07/08 11:15	13/08/08 09:55	0.3	0.7	0.10	0.2	1.4
Total		***12.1***	***9.5***	***1.99***	***4.0***	***27.7***
Site 6						
03/05/07 11:16	07/06/07 10:20	1.0	0.3	0.05	0.1	1.5
07/06/07 10:20	04/08/07 09:12	1.1	0.4	0.16	0.3	2.0
04/08/07 09:25	12/09/07 10:27	1.2	0.6	0.13	0.2	2.2
12/09/07 10:30	16/10/07 14:55	0.9	0.7	0.20	0.2	2.0
16/10/07 14:55	08/11/07 10:07	0.2	0.3	0.08	0.1	0.7
08/11/07 10:17	08/01/08 10:15	1.2	0.8	0.21	0.5	2.6
08/01/08 10:20	07/02/08 12:10	1.1	0.4	0.12	0.2	1.9
07/02/08 12:20	11/03/08 09:35	1.2	0.3	0.09	0.2	1.8
11/03/08 09:59	21/04/08 09:20	2.2	0.5	0.16	0.5	3.3
21/04/08 09:30	03/06/08 12:20	1.0	0.6	0.14	0.4	2.1
03/06/08 12:35	14/07/08 12:00	1.7	0.4	0.10	0.2	2.4
14/07/08 12:05	13/08/08 10:49	1.5	0.4	0.08	0.2	2.2
Total		***14.3***	***5.8***	***1.52***	***3.1***	***24.7***
Site 7						
03/05/07 11:40	07/06/07 11:10	0.3	0.2	0.04	0.1	0.7
07/06/07 11:10	03/08/07 10:45	0.7	0.4	0.14	0.2	1.5
03/08/07 11:05	12/09/07 11:05	0.4	0.4	0.09	0.2	1.1
12/09/07 11:05	16/10/07 16:08	1.1	0.5	0.16	0.2	1.9
16/10/07 16:15	08/11/07 10:57	0.1	0.2	0.07	0.1	0.6
08/11/07 11:00	08/01/08 14:45	0.9	0.6	0.26	0.5	2.3
08/01/08 12:20	07/02/08 14:37	1.3	0.4	0.14	0.2	2.0
07/02/08 14:45	11/03/08 10:58	1.2	0.3	0.08	0.2	1.8
11/03/08 11:05	21/04/08 10:05	1.8	0.5	0.11	0.3	2.7
21/04/08 10:20	03/06/08 14:16	0.4	0.4	0.12	0.3	1.3
03/06/08 14:17	14/07/08 13:01	0.5	0.3	0.06	0.2	1.0
14/07/08 13:10	13/08/08 11:40	0.9	0.2	0.06	0.2	1.3
Total		***9.8***	***4.5***	***1.34***	***2.6***	***18.3***
Site 8						
24/01/07 15:00	22/02/07 09:15	0.3	0.6	0.10	0.2	1.2
22/02/07 09:20	20/03/07 12:22	0.8	0.4	0.07	0.3	1.5
20/03/07 12:22	03/05/07 13:55	1.0	0.7	0.24	0.5	2.4
03/05/07 13:55	07/06/07 12:20	0.9	0.5	0.07	0.1	1.7
07/06/07 12:20	03/08/07 10:00	1.7	0.6	0.16	0.4	2.9
03/08/07 10:15	12/09/07 12:11	0.6	0.8	0.15	0.4	2.0
12/09/07 12:20	16/10/07 11:00	0.5	0.7	0.13	0.3	1.6
16/10/07 11:05	08/11/07 11:38	0.1	0.3	0.11	0.1	0.7
08/11/07 11:55	08/01/08 12:05	1.1	0.9	0.21	0.4	2.7

Table 18b Cont

Date on	Date off	NH_3 Meq m^{-2}	NO_2 meq m^{-2}	SO_2 Meq m^{-2}	HNO_3 meq m^{-2}	total meq m^{-2}
08/01/08 14:55	07/02/08 15:35	0.4	0.4	0.13	0.2	1.2
07/02/08 15:50	11/03/08 11:55	0.8	0.4	0.09	0.2	1.6
11/03/08 12:00	21/04/08 10:57	0.6	0.6	0.17	0.4	1.8
21/04/08 11:08	03/06/08 14:55	0.5	0.9	0.16	0.4	2.0
03/06/08 15:13	14/07/08 14:02	1.3	0.4	0.07	0.2	2.0
14/07/08 14:02	13/08/08 13:09	1.1	0.5	0.09	0.2	1.8
Total		***11.8***	***8.8***	***1.96***	***4.4***	***27.0***
Site 9						
04/05/07 17:20	07/06/07 13:00	1.6	0.7	0.04	0.1	2.5
07/06/07 13:00	06/08/07 17:30	3.5	1.2	0.13	0.8	5.6
06/08/07 17:40	11/09/07 17:36	2.1	0.8	0.06	0.3	3.2
11/09/07 17:43	22/10/07 17:45	3.7	0.7	0.10	0.3	4.8
22/10/07 17:50	09/11/07 17:45	1.3	0.2	0.05	0.1	1.6
09/11/07 17:50	08/01/08 16:00	4.7	0.6	0.09	0.4	5.9
08/01/08 16:15	10/02/08 18:15	3.6	0.5	0.10	0.3	4.5
10/02/08 18:30	16/03/08 12:10	4.5	0.5	0.08	0.4	5.5
16/03/08 12:10	21/04/08 18:00	2.9	0.6	0.08	0.3	3.9
21/04/08 18:15	12/06/08 17:00	2.9	1.1	0.11	0.8	4.9
23/06/08 12:30	18/07/08 10:20	2.2	0.7	0.04	0.2	3.2
18/07/08 10:30	13/08/08 17:51	2.2	0.5	0.04	0.2	2.9
Total		***35.4***	***8.0***	***0.94***	***4.3***	***48.5***
Site10						
07/06/07 13:20	12/07/07 16:30	0.6	0.1	0.04	0.1	0.9
12/07/07 16:30	03/08/07 09:20	0.4	0.1	0.07	0.1	0.7
03/08/07 09:30	16/09/07 14:00	1.2	0.1	0.05	0.1	1.4
16/09/07 14:00	04/10/07 18:00	0.1	0.1	0.05	0.2	0.4
04/10/07 18:00	05/11/07 11:20	0.5	0.1	0.08	0.2	0.8
05/11/07 11:20	19/01/08 13:00	0.5		0.12	0.3	0.9
19/01/08 13:00	07/02/08 16:30	0.4	0.3	0.06	0.1	0.9
07/02/08 16:30	14/03/08 21:30		0.3	0.09	0.3	0.7
14/03/08 13:00	03/05/08 15:30	1.6	0.4	0.10	0.4	2.5
Total		***5.3***	***1.5***	***0.67***	***1.7***	***9.2***

Table 19a displays results for the total of the wet and dry annual deposition flux of nitrogen and sulfur estimated at the various sites, and the proportion of dry deposition measured during 2004/2005. The dry deposition results in the Table have been adjusted to give the total deposition flux for each gas over 365 days rather than over the sampling period to annual fluxes which can be directly compared with other sampling periods. Total wet and dry deposition fluxes are given for sites 3, 5, 6, 7 and 8 since rainwater samples were not collected at Sites 1, 4, 9 or 10. The total annual deposition flux of nitrogen and sulfur varied from 14.3 meq m^{-2} yr^{-1} at Site 3 to 24.3 meq m^{-2} yr^{-1} at Site 6; this represents an increase over the background at Site 3, to the lower Burrup sites which average about 21.1 meq m^{-2} yr^{-1}. The proportion of dry deposition is high at each site, in the range of about 69 % – 85 %, due to the low rainfall amounts compared with a constant deposition of gas to the surface.

Table 19a. Estimated annual deposition flux of nitrogen and sulfur for the 2004/2005 period.

Site	NH_4^+ meq m^{-2}	NO_3^- meq m^{-2}	$*SO_4^{2-}$ meq m^{-2}	NH_3 meq m^{-2}	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	Tot Dry meq m^{-2}	Total meq m^{-2}	% Dry
1				4.3	1.8	0.8	1.9	8.8		
3	0.7	0.6	0.9	6.5	2.3	1.1	2.1	12.1	14.3	84.4
4				4.9	5.3	1.5	2.6	14.2		
5	0.9	0.8	1.0	5.5	7.3	1.7	3.1	17.7	20.4	86.7
6	3.6	2.0	1.8	6.9	5.5	1.4	3.1	16.9	24.3	69.3
7	1.7	1.8	2.8	5.7	4.2	1.1	2.6	13.7	19.9	68.8
8	1.1	1.0	0.9	6.0	6.4	1.3	3.2	16.9	19.8	85.3
9	–	–	–	31.9	6.7	0.7	1.1	40.4		
10	–	–	–	10.4	1.3	0.6	2.0	14.4		

Table 19b presents the annual wet deposition fluxes for nitrate, ammonium and non sea-salt sulfate and the dry deposition fluxes for ammonia, nitrogen dioxide, sulfur dioxide and nitric acid gases measured during 2007/2008. During this period dry deposition was estimated at all sites and wet deposition at sites 1, 3, 4, 6, 7 and 8. The Table shows that ammonium is the major contributor to wet deposition during 2007/2008 when fluxes ranged from 1.1 meq m^{-2} at site 6 to 4.3 meq m^{-2} at site 8. This is slightly elevated over the ammonium wet deposition fluxes during 2004/2005 and reflects the higher rainfall volume during the latter sampling period. Although this is true, the wet deposition fluxes of ammonium at the back ground sites average about 3.4 meq m^{-2} and these are slightly higher at the lower Burrup sites which have an average of about 2.8 meq m^{-2}. This infers that most, if not all the ammonia wet deposition flux at all sites is produced via natural emissions of ammonia gas which are converted to particulate species as the result of gas to particle conversions as reactions 25 and 26 show.

Nitrate wet deposition fluxes average 1.4 meq m^{-2} at the background sites during compared to about 3.2 meq m^{-2} at the lower Burrup sites, showing the small enhancement which has already been observed for nitrogen dioxide gas concentrations, and is assumed to be the result of increased motor vehicle activity and industrial activity near these sites. Non sea-salt wet deposition fluxes are about 1.2 meq m^{-2} at the background sites and about 2.6 meq m^{-2} at the lower Burrup sites.

Dry deposition fluxes, given Table 19b for 2007/2008, show the general increase in fluxes going from the background at sites 1, 3 and 10 to sites 3, 4, 5, 6, 7, 8 and 9 on the lower Burrup. The fluxes measured at all sites are remarkably consistent when the 2004/2005 and 2007/2008 sampling periods are compared. It even appears that a small difference can be discerned for nitrogen dioxide fluxes measured at sites 1 and 3 between the two annual sampling periods. For example, nitrogen dioxide dry deposition fluxes are 1.8 meq m^{-2} and 1.6 meq m^{-2} at site 1 for the first sampling period and 2.3 meq $m^{-2}$and 2.2 meq m^{-2} for the second sampling period. During the corresponding periods the fluxes at site 10 were 1.3 meq m^{-2} and 1.6 meq m^{-2} which very similar to site 1.

The total dry deposition fluxes at the background sites (1, 3 and 10) averaged about 12 meq m^{-2}, which is very similar to the corresponding flux of 9 meq m^{-2} measured during the latter sampling period. This is

somewhat lower than the total of the dry deposition fluxes of sites on the lower Burrup area (average of sites 4 - 8) which were about 16 meq m^{-2} yr^{-1} during 2004/2005 and 18 meq m^{-2} yr^{-1} during the latter sampling period. Site 9 both in 2004.and 2005 had high dry deposition fluxes and this was largely due to ammonia gas deposition. As noted previously this is probably due to fertilizer use in Karratha, and it was not included in comparisons with background sites or the lower Burrup sites.

The total of the wet and dry deposition fluxes are given in Tables 19a and 19b along with the contribution dry deposition contributes to the total. The Tables indicate that the wet plus dry background deposition flux was about 14 meq m^{-2} yr^{-1}, both in 2004/2005 and 2007/2008; vey little change has occurred to that flux. In contrast to this the wet and dry deposition flux at site 8 has increased from about 20 meq m^{-2} yr^{-1} to about 32 meq m^{-2} yr^{-1} from the first to the second sampling period, site 7 has increased slightly, and the flux at site 6 has decreased slightly. The reason for the increase at site 8 is mainly due to the increased amount of rainfall which increases the wet deposition of the acidic ions. The corollary to this is the fraction that dry deposition contributes to the total is generally lower in 2007/2008 than it was during 2004/2005.

Table 19b. Estimated annual deposition flux of nitrogen and sulfur for the 2007/2008 period.

Site	NH_4^+ meq m^{-2}	NO_3^- meq m^{-2}	$*SO_4^{2-}$ meq m^{-2}	NH_3 meq m^{-2}	NO_2 meq m^{-2}	SO_2 meq m^{-2}	HNO_3 meq m^{-2}	Tot Dry meq m^{-2}	Total meq m^{-2}	% Dry
1	3.2	0.8	1.0	3.9	1.6	0.8	1.8	8.1	13.1	61.8
3	3.6	1.9	1.4	3.8	2.2	1.1	1.8	8.8	15.7	56.0
4	3.6	3.5	4.8	5.7	5.3	1.3	2.5	14.8	26.7	55.4
5				9.5	7.4	1.6	3.1	21.6		
6	1.1	1.0	0.9	11.1	4.5	1.2	2.4	19.3	22.3	86.5
7	2.4	1.6	1.5	7.7	3.5	1.0	2.0	14.3	21.4	66.8
8	4.3	6.7	3.1	7.6	5.7	1.3	2.9	17.4	31.6	55.1
9				27.7	6.2	0.7	3.3	37.9		
10				5.9	1.6	0.7	1.9	10.1		

The annual nitrogen plus sulfur deposition fluxes measured at the Burrup sites can be compared to previous studies carried out in polluted and unpolluted sites in Malaysia and Indonesia, and a remote site in Australia. At the relatively unpolluted Indonesian GAW station site at Bukit Koto Tabang, the wet plus dry deposition flux of nitrogen plus sulfur was 23.4 meq m^{-2} yr^{-1}, (Gillett et al., 2000) and 53 meq m^{-2} yr^{-1} at a relatively undisturbed site in the Cameron Highlands, north of Kuala Lumpur. In Australia, rainwater composition and gas concentrations were measured at Charles Point, about 13 kilometres west of Darwin, across Port Darwin and the annual wet and dry deposition flux of nitrogen plus sulfur was about 20 meq m^{-2} yr^{-1} at this site (Ayers et. al., 2000).

The critical load concept can be used to compare with deposition fluxes to determine if adverse effects could result to rock or aboriginal rock art. For a fuller discussion of this see Ayers et al. (2000). The critical load has been defined as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified elements of the environment do not occur according to our current knowledge" (Nilsson and Grennfelt, 1988). In a global assessment of ecosystem sensitivity to acidic deposition Cinderby et al. (1998) have determined a critical load or deposition flux of 25 meq m^{-2} yr^{-1} for the most sensitive areas of the world. This means that depositions of about 25 meq m^{-2} yr^{-1} would only have a detrimental effect on the most sensitive ecosystems. The depositions presented in Table 19a and 19b indicate that some sites are subject to depositions of about 25 meq m^{-2} yr^{-1} in 2004/2005 and about 32 meq m^{-2} yr^{-1} in. 2007/2008. Given that the overall precision of passive gas measurements in this study was about ± 20% Site 6, for example, would have a deposition flux ranging from about 19.5 meq m^{-2} yr^{-1} to 29.2 meq m^{-2} yr^{-1}, which is only just above that for areas which are very sensistive to acid deposition. The wet plus dry deposition flux at site 8 during 2007/2008 would probably range from about 26 meq m^{-2} yr^{-1} to 38 meq m^{-2} yr^{-1} given the precision of the passive samplers. In fact the assessment by Cinderby et al. (1988) lists 5 sensitivity classes consisting of 25 meq m^{-2} yr^{-1}, 50 meq m^{-2} yr^{-1}, 100 meq meq m^{-2} yr^{-1}, 150 meq meq m^{-2} yr^{-1}, 200 meq m^{-2} yr^{-1} and >200 meq meq m^{-2} yr^{-1}, and places the Burrup area in the least sensitive class. This

means that the critical load for the Burrup area is at least 200 meq m^{-2} yr^{-1}, and since this is significantly more than the observed deposition fluxes at the sites they are unlikely to cause any deleterious effects to rock or rock art on the Burrup Peninsula. In fact the anthropogenic contribution of the total wet and dry deposition flux estimated at these sites is probably less than the data presented in Tables 19a and 19b. The deposition of ammonia, for example does not vary much from the background sites to the industrial areas suggesting that most of the ammonia deposition results from natural rather than anthropogenic sources. This is also true for some of the other species, but the contributions can not easily be quantified.

The deposition fluxes estimated for any of the Burrup sites are very low when compared to heavily polluted areas in Malaysia and Indonesia. In the heavily polluted urban site at Petaling Jaya, near Kuala Lumpur the total deposition flux of nitrogen and sulfur ranged from 279 meq m^{-2} yr^{-1} to 483 meq m^{-2} yr^{-1}, over 5 consecutive years from 1990 to 1998 (Ayers et al., 2000). At other polluted sites in Malaysia total wet and dry deposition fluxes ranged from 122 meq m^{-2} yr^{-1} to 345 meq m^{-2} yr^{-1} (Ayers et al., 2000). In a study by Gillett et al. (2000) at Jakarta and Bogor total deposition fluxes of nitrogen and sulfur were about 240 meq m^{-2} yr^{-1} were estimated during 1992 and 1996.

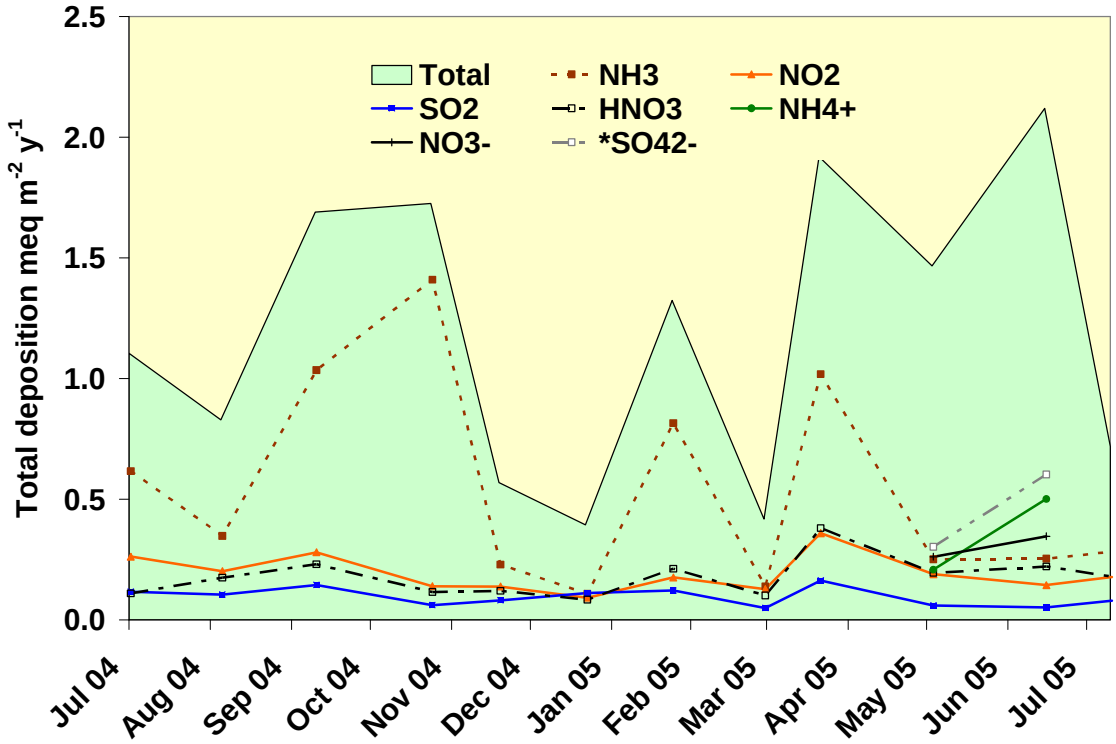


Figure 27. Total annual deposition of nitrogen and sulfur at site 3 during 2005/2005.

Figures 27 to 30 have been included to show how various species contribute to the total wet plus dry deposition. Sites 3 and 6 are included because they are typical of deposition fluxes estimated at the background areas and in the industrial areas respectively. Site 8 is included because in 2007/2008 it was the site with the highest deposition flux.

Figures 27 and 28 show the contributions the various sources of nitrogen and sulfur make to the total wet and dry deposition flux of nitrogen and sulfur estimated for Site 3 during 2004/2005 respectively. Figure 27 shows that for most months deposition of ammonia is the largest contributor to the total annual sulfur and nitrogen deposition flux at Site 3; on an annual basis it contributes about 45% of the total deposition. This is because the other gases have a lower deposition flux at the background sites, and because ammonia appears to be derived from natural sources, since the concentrations vary little from site to site. The contribution of ammonia deposition flux is reduced during the periods when rain fell due to the supplementary contributions to the total deposition flux in the form of non sea-salt sulfate, ammonium and

nitrate derived from rain. Over the whole year dry deposition at site 3 is about 84 % of the total deposition and nitrogen deposition accounts for about 86 % of the total compared with only about 13 % for sulfur. Figures 29 to 31 show the wet and dry deposition fluxes at site 6 in 2004/2005 and 2007/2008 and site 8 during 2007/2008. They show that ammonia gas is a large contributor to the overall deposition flux, and that deposition fluxes increase during periods of rain.

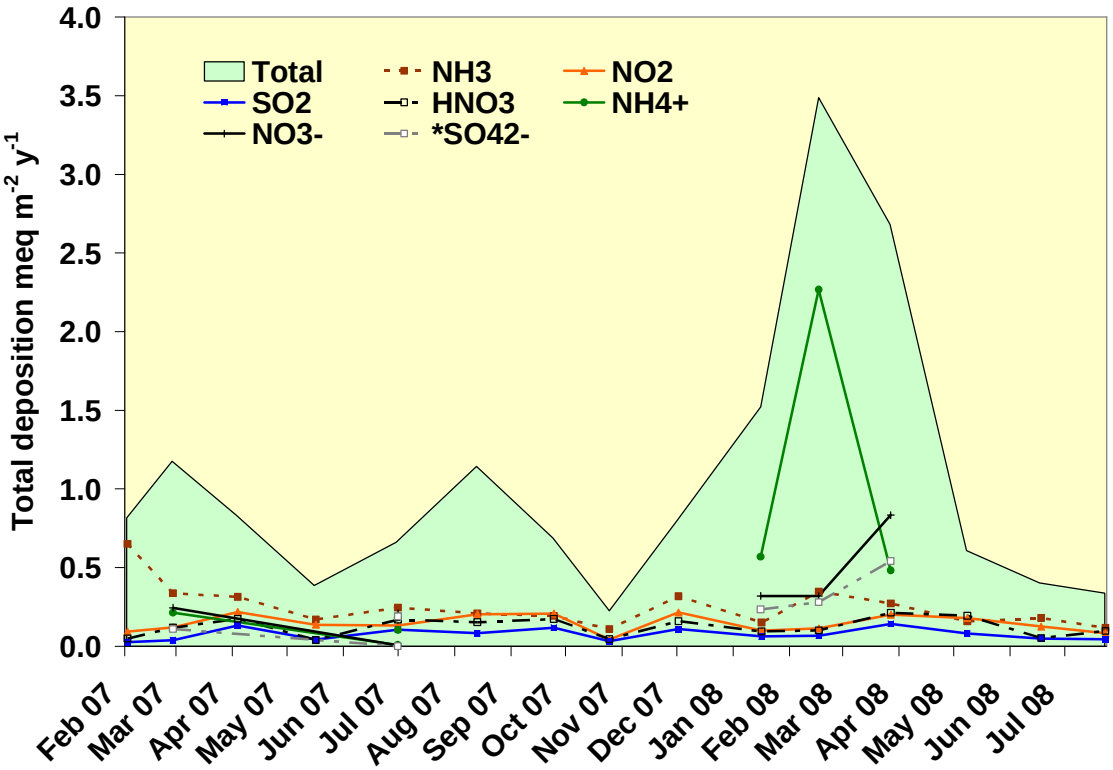


Figure 28. Total annual deposition of nitrogen and sulfur at site 3 during 2007/2008.

The monthly deposition fluxes of sulfur and nitrogen at Site 6 during 2004/2005, and their individual contributions to them are shown in Figure 29. At this site nitrogen deposition, from ammonia gas, makes a large fraction of the total deposition during a few of the months. During other periods nitrogen deposition from nitrogen dioxide is a significant proportion of the total deposition flux. During the period around the 16th February 2005 wet deposition of ammonium, nitrate and sulfate make large contributions to the total flux during that month. Dry deposition over the whole year is about 69 % and nitrogen deposition is about 87 % compared with only about 13 % deposition of sulfur. Figure 30 shows the distribution of the various species which contribute to the total wet plus dry deposition at site 6. Again ammonia gas deposition makes a large contribution, about half of the total during 2007/2008, and wet deposition especially of ammonium ion during March 2008.

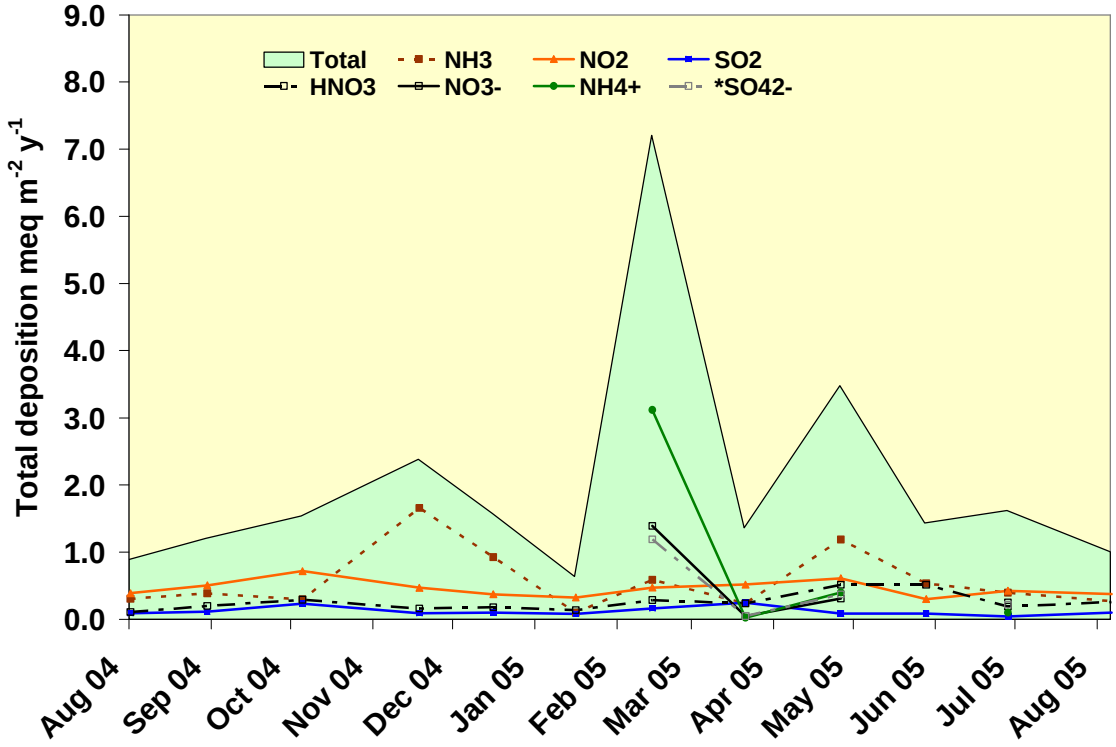


Figure 29. Total annual deposition of nitrogen and sulfur at site 6 during 2004/2005.

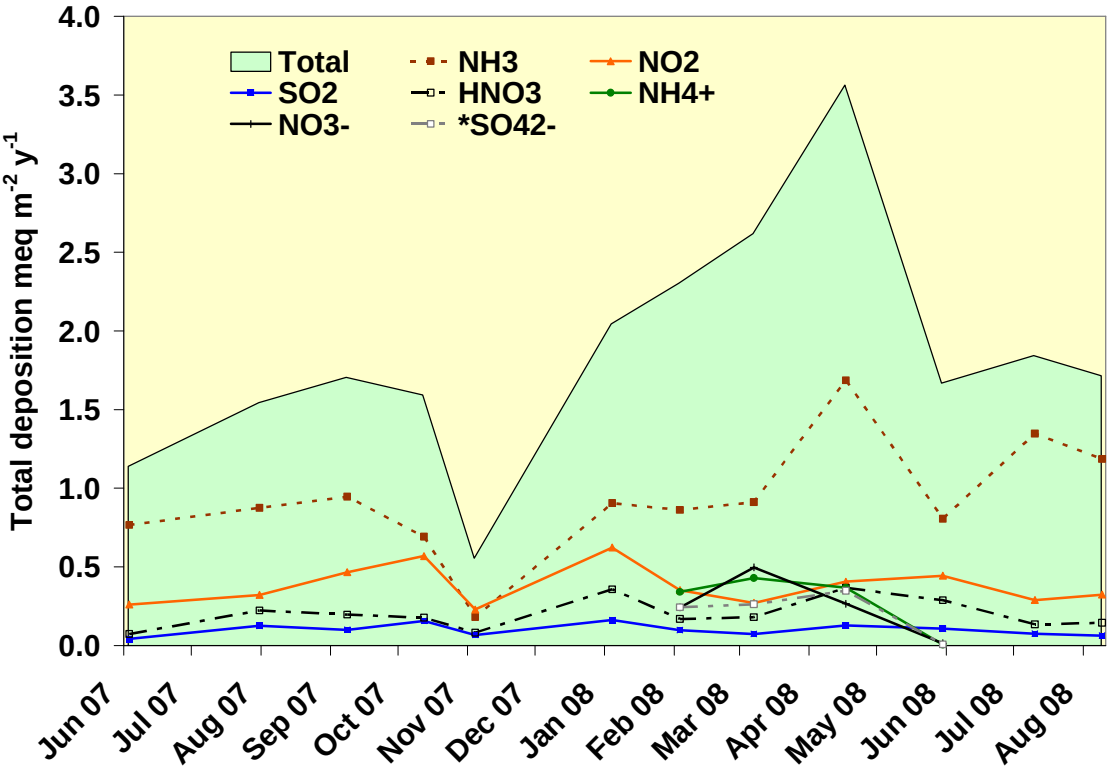


Figure 30. Total annual deposition of nitrogen and sulfur at site 6 during 2007/2008.

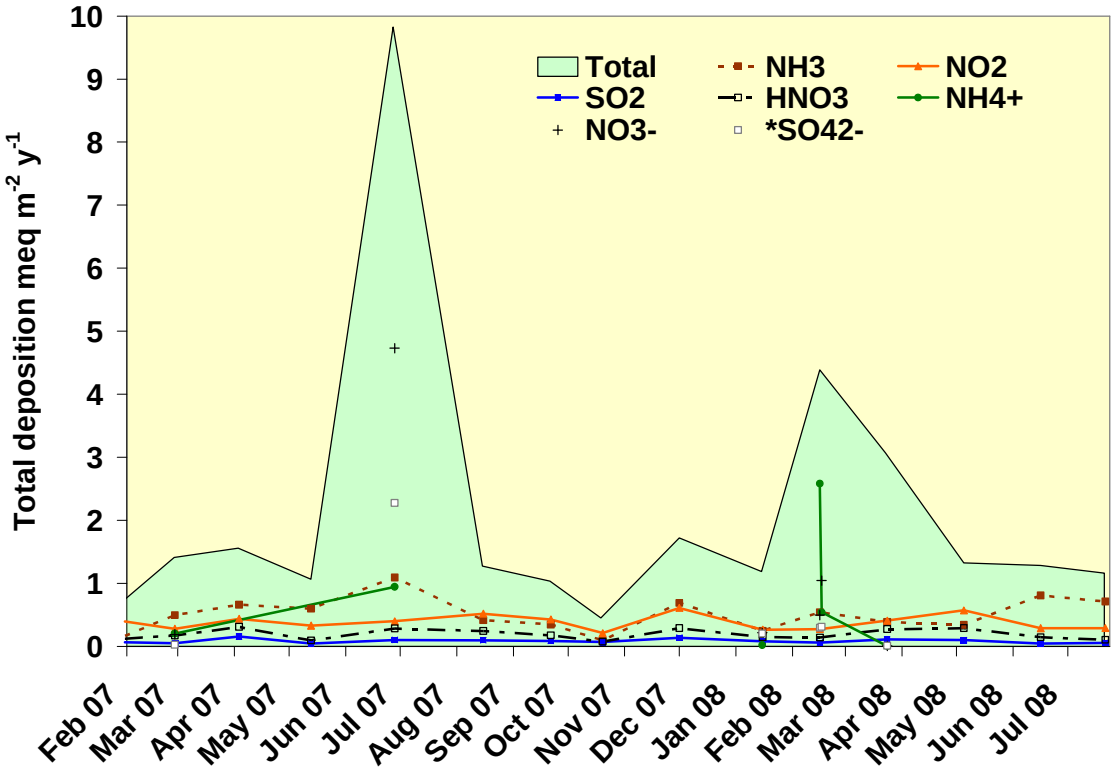


Figure 30. Total annual deposition of nitrogen and sulfur at site 8 during 2007/2008.

5.7 Comparison with modelling studies.

The annual average concentration of nitrogen dioxide, sulfur dioxide and ammonia, and their deposition are provided in this study, and they can be used to compare with the results of a modelling study (SKM, 2003). SKM, (2003) modelled annual average nitrogen dioxide concentrations around the Burrup Peninsula area using two model approaches: TAPM and CALPUFF. In both cases the modelling was done for the industry which was located on the Burrup Peninsula in 2003. Since the concentrations of gases have varied little between the 2004/2005 and 2007/2008 sampling periods this section only compares the concentrations measured during 2004/2005 with the results of the modelling study.

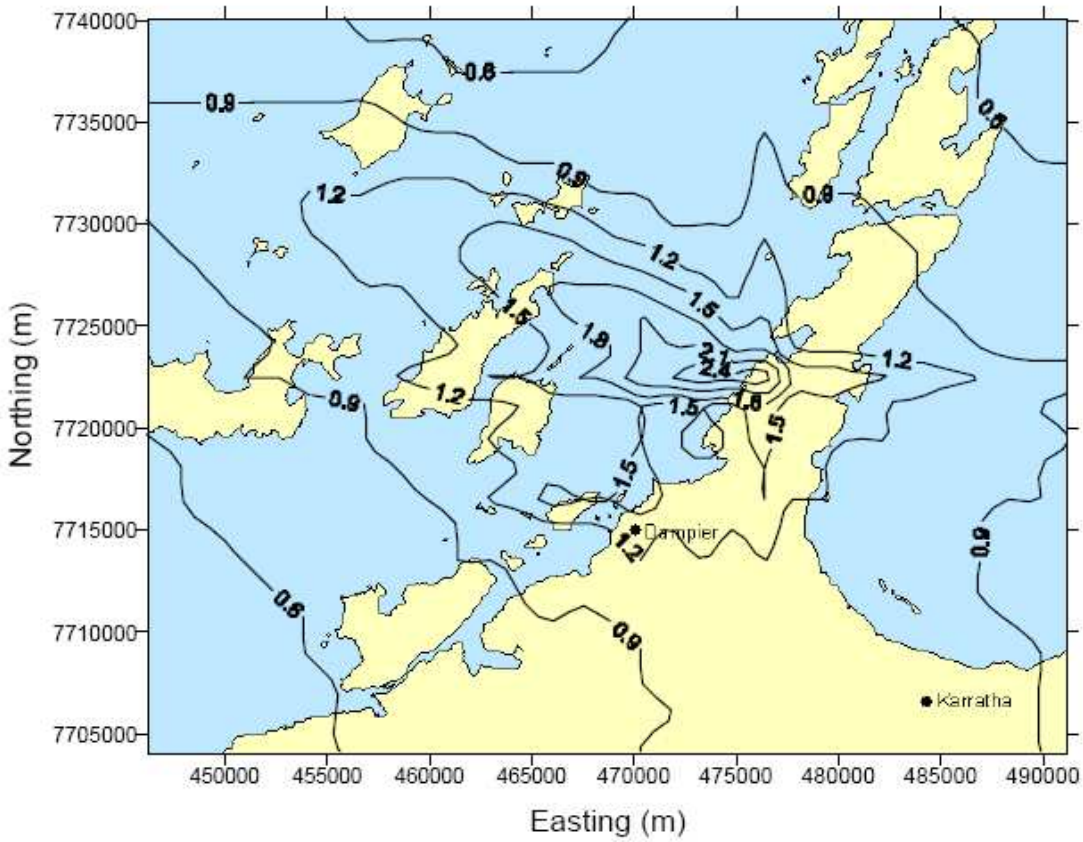


Figure 31. TAPM predicted annual nitrogen dioxide concentrations (ppb) for existing industry (SKM, 2003).

Figure 31 shows the results nitrogen dioxide concentrations predicted by TAPM modelling for the Burrup Peninsula, and the surrounding region. The TAPM model results suggest higher nitrogen dioxide concentrations compared with the results of the CALPUFF modelling shown in Figure 32. The results of nitrogen dioxide concentrations produced in TAPM and CALPUFF modelling are summarised in Table 20, and compared with annual average concentrations at the sites used in the current study.

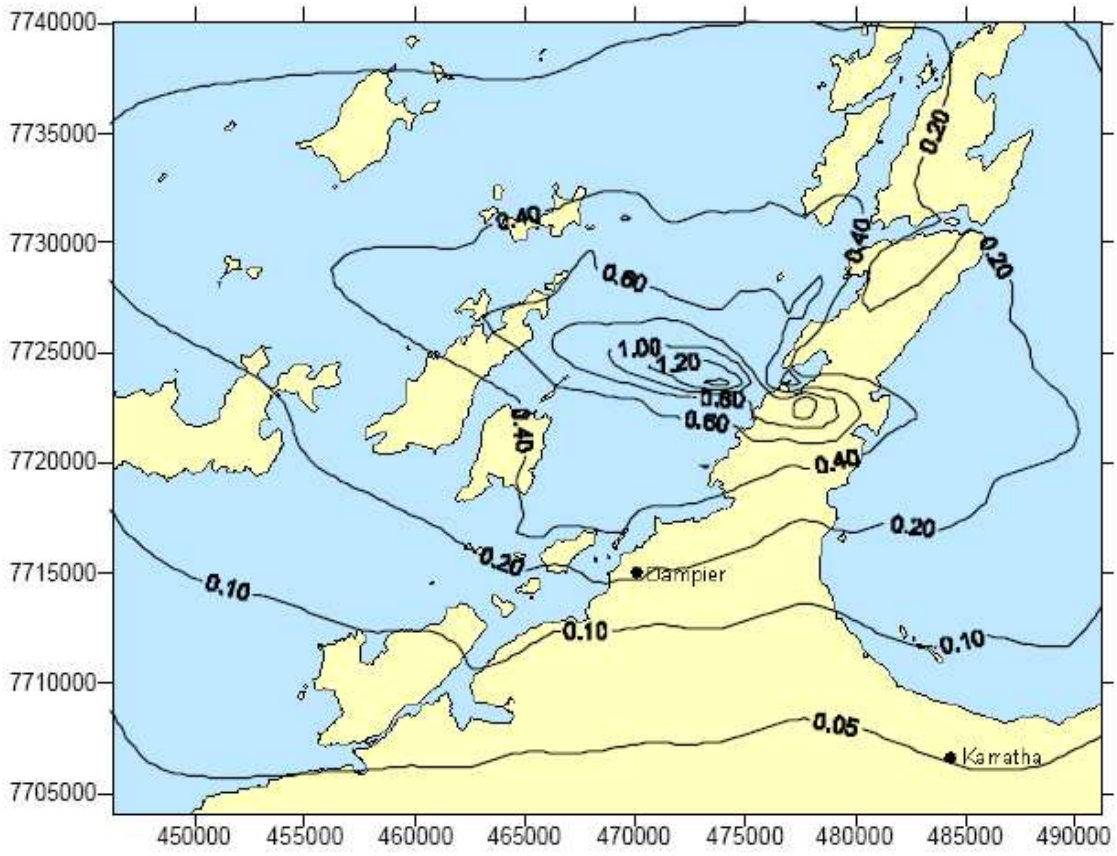


Figure 32. CALPUFF predicted annual nitrogen dioxide concentrations (ppb) for existing industry, (SKM, 2003).

Of the two modelling approaches, TAPM appears to compare much better with the measured values generated during this study. The modelled CALPUFF results appears to underestimate nitrogen dioxide concentrations at all sites, relative to measured values. The TAPM results however, are quite close to the measured concentrations at Sites 1, 3 and 4, and a little lower than the measured results at the other sites. At Site 9, Karratha the TAPM modelled result is about 1 ppb and appears to underestimate the nitrogen dioxide concentration of 2.22 measured at this site.

Table 20. Annual average nitrogen dioxide concentrations at Burrup sites produced by TAPM and CALPUFF modelling, and measured nitrogen dioxide concentrations at the sites.

Site	Measured ppb	TAPM ppb	CALPUFF ppb
1	0.59	0.7	0.20
3	0.74	0.8	0.20
4	1.75	1.8	1.00
5	2.41	1.4	0.35
6	1.83	1.4	0.30
7	1.44	1.4	0.25
8	2.12	1.4	0.30
9	2.22	1.0	0.05

The deposition fluxes of nitrogen dioxide produced from TAPM modelling are presented in Figure 33, in kg ha^{-1} yr^{-1}. Table 21 shows these results compared with the estimated nitrogen deposition fluxes generated in this measurement program. The TAPM modelled results are converted from kg ha^{-1} yr^{-1} to meq m^{-2} yr^{-1} in order to make the comparison. The data in the Table show that the TAPM results are substantially lower than those estimated by measurements. This is in part due to the lower nitrogen dioxide concentrations

TAPM predicts at some sites; Site 9, for example. The other reason is probably due to the deposition velocity used in TAPM compared to the values used in this study. When the concentration ratio between TAPM and this study is considered, the ratio of the deposition flux produced in this study appears to be about 3.3 times that from TAPM. This suggests that the deposition rate used in this study is about 3.3 times that in TAPM. Deposition fluxes of nitrogen dioxide estimated from CALPUFF are not considered here since they were much lower than the TAPM predictions.

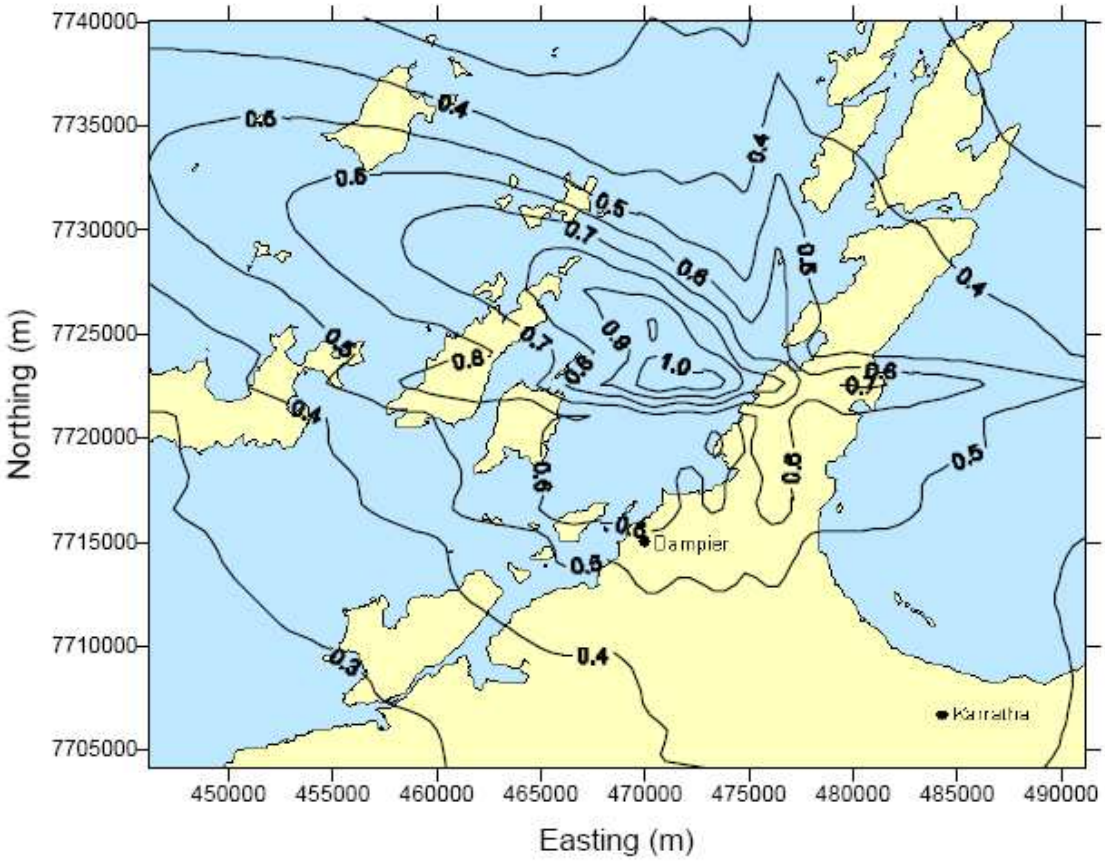


Figure 33. TAPM predicted annual nitrogen dioxide deposition (kg ha^{-1} yr^{-1}) for existing industry, (SKM, 2003).

Table 21. Annual average deposition flux of nitrogen dioxide estimated from measurements at the Burrup Peninsula sites compared with TAPM model results.

Site	Measured meq m^{-2} yr^{-1}	TAPM meq m^{-2} yr^{-1}
1	1.82	0.54
3	2.29	0.91
4	5.25	1.06
5	7.34	1.30
6	5.49	1.28
7	4.20	1.30
8	6.39	1.30
9	6.73	0.93

In the report by SKM (2003) TAPM and CALPUFF models were used to predict the annual average sulfur dioxide concentrations for the industrial conditions existing at that time. Figures 34 and 35 are taken from SKM (2003), and show the sulfur dioxide concentrations predicted by TAPM and CALPUFF respectively. The minimum sulfur dioxide concentration predicted by TAPM is 100 ppt and the maximum is about 600

ppt in contours just north and east of Dampier. CALPUFF modelling shown in Figure 35 gives more detailed results; the minimum contour is 20 ppt and the maximum is about 800 ppt near East Intercourse Island, immediately east of Dampier.

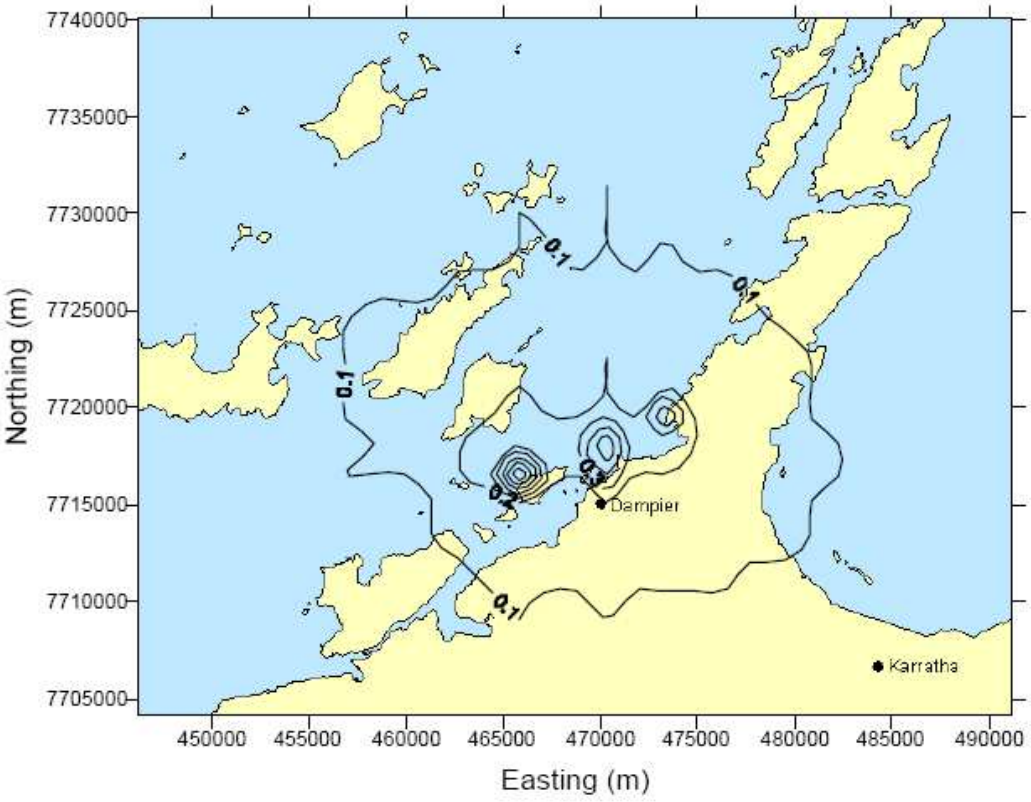


Figure 34. TAPM predicted annual sulfur dioxide concentrations (ppb) for existing industry (SKM, 2003).

A summary of the annual average concentrations of sulfur dioxide estimated by TAPM and CALPUFF modelling and measured in the current study is given in Table 22. The Table shows that the measured sulfur dioxide concentrations are quite close to the concentrations predicted by both TAPM and CALPUFF. The concentrations measured in this study generally seem to be a little higher than the modelled results, especially for TAPM, which gives lower values than CALPUFF, except at Site 8 which has measured concentrations slightly lower than the models predict.

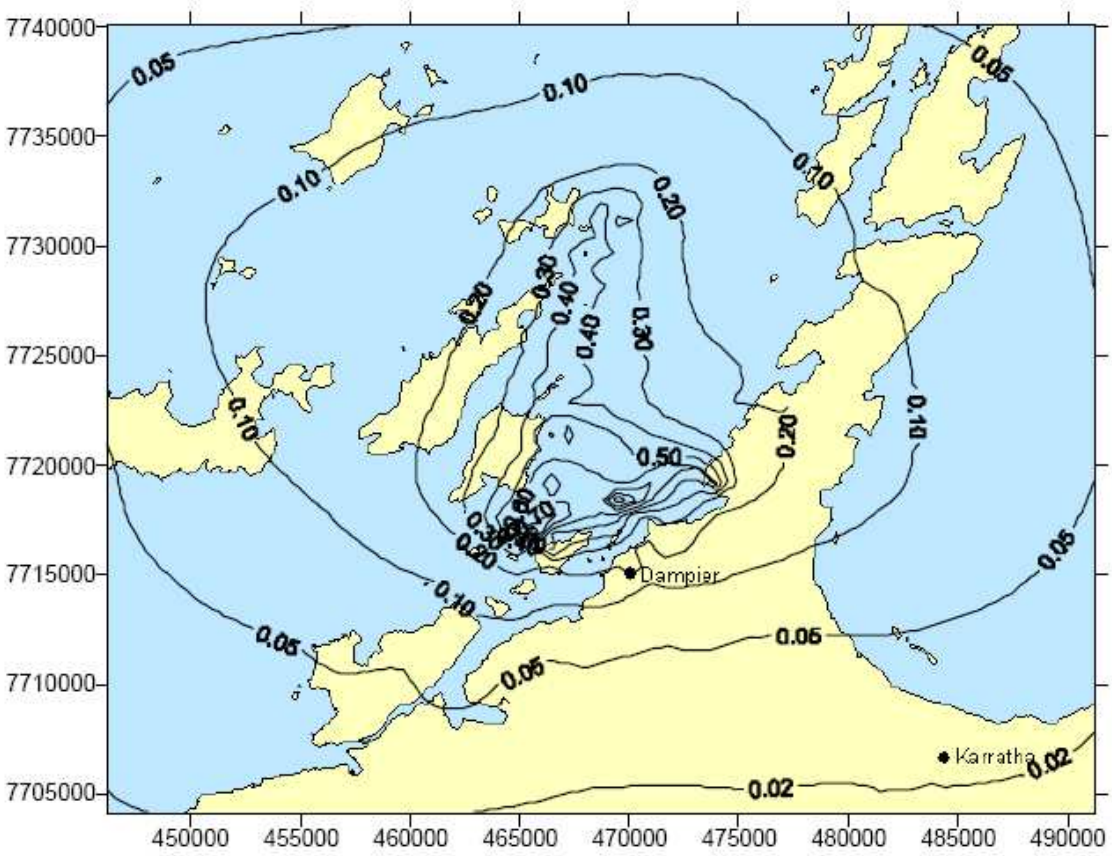


Figure 35. CALPUFF predicted annual sulfur dioxide concentrations (ppb) for existing industry (SKM, 2003).

Table 22. Annual average sulfur dioxide concentrations at Burrup sites produced by TAPM and CALPUFF modelling, and measured sulfur dioxide concentrations at the sites.

Site	Measured ppt	TAPM ppt	CALPUFF ppt
1	101	<100	50
3	139	<100	90
4	178	130	200
5	215	190	220
6	241	120	170
7	141	150	130
8	164	220	250
9	89	<100	28

The deposition fluxes have also been predicted using TAPM and CALPUFF models and the results of these are taken from SKM, (2003), and are displayed in Figures 36 and 37. A summary of these results, converted to meq m^{-2} yr^{-1}, are given in Table 23, along with the results measured at each site. The Table shows that the TAPM and CALPUFF results range from <0.16 meq m^{-2} yr^{-1} at Site 9 to 0.78 meq m^{-2} yr^{-1} at Site 8. However, the deposition fluxes estimated from the gas concentration measured in this study, and the deposition velocity are significantly greater than the fluxes suggested by the models. The measured fluxes are usually a factor of about 3 – 5 times more than the model predictions, and this may be due to the deposition velocities used in the conversion of the gas concentration to a deposition flux.

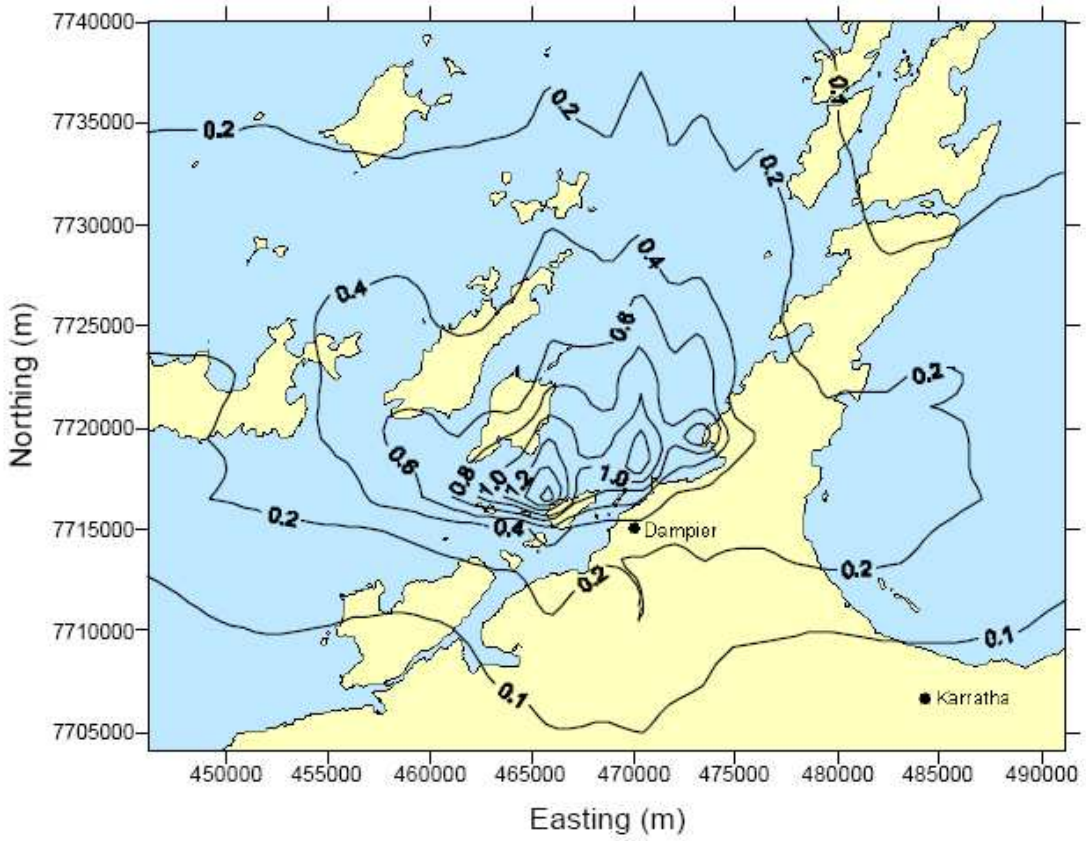


Figure 36. TAPM predicted annual sulfur dioxide deposition (kg ha^{-1} yr^{-1}) for existing industry (SKM, 2003).

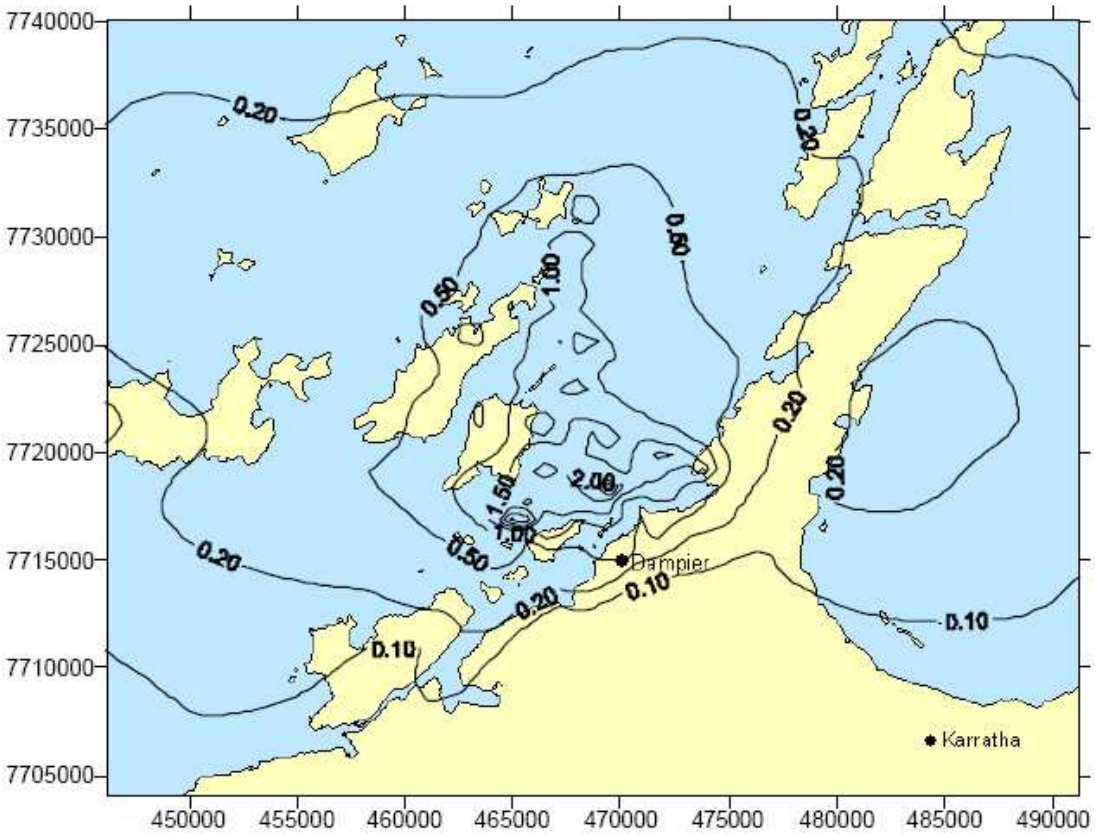


Figure 37. CALPUFF predicted annual sulfur dioxide deposition (kg ha^{-1} yr^{-1}) for existing industry (SKM, 2003).

Table 23. Annual average deposition flux of sulfur dioxide estimated from measurements at the Burrup Peninsula sites compared with TAPM model results.

Site	Measured meq m^{-2} yr^{-1}	TAPM meq m^{-2} yr^{-1}	CALPUFF meq m^{-2} yr^{-1}
1	0.81	0.16	0.22
3	1.14	0.16	0.30
4	1.46	0.42	0.45
5	1.74	0.62	0.55
6	1.42	0.55	0.31
7	1.15	0.55	0.31
8	1.32	0.62	0.78
9	0.70	0.13	<0.16

6. SUMMARY AND CONCLUSIONS

This document reports results from a study of air pollution, rainwater composition and acid deposition on the Burrup Peninsula during two distinct periods from August 2004 until September 2005 (2005/2005) and from February 2007 until September 2008 (2007/2008). A total of nine sites were used in the study, 7 of these, Sites 1, 3, 4, 5, 6, 7, and 8, were on the Burrup Peninsula, one was located in Karratha, and the other at Mardie Station 81 Km from Karratha on a bearing of 215º. The study incorporated measurements of concentrations of gases including sulfur dioxide, nitrogen dioxide, nitric acid, ammonia and BTEX. TSP samples were collected at seven sites, and conditional sampling for PM_{10} was carried out at Site 8 and near the ore loading facilities at Parker Point. Sampling was conducted over approximate monthly periods and TSP concentration and chemical composition were measured on the samples. Measurements of ionic composition and pH were made on rainwater samples collected at sites 3, 5, 6, 7 and 8, during 2004/2005 and at sites 1, 3, 4, 6, 7 and 8 in 2007/2008. An aerosol spectrometer was used to measure the size distribution of TSP at each of the sites over a limited period. Size distributions from the measurements were converted to mass concentration and deposition flux to estimate the magnitude of dust deposition at the sites on the Burrup. A DustTrak instrument was used at sire 8 to measure PM_{10} concentrations at a frequency of 3 minutes. Wind speed and wind direction data was also collected at site 8 at 2 minute at a frequency of 2 minutes, and this was combined with the PM_{10} data to gain some insight on how the ore loading facilities at parker Pint influenced PM_{10} concentrations at site 8.

The gas concentrations in all cases are very low when compared to polluted urban areas. Annual average, and monthly average nitrogen dioxide, sulfur dioxide and nitric acid concentrations varied very little at each between the two sampling periods. There were some small increases in ammonia gas concentrations at sites 5, 6, 7 and 8 which are located near to industry. At site 5 the increase was due almost entirely to one month in June/July when the concentration averaged 3.0 ppb. Local background concentrations, deduced from sites 1, 3 and 10 during 2004/2005 and 2007/2008 were ammonia 0.5 ppb, nitrogen dioxide 0.6 ppb, sulfur dioxide 116 ppt and nitric acid 154 ppt. Ammonia concentrations showed little spatial variation in concentration indicating that most ambient ammonia has a natural source. There was some small enhancement of nitrogen dioxide, sulfur dioxide and nitric acid concentrations over those at sites which are assumed to represent the local background. Even so, the concentrations of ammonia, nitrogen dioxide, sulfur dioxide and nitric acid are very low compared with measurements made at other remote locations. BTEX concentrations were also very low at all sites and for all sampling periods. The benzene concentration at the background sites 1, 3 and 10 was about 19 ppt and the average at the other sites about 21 ppt. Benzene, and other BTEX gas concentrations showed little enhancement over the background levels suggesting that their concentration has a large natural component.

During 2004/2005 TSP mass concentrations at the background sites (1 and 3), had an annual average of approximately 18 $\mu g\ m^{-3}$ compared with 22 $\mu g\ m^{-3}$ measured during 2007/2008. In contrast to this the annual average concentrations on the lower Burrup was approximately 34 $\mu g\ m^{-3}$ during 2004/2005 and 34 $\mu g\ m^{-3}$ during 2007/2008. TSP on the lower Burrup, where most of the industrial and anthropogenic activities occur, is moderately enhanced over the local background concentration. Samples collected near Parker Point and at other sites were analysed for a range of elements including iron. TSP at Sites 4, 5, 7 and 8 displayed a higher fraction of iron and less sea-salt than the background TSP at Site 1. This indicates that the observed increase in TSP at these sites could be due to dust from the ore loading and transportation processes. This suggestion is reinforced by enhanced PM_{10} concentrations of periods at Site 8 when the air was passing over the ore loading facilities at Parker Point reached site 8.

An aerosol spectrometer was used for a short period to produce particle mass-size distribution data and dust deposition fluxes at each of the sites. The average mass concentrations of 30 $\mu g\ m^{-3}$ calculated from the aerosol spectrometer data at Site 8 are consistent with those measured with the DustTrak instrument. The dust deposition flux at Sites 1 and 3 averaged about 10 mg $m^{-2}\ day^{-1}$ compared to about 68 mg $m^{-2}\ day^{-1}$ at

site 8 and about 30 mg m^{-2} day^{-1} at sites 4, 5, 6, and 7. They indicate a higher dust deposition flux in the more industrialised area of the Burrup, especially at Site 8 which is closest to the ore loading facilities.

The total deposition flux of nitrogen and sulfur was determined at sites 3, 5, 6, 7 and 8 in 2004/2005, and sites 1, 3, 4, 6, 7 and 8 in 2007/2008. This included dry deposition in the form of ammonia, nitrogen dioxide, sulfur dioxide and nitric acid gases, and in wet deposition in the form of nitrate, ammonia and non sea-salt sulfate in rainwater. The study shows that the total wet and dry deposition flux of nitrogen and sulfur of 14 meq m^{-2} yr^{-1} is typical for areas of the Burrup Peninsula which have no or little anthropogenic influences. It also shows that 60 % - 85 % of the deposition is contributed by dry deposition. At the sites close to industrial influences the deposition fluxes of nitrogen and sulfur ranged from 20 mg m^{-2} day^{-1} to 24 mg m^{-2} day^{-1} in 2004/2005 and 21 mg m^{-2} day^{-1} to 33 mg m^{-2} day^{-1} in 2007/2008. The slight increase in the flux from 2004/2005 to 2007/2008 is due largely to an increase in the amount of rainfall in the latter period, and on the Burrup Peninsula this appears to be the major variable in the flux of nitrogen and sulfur to the ground.

The measurements are similar to previous measurements recorded at another remote location in Australia, and lower than relatively unpolluted sites in Malaysia, and at the Indonesian GAW station. The deposition fluxes at each site were very low and lower than the critical load for even the most sensitive areas to nitrogen and sulfur deposition. Previous ecological studies have suggested that the Burrup Peninsula area is quite insensitive to acid deposition, and a corollary is that the deposition flux of nitrogen and sulfur is only a small fraction of the critical load. The deposition fluxes observed are not of the magnitude which is expected to cause any deterioration of the rock on the Burrup Peninsula.

The concentrations of nitrogen dioxide and sulfur dioxide concentrations observed in this study were compared with results of modelled concentrations predicted using TAPM and CALPUFF. Nitrogen dioxide concentrations at Sites 1, 3 and 4 compared favourably with TAPM predictions, but tended to be a little higher at the other sites especially at Site 9 Karratha, where the measured concentration was about double that predicted by TAPM. The nitrogen dioxide gas concentrations measured in this study compared closely with the TAPM results and were much higher than those predicted by CALPUFF. However, CALPUFF predicts higher sulfur dioxide concentrations than TAPM and are more consistent with the concentrations measured in this study.

Both TAPM and CALPUFF provide deposition fluxes of nitrogen and sulfur and comparisons with the measured fluxes shows that the models always predict less than that suggested by the measured values provided by the current study. The average annual nitrogen dioxide deposition fluxes predicted by TAPM are lower than the measured values by a factor of between about 2 and 5, and may be due to a combination of a lower TAPM predicted concentration and the deposition velocity used in the current study. The predicted deposition fluxes of sulfur dioxide from TAPM and CALPUFF models are similar to each other, but less than those measured in the current study. Measured deposition fluxes are higher than the models by a factor of around 2 to 5, and this may be due to the deposition velocities used in the models, and in the current study.

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9. APPENDIX A ELEMENTAL AND ION CONCENTRATIONS OF TSP SAMPLES COLLECTED DURING 2004/2005.

Table A1. Elemental concentrations of TSP and PM_{10} samples at various sites measured by PIXE analysis.

Site	Date on	Date off	Na $\mu g\ m^{-3}$	Al $\mu g\ m^{-3}$	Si $\mu g\ m^{-3}$	P $\mu g\ m^{-3}$	S $\mu g\ m^{-3}$	Cl $\mu g\ m^{-3}$	K $\mu g\ m^{-3}$	Ca $\mu g\ m^{-3}$
1	29/07/04	02/09/04	2.822	0.107	0.520	0.000	0.235	2.151	0.094	0.202
1	02/09/04	08/10/04	3.405	0.133	0.556	0.000	0.354	2.321	0.131	0.203
1	08/10/04	21/11/04	5.020	0.238	0.945	0.000	0.644	2.848	0.284	0.341
1	21/11/04	17/12/04	8.232	0.364	1.331	0.000	0.857	5.752	0.315	0.495
1	17/12/04	19/01/05	8.574	0.313	1.329	0.000	0.972	5.856	0.272	0.690
1	19/01/05	21/02/05	9.597	0.267	0.977	0.000	0.908	6.842	0.237	0.556
1	21/02/05	28/03/05	5.784	0.451	1.637	0.000	0.681	3.337	0.239	0.358
1	28/03/05	18/04/05	3.092	0.153	0.686	0.000	0.455	1.920	0.109	0.149
1	18/04/05	31/05/05	1.919	0.340	0.549	0.025	0.301	1.886	0.279	0.149
1	31/05/05	13/07/05	0.000	0.208	0.643	0.001	0.153	1.133	0.063	0.098
1	13/07/05	07/08/05	2.411	0.080	0.332	0.000	0.273	1.494	0.061	0.097
1	07/08/05	14/09/05	3.005	0.145	0.351	0.000	0.278	2.145	0.083	0.125
4	01/08/04	01/09/04	2.138	0.247	0.828	0.000	0.223	1.912	0.116	0.709
4	01/09/04	07/10/04	0.636	0.130	0.559	0.000	0.118	0.842	0.071	0.619
4	07/10/04	20/11/04	3.240	0.900	3.415	0.000	0.699	4.279	0.495	3.610
4	20/11/04	18/12/04	8.251	1.175	3.916	0.000	0.835	5.532	0.560	3.427
4	18/12/04	18/01/05	9.681	1.078	4.006	0.000	0.976	6.477	0.500	4.645
4	18/01/05	16/02/05	8.495	0.819	2.917	0.000	0.938	6.326	0.416	3.734
4	16/02/05	23/03/05	5.632	0.863	3.125	0.000	0.617	3.605	0.364	2.150
4	23/03/05	28/04/05	2.306	0.566	1.987	0.000	0.426	1.841	0.216	2.004
4	28/04/05	30/05/05	1.705	0.420	1.550	0.000	0.384	1.710	0.230	1.623
4	30/05/05	30/06/05	4.373	0.191	0.791	0.000	0.355	3.475	0.149	0.297
4	30/06/05	08/08/05	1.223	0.248	0.917	0.000	0.273	1.310	0.099	0.638
4	08/08/05	13/09/05	2.949	0.628	2.112	0.000	0.310	2.210	0.245	2.845
5	07/10/04	20/11/04	4.411	0.387	1.526	0.000	0.676	3.015	0.327	0.508
5	18/01/05	16/02/05	7.665	0.407	1.485	0.000	0.753	5.277	0.228	0.523
5	16/02/05	23/03/05	4.192	0.661	2.363	0.000	0.481	2.155	0.271	0.533
5	23/03/05	28/04/05	2.022	0.351	1.280	0.000	0.345	0.915	0.143	0.349
5	28/04/05	30/05/05	1.186	0.284	1.026	0.000	0.329	0.850	0.179	0.280
5	08/08/05	13/09/05	2.383	0.200	0.738	0.000	0.281	1.705	0.112	0.278
7	01/08/04	01/09/04	2.411	0.332	1.277	0.000	0.212	1.986	0.148	0.456
7	01/09/04	07/10/04	2.363	0.337	1.200	0.000	0.268	1.673	0.150	0.543
7	07/10/04	20/11/04	4.526	0.563	1.913	0.000	0.597	2.967	0.329	0.802
7	20/11/04	18/12/04	6.524	1.017	3.318	0.000	0.849	4.812	0.438	1.269
7	18/12/04	18/01/05	6.927	0.701	2.707	0.000	0.740	5.088	0.327	1.188
7	18/01/05	16/02/05	22.390	2.045	7.481	0.000	2.172	16.370	0.951	3.087
7	16/02/05	23/03/05	3.920	0.772	2.685	0.000	0.455	2.310	0.289	0.679
7	23/03/05	28/04/05	2.156	0.549	1.687	0.000	0.341	1.247	0.174	0.691
7	28/04/05	30/05/05	2.208	0.285	0.869	0.000	0.333	1.257	0.155	0.320
7	30/05/05	30/06/05	3.904	0.152	0.567	0.000	0.272	2.905	0.107	0.205
7	30/06/05	08/08/05	2.070	0.180	0.685	0.000	0.251	1.338	0.090	0.278
7	08/08/05	13/09/05	2.751	0.235	0.790	0.000	0.271	1.902	0.110	0.411
8	03/08/04	01/09/04	1.783	0.351	1.251	0.000	0.208	1.772	0.127	0.501
8	01/09/04	07/10/04	2.702	0.370	1.286	0.000	0.292	1.748	0.151	0.522
8	07/10/04	20/11/04	4.557	0.694	2.308	0.000	0.541	3.046	0.302	1.167
8	20/11/04	18/12/04	6.306	0.771	2.341	0.000	0.844	4.738	0.373	1.059

Table A1 cont

Site	Date on	Date off	Na µg m^{-3}	Al µg m^{-3}	Si µg m^{-3}	P µg m^{-3}	S µg m^{-3}	Cl µg m^{-3}	K µg m^{-3}	Ca µg m^{-3}
8	18/12/04	18/01/05	8.129	0.848	3.250	0.000	1.058	6.813	0.392	1.291
8	18/01/05	16/02/05	9.630	1.297	4.481	0.000	0.967	6.671	0.508	1.964
8	16/02/05	23/03/05	3.281	0.621	2.114	0.000	0.411	2.082	0.226	0.550
8	23/03/05	28/04/05	12.630	2.041	7.251	0.000	1.732	7.730	0.745	2.192
8 Cond	04/08/04	01/09/04	1.282	0.219	0.747	0.002	0.162	1.408	0.084	0.291
8 Cond	01/09/04	07/10/04	1.146	0.256	0.913	0.001	0.280	1.740	0.126	0.304
8 Cond	07/10/04	20/11/04	0.000	0.475	1.634	0.006	0.568	1.757	0.383	0.485
8 Cond	20/11/04	18/12/04	0.000	0.823	2.781	0.001	0.664	2.940	0.516	0.452
8 Cond	18/12/04	18/01/05	4.063	1.357	3.862	0.000	0.748	4.496	0.400	0.905
8 Cond	18/01/05	16/02/05	5.949	0.932	2.705	0.000	0.762	6.874	0.327	0.763
8 Cond	16/02/05	23/03/05	2.364	0.766	2.381	0.000	0.577	2.687	0.250	0.416
8 Cond	23/03/05	28/04/05	0.000	0.462	1.039	0.000	0.304	0.761	0.111	0.237
8 Cond	28/04/05	30/05/05	1.345	0.205	0.616	0.000	0.353	1.109	0.142	0.188
8 Cond	30/05/05	30/06/05	3.120	0.181	0.556	0.000	0.274	2.464	0.106	0.232
8 Cond	30/06/05	08/08/05	1.428	0.264	0.596	0.001	0.233	0.856	0.070	0.260
8 Cond	08/08/05	13/09/05	2.066	0.303	0.898	0.001	0.249	1.780	0.110	0.399
8Hi	04/08/04	02/09/04	3.367	1.497	4.282	0.000	0.355	2.714	0.370	1.706
8Hi	02/09/04	08/10/04	3.573	0.923	2.547	0.000	0.419	2.402	0.301	1.783
8Hi	08/10/04	30/11/04	5.749	1.074	2.857	0.000	0.522	3.264	0.405	2.838
8Hi	30/11/04	20/12/04	7.193	1.214	3.034	0.000	0.754	5.317	0.376	3.668
8Hi	20/12/04	20/01/05	8.472	0.731	1.804	0.000	1.019	6.148	0.294	1.297
8Hi	20/01/05	23/02/05	58.009	5.862	17.449	0.000	5.822	38.542	2.543	19.839
8Hi	23/02/05	31/03/05	4.881	0.955	2.577	0.000	0.663	2.844	0.289	1.446
8Hi	31/03/05	02/05/05	3.465	1.365	4.087	0.000	0.516	1.727	0.409	1.651
8Hi	02/05/05	09/06/05	2.051	1.802	4.535	0.009	0.422	1.337	0.373	1.407
8Hi	09/06/05	01/07/05	0.000	1.160	1.987	0.021	0.197	2.053	0.077	0.267
8Hi	01/07/05	09/08/05	0.000	1.723	2.529	0.063	0.299	1.202	0.096	0.616
8Hi	09/08/05	16/09/05	4.152	1.200	2.673	0.000	0.487	2.849	0.233	2.668

Table A2. Elemental concentrations of TSP and PM_{10} samples at various sites measured by PIXE analysis.

Site	Date on	Date off	Ti µg m^{-3}	V µg m^{-3}	Cr µg m^{-3}	Mn µg m^{-3}	Fe µg m^{-3}	Co µg m^{-3}	Ni µg m^{-3}	Cu µg m^{-3}
1	29/07/04	02/09/04	0.017	0.002	0.000	0.007	0.771	0.004	0.000	0.000
1	02/09/04	08/10/04	0.016	0.002	0.002	0.008	0.616	0.007	0.001	0.002
1	08/10/04	21/11/04	0.025	0.004	0.000	0.013	0.874	0.012	0.000	0.004
1	21/11/04	17/12/04	0.039	0.000	0.000	0.010	0.647	0.008	0.004	0.013
1	17/12/04	19/01/05	0.041	0.000	0.000	0.014	0.754	0.007	0.002	0.004
1	19/01/05	21/02/05	0.032	0.000	0.000	0.011	0.451	0.000	0.000	0.001
1	21/02/05	28/03/05	0.053	0.002	0.004	0.018	1.012	0.008	0.003	0.010
1	28/03/05	18/04/05	0.017	0.004	0.000	0.006	0.537	0.002	0.001	0.004
1	18/04/05	31/05/05	0.017	0.000	0.003	0.007	0.471	0.005	0.004	0.001
1	31/05/05	13/07/05	0.012	0.004	0.009	0.014	0.585	0.001	0.003	0.025
1	13/07/05	07/08/05	0.010	0.002	0.001	0.006	0.501	0.003	0.000	0.000
1	07/08/05	14/09/05	0.011	0.003	0.000	0.007	0.482	0.003	0.000	0.001
4	01/08/04	01/09/04	0.027	0.000	0.002	0.012	0.945	0.009	0.001	0.005
4	01/09/04	07/10/04	0.019	0.000	0.006	0.010	0.826	0.007	0.001	0.002
4	07/10/04	20/11/04	0.122	0.010	0.000	0.070	4.319	0.043	0.003	0.012
4	20/11/04	18/12/04	0.154	0.000	0.002	0.044	2.366	0.037	0.005	0.007
4	18/12/04	18/01/05	0.155	0.000	0.000	0.043	2.766	0.028	0.000	0.001
4	18/01/05	16/02/05	0.121	0.008	0.000	0.045	2.234	0.025	0.000	0.007
4	16/02/05	23/03/05	0.119	0.002	0.002	0.040	2.920	0.032	0.001	0.005
4	23/03/05	28/04/05	0.074	0.003	0.000	0.021	1.867	0.018	0.000	0.003
4	28/04/05	30/05/05	0.055	0.001	0.004	0.020	1.264	0.013	0.000	0.007
4	30/05/05	30/06/05	0.019	0.001	0.003	0.016	0.896	0.010	0.003	0.004
4	30/06/05	08/08/05	0.034	0.001	0.001	0.012	0.975	0.008	0.001	0.001
4	08/08/05	13/09/05	0.084	0.000	0.001	0.023	1.743	0.016	0.000	0.001
5	07/10/04	20/11/04	0.044	0.004	0.001	0.029	4.080	0.023	0.000	0.005
5	18/01/05	16/02/05	0.047	0.002	0.000	0.022	1.707	0.025	0.000	0.005
5	16/02/05	23/03/05	0.084	0.003	0.003	0.030	2.967	0.025	0.003	0.011
5	23/03/05	28/04/05	0.044	0.002	0.002	0.025	2.559	0.023	0.003	0.019
5	28/04/05	30/05/05	0.031	0.001	0.001	0.018	1.968	0.014	0.000	0.006
5	08/08/05	13/09/05	0.027	0.003	0.003	0.022	2.710	0.023	0.002	0.010
7	01/08/04	01/09/04	0.042	0.001	0.002	0.021	2.696	0.014	0.001	0.005
7	01/09/04	07/10/04	0.038	0.003	0.000	0.024	3.094	0.022	0.001	0.007
7	07/10/04	20/11/04	0.066	0.002	0.003	0.041	5.118	0.042	0.000	0.012
7	20/11/04	18/12/04	0.110	0.005	0.012	0.053	5.864	0.054	0.011	0.028
7	18/12/04	18/01/05	0.100	0.004	0.004	0.036	4.047	0.045	0.002	0.011
7	18/01/05	16/02/05	0.281	0.008	0.000	0.099	12.602	0.111	0.005	0.046
7	16/02/05	23/03/05	0.104	0.003	0.003	0.036	3.164	0.028	0.001	0.012
7	23/03/05	28/04/05	0.068	0.003	0.004	0.023	2.788	0.024	0.000	0.010
7	28/04/05	30/05/05	0.028	0.001	0.002	0.016	1.809	0.010	0.000	0.000
7	30/05/05	30/06/05	0.020	0.000	0.000	0.010	1.155	0.007	0.000	0.008
7	30/06/05	08/08/05	0.023	0.001	0.002	0.010	0.976	0.005	0.001	0.003
7	08/08/05	13/09/05	0.026	0.003	0.003	0.020	2.495	0.021	0.003	0.005
8	03/08/04	01/09/04	0.049	0.006	0.000	0.041	6.107	0.041	0.000	0.009
8	01/09/04	07/10/04	0.051	0.003	0.001	0.045	7.565	0.063	0.002	0.015
8	07/10/04	20/11/04	0.110	0.009	0.007	0.087	19.292	0.177	0.009	0.049
8	20/11/04	18/12/04	0.073	0.010	0.011	0.057	7.920	0.054	0.000	0.013
8	18/12/04	18/01/05	0.124	0.003	0.005	0.082	13.210	0.109	0.003	0.015
8	18/01/05	16/02/05	0.179	0.012	0.003	0.132	19.678	0.194	0.020	0.056
8	16/02/05	23/03/05	0.070	0.004	0.005	0.035	5.275	0.046	0.000	0.009
8	23/03/05	28/04/05	0.217	0.000	0.042	0.173	29.294	0.251	0.001	0.068

Table A2 cont

Site	Date on	Date off	Ti µg m^{-3}	V µg m^{-3}	Cr µg m^{-3}	Mn µg m^{-3}	Fe µg m^{-3}	Co µg m^{-3}	Ni µg m^{-3}	Cu µg m^{-3}
8 Cond	04/08/04	01/09/04	0.019	0.000	0.002	0.009	0.726	0.006	0.001	0.002
8 Cond	01/09/04	07/10/04	0.027	0.003	0.046	0.017	1.186	0.000	0.006	0.001
8 Cond	07/10/04	20/11/04	0.041	0.000	0.002	0.025	2.883	0.016	0.000	0.008
8 Cond	20/11/04	18/12/04	0.081	0.003	0.022	0.023	1.638	0.029	0.010	0.011
8 Cond	18/12/04	18/01/05	0.109	0.000	0.108	0.044	4.166	0.025	0.061	0.021
8 Cond	18/01/05	16/02/05	0.070	0.000	0.004	0.018	1.586	0.019	0.000	0.012
8 Cond	16/02/05	23/03/05	0.075	0.001	0.002	0.022	1.614	0.010	0.002	0.009
8 Cond	23/03/05	28/04/05	0.028	0.001	0.089	0.013	1.398	0.008	0.048	0.011
8 Cond	28/04/05	30/05/05	0.020	0.000	0.000	0.009	0.690	0.000	0.000	0.002
8 Cond	30/05/05	30/06/05	0.018	0.001	0.000	0.008	0.569	0.005	0.001	0.004
8 Cond	30/06/05	08/08/05	0.020	0.001	0.049	0.008	0.836	0.004	0.025	0.004
8 Cond	08/08/05	13/09/05	0.028	0.001	0.009	0.018	1.978	0.009	0.000	0.004
8Hi	04/08/04	02/09/04	0.167	0.005	0.007	0.164	29.857	0.234	0.013	0.055
8Hi	02/09/04	08/10/04	0.102	0.004	0.007	0.119	16.905	0.131	0.010	0.042
8Hi	08/10/04	30/11/04	0.140	0.005	0.008	0.146	24.653	0.293	0.058	0.169
8Hi	30/11/04	20/12/04	0.127	0.002	0.012	0.133	19.797	0.135	0.007	0.033
8Hi	20/12/04	20/01/05	0.079	0.012	0.003	0.091	12.067	0.083	0.000	0.019
8Hi	20/01/05	23/02/05	0.825	0.036	0.000	0.708	94.333	0.806	0.009	0.209
8Hi	23/02/05	31/03/05	0.104	0.003	0.007	0.103	12.535	0.078	0.001	0.021
8Hi	31/03/05	02/05/05	0.179	0.004	0.016	0.149	17.493	0.112	0.000	0.016
8Hi	02/05/05	09/06/05	0.205	0.002	0.021	0.232	34.902	0.161	0.000	0.216
8Hi	09/06/05	01/07/05	0.105	0.000	0.018	0.201	27.673	0.116	0.000	0.271
8Hi	01/07/05	09/08/05	0.107	0.010	0.010	0.364	34.789	0.041	0.000	0.019
8Hi	09/08/05	16/09/05	0.157	0.005	0.020	0.299	45.562	0.292	0.000	0.053

Table A3. Elemental concentrations of TSP and PM_{10} samples at various sites measured by PIXE analysis, total elemental mass, gravimetric mass and fraction of iron in gravimetric mass.

Site	Date on	Date off	Zn $\mu g\ m^{-3}$	Br $\mu g\ m^{-3}$	Pb $\mu g\ m^{-3}$	Total elemental $\mu g\ m^{-3}$	Gravimetric Mass $\mu g\ m^{-3}$	% Total mass	% Fe
1	29/07/04	02/09/04	0.004	0.005	0.000	10.10	11.59	87.16	6.65
1	02/09/04	08/10/04	0.004	0.007	0.000	12.20	14.04	86.90	4.39
1	08/10/04	21/11/04	0.009	0.021	0.010	18.90	24.30	77.77	3.60
1	21/11/04	17/12/04	0.013	0.024	0.014	26.90	32.44	82.93	2.00
1	17/12/04	19/01/05	0.005	0.011	0.014	30.00	35.03	85.63	2.15
1	19/01/05	21/02/05	0.005	0.015	0.008	30.80	36.57	84.22	1.23
1	21/02/05	28/03/05	0.007	0.008	0.017	22.40	25.14	89.10	4.03
1	28/03/05	18/04/05	0.003	0.008	0.020	11.70	13.57	86.23	3.95
1	18/04/05	31/05/05	0.009	0.007	0.002	10.20	25.04	40.73	1.88
1	31/05/05	13/07/05	0.013	0.013	0.012	14.30	33.60	42.56	1.74
1	13/07/05	07/08/05	0.000	0.008	0.002	7.70	8.81	87.42	5.69
1	07/08/05	14/09/05	0.002	0.004	0.001	9.50	11.41	83.23	4.22
4	01/08/04	01/09/04	0.004	0.004	0.000	11.50	15.31	75.07	6.17
4	01/09/04	07/10/04	0.005	0.005	0.007	7.98	12.08	66.01	6.84
4	07/10/04	20/11/04	0.008	0.000	0.000	36.89	42.56	86.68	10.15
4	20/11/04	18/12/04	0.012	0.021	0.005	43.93	60.31	72.85	3.92
4	18/12/04	18/01/05	0.000	0.028	0.000	50.29	60.56	83.04	4.57
4	18/01/05	16/02/05	0.010	0.023	0.001	43.82	55.21	79.36	4.05
4	16/02/05	23/03/05	0.014	0.015	0.013	35.85	47.65	75.24	6.13
4	23/03/05	28/04/05	0.007	0.007	0.009	21.42	28.51	75.13	6.55
4	28/04/05	30/05/05	0.013	0.008	0.024	16.53	22.55	73.31	5.61
4	30/05/05	30/06/05	0.004	0.008	0.000	15.08	17.65	85.43	5.08
4	30/06/05	08/08/05	0.001	0.000	0.007	10.57	15.59	67.82	6.26
4	08/08/05	13/09/05	0.010	0.004	0.000	22.99	33.24	69.18	5.24
5	07/10/04	20/11/04	0.015	0.014	0.003	25.45	32.02	79.46	12.74
5	18/01/05	16/02/05	0.014	0.014	0.001	25.91	36.38	71.23	4.69
5	16/02/05	23/03/05	0.012	0.007	0.003	28.52	30.71	92.87	9.66
5	23/03/05	28/04/05	0.018	0.003	0.017	21.05	17.78	118.35	14.39
5	28/04/05	30/05/05	0.013	0.000	0.012	13.87	15.46	89.73	12.73
5	08/08/05	13/09/05	0.018	0.011	0.003	13.02	17.00	76.59	15.94
7	01/08/04	01/09/04	0.009	0.006	0.012	16.49	19.16	86.05	14.07
7	01/09/04	07/10/04	0.006	0.006	0.009	18.28	21.80	83.88	14.20
7	07/10/04	20/11/04	0.016	0.012	0.004	31.76	46.60	68.14	10.98
7	20/11/04	18/12/04	0.022	0.013	0.000	43.94	58.41	75.22	10.04
7	18/12/04	18/01/05	0.017	0.014	0.002	39.16	42.39	92.38	9.55
7	18/01/05	16/02/05	0.049	0.030	0.021	120.88	135.95	88.91	9.27
7	16/02/05	23/03/05	0.011	0.008	0.003	29.35	34.71	84.56	9.12
7	23/03/05	28/04/05	0.010	0.006	0.000	19.28	21.26	90.73	13.12
7	28/04/05	30/05/05	0.013	0.005	0.000	13.34	15.02	88.83	12.04
7	30/05/05	30/06/05	0.008	0.012	0.005	14.10	15.14	93.09	7.62
7	30/06/05	08/08/05	0.004	0.004	0.003	10.45	11.37	91.88	8.59
7	08/08/05	13/09/05	0.016	0.005	0.003	15.60	16.84	92.66	14.82
8	03/08/04	01/09/04	0.019	0.019	0.017	20.41	22.86	89.31	26.72
8	01/09/04	07/10/04	0.024	0.015	0.025	25.41	28.16	90.24	26.86
8	07/10/04	20/11/04	0.064	0.036	0.037	54.08	52.68	102.65	36.62
8	20/11/04	18/12/04	0.033	0.023	0.010	40.63	53.44	76.04	14.82
8	18/12/04	18/01/05	0.039	0.027	0.013	58.08	61.67	94.17	21.42
8	18/01/05	16/02/05	0.091	0.054	0.111	78.49	94.61	82.96	20.80

Table A3 cont

Site	Date on	Date off	Zn µg m^{-3}	Br µg m^{-3}	Pb µg m^{-3}	Total elemental µg m^{-3}	Gravimetric Mass µg m^{-3}	% Total mass	% Fe
8	16/02/05	23/03/05	0.021	0.009	0.011	26.43	29.27	90.31	18.02
8	23/03/05	28/04/05	0.077	0.016	0.000	114.66	135.16	84.83	21.67
8 Cond	04/08/04	01/09/04	0.008	0.000	0.009	7.89	10.34	76.33	7.02
8 Cond	01/09/04	07/10/04	0.004	0.006	0.003	10.29	13.18	78.11	9.00
8 Cond	07/10/04	20/11/04	0.021	0.015	0.006	15.68	21.45	73.11	13.44
8 Cond	20/11/04	18/12/04	0.006	0.004	0.017	20.76	30.97	67.02	5.29
8 Cond	18/12/04	18/01/05	0.012	0.014	0.029	35.32	42.91	82.32	9.71
8 Cond	18/01/05	16/02/05	0.005	0.007	0.005	28.75	31.96	89.97	4.96
8 Cond	16/02/05	23/03/05	0.010	0.017	0.030	20.04	24.08	83.22	6.70
8 Cond	23/03/05	28/04/05	0.007	0.007	0.000	9.01	12.97	69.50	10.78
8 Cond	28/04/05	30/05/05	0.001	0.002	0.012	8.01	16.10	49.73	4.29
8 Cond	30/05/05	30/06/05	0.003	0.004	0.001	10.07	10.65	94.49	5.34
8 Cond	30/06/05	08/08/05	0.001	0.001	0.001	7.59	8.84	85.89	9.46
8 Cond	08/08/05	13/09/05	0.003	0.009	0.000	12.22	13.63	89.65	14.51
8Hi	04/08/04	02/09/04	0.059	0.085	0.126	74.57	86.37	86.34	34.57
8Hi	02/09/04	08/10/04	0.057	0.029	0.039	49.57	64.80	76.49	26.09
8Hi	08/10/04	30/11/04	0.201	0.130	0.107	71.18	96.57	73.70	25.53
8Hi	30/11/04	20/12/04	0.077	0.028	0.026	67.34	78.98	85.26	25.07
8Hi	20/12/04	20/01/05	0.033	0.037	0.037	49.05	52.97	92.59	22.78
8Hi	20/01/05	23/02/05	0.050	0.024	0.021	395.38	560.92	70.49	16.82
8Hi	23/02/05	31/03/05	0.041	0.034	0.037	44.31	49.29	89.90	25.43
8Hi	31/03/05	02/05/05	0.065	0.028	0.047	56.16	81.08	69.26	21.57
8Hi	02/05/05	09/06/05	0.065	0.010	0.037	81.31	81.42	99.87	42.87
8Hi	09/06/05	01/07/05	0.016	0.005	0.000	54.98	49.65	110.74	55.74
8Hi	01/07/05	09/08/05	0.007	0.006	0.004	68.70	82.04	83.74	42.41
8Hi	09/08/05	16/09/05	0.092	0.118	0.127	99.11	115.25	86.00	39.53

Table A4. Cation concentrations measured in TSP collected at various sites and pH and cation and anion sums of the TSP extracts.

Site	Date on	Date off	pH	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cation Sum	Anion Sum
				µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µeq l^{-1}	µeq l^{-1}
1	29/07/04	02/09/04	6.355	1.51	0.03	0.07	0.15	0.14	1122.6	1140.2
1	02/09/04	08/10/04	5.530	2.13	0.03	0.10	0.24	0.18	1575.3	1567.5
1	08/10/04	21/11/04	6.018	3.21	0.04	0.24	0.38	0.33	2732.0	2646.6
1	21/11/04	17/12/04	5.751	4.57	0.10	0.29	0.52	0.47	1461.0	1437.2
1	17/12/04	19/01/05	5.778	5.30	0.09	0.24	0.62	0.68	2317.5	2306.9
1	19/01/05	21/02/05	5.590	6.24	0.09	0.24	0.73	0.63	3294.3	3323.3
1	21/02/05	28/03/05	5.191	1.02	0.03	0.05	0.31	0.31	833.5	840.7
1	28/03/05	18/04/05	5.217	1.77	0.10	0.07	0.17	0.11	665.3	673.8
1	18/04/05	31/05/05	5.266	0.44	0.01	0.08	0.15	0.14	412.8	420.6
1	31/05/05	13/07/05	5.060	0.56	0.01	0.02	0.18	0.14	666.3	687.4
1	13/07/05	07/08/05	5.337	1.16	0.06	0.05	0.11	0.08	618.3	628.1
1	07/08/05	14/09/05	5.329	1.68	0.03	0.08	0.19	0.12	1339.7	1329.5
4	01/08/04	01/09/04	7.388	1.35	0.03	0.06	0.14	0.49	1088.6	1078.4
4	01/09/04	07/10/04	7.318	1.11	0.02	0.05	0.11	0.38	1001.0	998.6
4	07/10/04	20/11/04	7.360	2.76	0.10	0.20	0.26	1.49	487.0	515.6
4	20/11/04	18/12/04	7.635	4.00	0.12	0.27	0.44	2.34	1074.9	1057.9
4	18/12/04	18/01/05	7.678	4.78	0.12	0.22	0.54	2.48	1364.9	1352.8
4	18/01/05	16/02/05	7.766	5.40	0.07	0.21	0.62	1.88	2417.0	2454.9
4	16/02/05	23/03/05	7.743	3.60	0.09	0.16	0.42	1.24	2473.6	2510.3
4	23/03/05	28/04/05	7.771	1.74	0.08	0.08	0.20	1.16	1302.1	1300.1
4	28/04/05	30/05/05	7.425	1.36	0.09	0.12	0.12	0.85	571.3	588.3
4	30/05/05	30/06/05	6.177	2.37	0.04	0.11	0.23	0.26	777.5	785.4
4	30/06/05	08/08/05	6.869	1.14	0.06	0.05	0.09	0.36	421.4	433.4
4	08/08/05	13/09/05	7.847	1.68	0.05	0.07	0.18	1.54	940.1	972.5
5	07/10/04	20/11/04	6.453	2.92	0.07	0.24	0.33	0.46	1610.5	1554.9
5	18/01/05	16/02/05	5.541	4.48	0.08	0.17	0.51	0.52	1783.7	1791.2
5	16/02/05	23/03/05	6.479	2.42	0.05	0.12	0.28	0.41	1963.2	1983.7
5	23/03/05	28/04/05	6.415	1.22	0.04	0.06	0.13	0.24	1034.7	1016.4
5	28/04/05	30/05/05	5.740	0.99	0.04	0.12	0.11	0.18	756.2	730.2
5	08/08/05	13/09/05	6.355	1.52	0.02	0.08	0.17	0.21	1214.7	1206.4
7	01/08/04	01/09/04	7.056	1.46	0.03	0.07	0.15	0.26	1023.1	1046.4
7	01/09/04	07/10/04	6.941	1.76	0.03	0.09	0.20	0.37	1473.0	1458.1
7	07/10/04	20/11/04	7.267	3.04	0.07	0.24	0.35	0.72	1863.0	1823.6
7	20/11/04	18/12/04	7.087	3.96	0.14	0.29	0.43	1.00	1017.5	1009.2
7	18/12/04	18/01/05	7.024	4.27	0.07	0.22	0.47	0.83	1807.5	1823.5
7	18/01/05	16/02/05	6.965	14.70	0.25	0.58	1.66	2.25	2596.4	2616.1
7	16/02/05	23/03/05	6.636	2.66	0.05	0.12	0.31	0.49	2166.0	2186.1
7	23/03/05	28/04/05	7.173	1.39	0.06	0.07	0.15	0.39	1255.6	1253.3
7	28/04/05	30/05/05	5.989	1.22	0.03	0.12	0.13	0.23	925.1	883.0
7	30/05/05	30/06/05	5.846	2.12	0.02	0.09	0.23	0.18	1376.2	1385.8
7	30/06/05	08/08/05	6.664	1.13	0.05	0.05	0.11	0.17	991.6	1004.8
7	08/08/05	13/09/05	6.801	1.70	0.03	0.08	0.18	0.26	1365.7	1368.5
8	03/08/04	01/09/04	7.087	1.30	0.04	0.06	0.13	0.27	886.9	913.1
8	01/09/04	07/10/04	6.932	1.81	0.04	0.10	0.20	0.37	1532.0	1528.5
8	07/10/04	20/11/04	7.056	2.89	0.06	0.18	0.32	0.74	1286.5	1281.5
8	20/11/04	18/12/04	6.854	3.96	0.17	0.28	0.41	0.86	986.3	974.3
8	18/12/04	18/01/05	6.460	5.32	0.21	0.24	0.57	0.95	1145.0	1141.5
8	18/01/05	16/02/05	7.310	6.47	0.12	0.25	0.71	1.37	2204.1	2243.0
8	16/02/05	23/03/05	6.718	2.06	0.07	0.10	0.23	0.39	1704.3	1715.1
8	23/03/05	28/04/05	6.655	8.60	0.40	0.36	0.88	1.58	844.4	853.4
8 Con	04/08/04	01/09/04	6.071	0.85	0.05	0.04	0.06	0.11	193.3	204.5
8 Con	01/09/04	07/10/04	5.610	1.25	0.07	0.06	0.10	0.15	272.0	275.5
8 Con	07/10/04	20/11/04	5.592	1.17	0.23	0.26	0.08	0.18	204.2	198.9

Table A4 Continued

Site	Date on	Date off	pH	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cation Sum	Anion Sum
				$\mu g\ m^{-3}$	$\mu g\ m^{-3}$	$\mu g\ m^{-3}$	$\mu g\ m^{-3}$	$\mu g\ m^{-3}$	$\mu eq\ l^{-1}$	$\mu eq\ l^{-1}$
8 Con	20/11/04	18/12/04	5.417	2.25	0.19	0.31	0.15	0.18	187.8	196.0
8 Con	18/12/04	18/01/05	5.934	3.09	0.21	0.15	0.26	0.48	411.3	417.4
8 Con	18/01/05	16/02/05	5.496	3.61	0.13	0.11	0.25	0.31	247.5	261.3
8 Con	16/02/05	23/03/05	5.430	1.90	0.16	0.09	0.17	0.24	430.6	440.5
8 Con	23/03/05	28/04/05	5.662	0.71	0.14	0.03	0.05	0.09	191.6	196.3
8 Con	28/04/05	30/05/05	5.283	0.96	0.12	0.10	0.08	0.11	411.4	398.7
8 Con	30/05/05	30/06/05	5.868	1.42	0.05	0.06	0.13	0.13	688.8	699.4
8 Con	30/06/05	08/08/05	6.397	0.70	0.08	0.03	0.06	0.14	480.9	479.0
8 Con	08/08/05	13/09/05	6.054	1.12	0.04	0.04	0.09	0.19	327.4	336.5
8Hi	04/08/04	02/09/04	7.172	1.68	0.07	0.06	0.16	0.76	490.9	503.1
8Hi	02/09/04	08/10/04	7.638	2.23	0.10	0.11	0.24	1.06	1306.6	1319.9
8Hi	08/10/04	30/11/04	7.918	3.36	0.14	0.22	0.38	1.05	2886.8	3149.7
8Hi	30/11/04	20/12/04	7.798	3.93	0.15	0.17	0.42	1.58	1537.0	1679.8
8Hi	20/12/04	20/01/05	6.880	4.41	0.17	0.20	0.47	0.95	1243.7	1248.1
8Hi	20/01/05	23/02/05	7.848	31.53	0.93	1.24	3.45	9.00	2416.8	2651.9
8Hi	23/02/05	31/03/05	7.389	2.29	0.16	0.10	0.24	0.86	1103.4	1157.6
8Hi	31/03/05	02/05/05	7.408	1.87	0.16	0.09	0.21	1.16	771.8	809.8
8Hi	02/05/05	09/06/05	6.941	1.17	0.17	0.09	0.10	0.65	245.3	253.2
8Hi	09/06/05	01/07/05	5.292	1.01	0.05	0.02	0.04	0.11	45.3	48.2
8Hi	01/07/05	09/08/05	5.756	0.83	0.17	0.03	0.04	0.17	64.0	71.0
8Hi	09/08/05	16/09/05	7.698	2.44	0.11	0.10	0.28	1.53	1113.0	1184.0

Table A5. Anion concentrations measured in TSP collected at various sites in 2004/2005.

Site	Cl^- µg m^{-3}	NO_3^- µg m^{-3}	SO_4^{2-} µg m^{-3}	$C_2O_4^{2-}$ µg m^{-3}	PO_4^{3-} µg m^{-3}	F^- µg m^{-3}	CH_3COO^- µg m^{-3}	$HCOO^-$ µg m^{-3}	$CH_3SO_3^-$ µg m^{-3}	HCO_3^- µg m^{-3}
1	2.40	0.31	0.68	0.07	<0.01	<0.01	<0.01	0.01	0.01	0.06
1	3.15	0.59	1.10	0.18	<0.01	<0.01	<0.01	0.01	0.02	0.01
1	4.32	0.96	2.06	0.35	0.01	<0.01	<0.01	0.01	0.04	0.02
1	6.65	1.49	2.44	0.35	<0.01	<0.01	0.01	0.03	0.07	0.03
1	7.71	2.01	3.03	0.41	0.01	<0.01	0.01	0.02	0.14	0.03
1	9.82	1.55	3.12	0.36	<0.01	<0.01	<0.01	0.02	0.12	0.01
1	1.25	0.65	1.96	0.29	<0.01	<0.01	<0.01	0.01	0.02	0.00
1	2.06	1.06	1.27	0.19	<0.01	<0.01	<0.01	0.01	0.02	0.01
1	0.47	0.30	1.18	0.35	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1	0.93	0.07	0.29	0.04	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
1	1.52	0.58	0.73	0.07	<0.01	<0.01	<0.01	0.01	0.01	0.01
1	2.50	0.44	0.81	0.11	<0.01	<0.01	<0.01	0.01	0.01	<0.01
4	2.22	0.33	0.71	0.06	<0.01	0.01	0.01	0.04	0.01	0.68
4	1.79	0.34	0.53	0.06	<0.01	<0.01	0.01	0.02	0.01	0.50
4	4.11	0.90	2.06	0.31	<0.01	0.02	0.04	0.11	0.02	3.31
4	6.03	1.73	2.59	0.32	<0.01	0.01	0.04	0.13	0.07	4.25
4	7.28	2.02	3.00	0.41	<0.01	0.01	0.04	0.11	0.12	4.22
4	8.70	1.72	2.92	0.32	<0.01	0.02	0.06	0.10	0.10	2.92
4	5.34	1.83	2.27	0.25	<0.01	0.01	0.04	0.06	0.05	1.83
4	2.30	1.15	1.43	0.20	<0.01	<0.01	0.02	0.05	0.02	2.20
4	1.82	0.74	1.24	0.23	<0.01	0.01	0.02	<0.01	0.01	1.73
4	3.75	0.56	0.99	0.10	<0.01	<0.01	0.01	0.04	0.01	0.08
4	1.50	0.59	0.93	0.09	<0.01	<0.01	0.01	0.04	0.01	0.44
4	2.66	0.59	1.01	0.10	<0.01	0.01	0.02	0.08	0.01	3.95
5	3.81	1.03	2.11	0.39	<0.01	0.01	0.01	0.03	0.04	0.10
5	7.09	1.34	2.11	0.25	<0.01	<0.01	0.01	0.02	0.09	0.02
5	3.18	1.40	1.74	0.25	<0.01	<0.01	0.01	0.02	0.04	0.07
5	1.23	0.89	1.08	0.22	<0.01	<0.01	<0.01	0.02	0.02	0.06
5	0.95	0.57	0.96	0.27	<0.01	<0.01	<0.01	0.01	0.01	0.01
5	2.23	0.46	0.87	0.12	<0.01	<0.01	<0.01	0.02	0.01	0.05
7	2.37	0.33	0.65	0.07	<0.01	<0.01	0.01	0.03	0.01	0.32
7	2.71	0.60	0.95	0.15	<0.01	<0.01	0.01	0.02	0.02	0.21
7	4.27	1.10	2.15	0.34	<0.01	0.01	0.02	0.04	0.04	0.64
7	5.56	1.91	2.50	0.41	<0.01	0.01	0.03	0.07	0.07	1.02
7	6.53	1.55	2.35	0.33	<0.01	0.01	0.02	0.05	0.10	0.50
7	23.14	4.33	7.41	0.99	<0.01	0.01	0.03	0.14	0.26	1.01
7	3.69	1.43	1.76	0.24	<0.01	<0.01	0.01	0.03	0.04	0.11
7	1.64	0.97	1.11	0.22	<0.01	<0.01	0.01	0.02	0.02	0.36
7	1.37	0.61	1.00	0.26	0.01	<0.01	<0.01	0.01	0.01	0.03
7	3.48	0.46	0.78	0.07	<0.01	<0.01	0.01	0.02	0.01	0.02
7	1.54	0.52	0.73	0.09	<0.01	<0.01	<0.01	0.01	0.01	0.10
7	2.61	0.50	0.88	0.11	<0.01	<0.01	<0.01	0.02	0.01	0.15
8	2.09	0.34	0.63	0.07	<0.01	<0.01	0.01	0.03	0.01	0.36
8	2.71	0.68	1.10	0.15	<0.01	<0.01	<0.01	0.02	0.02	0.21
8	4.39	0.88	1.91	0.30	0.01	0.01	0.01	0.05	0.03	0.54
8	5.60	1.84	2.51	0.36	<0.01	0.01	0.02	0.08	0.07	0.60
8	7.96	2.12	3.15	0.41	<0.01	0.01	0.02	0.06	0.14	0.27
8	10.20	2.03	3.59	0.39	<0.01	0.01	0.01	0.09	0.12	1.21
8	2.80	1.21	1.42	0.19	<0.01	<0.01	<0.01	0.02	0.03	0.13
8	10.70	5.21	6.34	1.05	<0.01	<0.01	<0.01	0.01	0.01	0.11
8 Con	1.34	0.19	0.46	0.05	<0.01	0.01	<0.01	0.02	0.00	0.10
8 Con	1.81	0.44	0.72	0.10	<0.01	0.01	<0.01	0.02	0.01	0.04
8 Con	1.48	0.59	1.27	0.22	<0.01	0.01	0.01	0.02	0.02	0.05
8 Con	2.75	1.52	1.75	0.25	<0.01	0.01	<0.01	0.01	0.01	0.02

Table A5 Continued

Site	Cl^- µg m^{-3}	NO_3^- µg m^{-3}	SO_4^{2-} µg m^{-3}	$C_2O_4^{2-}$ µg m^{-3}	PO_4^{3-} µg m^{-3}	F^- µg m^{-3}	CH_3COO^- µg m^{-3}	$HCOO^-$ µg m^{-3}	$CH_3SO_3^-$ µg m^{-3}	HCO_3^- µg m^{-3}
8 Con	4.34	1.48	1.98	0.28	<0.01	0.01	0.01	0.04	0.06	0.13
8 Con	5.57	1.09	1.68	0.13	<0.01	0.03	0.01	0.04	0.06	0.08
8 Con	2.47	1.02	1.46	0.18	<0.01	0.01	0.01	0.03	0.02	0.02
8 Con	0.75	0.55	0.73	0.13	<0.01	0.01	<0.01	0.02	0.00	0.04
8 Con	1.09	0.47	0.90	0.16	0.01	<0.01	<0.01	0.01	0.01	0.01
8 Con	2.20	0.41	0.61	0.06	<0.01	<0.01	<0.01	0.03	0.01	0.03
8 Con	0.83	0.44	0.60	0.07	<0.01	<0.01	<0.01	0.02	0.01	0.08
8 Con	1.64	0.42	0.63	0.08	<0.01	0.01	<0.01	0.03	0.01	0.07
8Hi	2.76	0.39	1.06	0.10	<0.01	0.01	0.01	0.10	0.01	1.22
8Hi	3.50	0.78	1.51	0.18	<0.01	0.02	0.02	0.06	0.02	1.84
8Hi	5.27	1.24	2.40	0.30	0.01	0.02	0.05	0.07	0.04	2.17
8Hi	6.50	1.09	2.37	0.33	<0.01	0.02	0.06	0.09	0.07	3.78
8Hi	6.70	1.67	2.76	0.33	<0.01	0.01	0.01	0.06	0.10	0.55
8Hi	51.83	8.78	18.31	2.44	<0.01	0.01	0.38	0.58	0.58	19.84
8Hi	3.14	1.65	1.90	0.21	0.02	0.01	0.02	0.05	0.03	1.20
8Hi	2.55	1.17	1.91	0.26	<0.01	0.02	0.02	0.29	0.02	1.73
8Hi	1.46	0.74	1.27	0.25	<0.01	0.01	<0.01	0.02	0.01	0.39
8Hi	1.73	0.27	0.53	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
8Hi	1.23	0.50	0.84	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
8Hi	4.09	0.76	2.06	0.19	<0.01	0.02	0.03	0.07	0.02	2.98

APPENDIX B ELEMENTAL AND ION CONCENTRATIONS OF TSP SAMPLES COLLECTED DURING 2007/2008.

Table B1. Elemental concentrations of TSP and PM_{10} samples at various sites measured by PIXE analysis.

Site	Date on	Date off	Na $\mu g\ m^{-3}$	Al $\mu g\ m^{-3}$	Si $\mu g\ m^{-3}$	P $\mu g\ m^{-3}$	S $\mu g\ m^{-3}$	Cl $\mu g\ m^{-3}$	K $\mu g\ m^{-3}$	Ca $\mu g\ m^{-3}$
1	04/05/07	14/06/07								
1	14/06/07	02/08/07								
1	02/08/07	09/09/07								
1	09/09/07	25/10/07								
1	25/10/07	09/11/07								
1	09/11/07	09/01/08								
1	09/01/08	08/02/08								
1	08/02/08	12/03/08								
1	12/03/08	27/04/08								
1	27/04/08	04/06/08								
1	04/06/08	17/07/08								
1	17/07/08	14/08/08								
6	03/05/07	07/06/07								
6	07/06/07	04/08/07								
6	04/08/07	12/09/07								
6	12/09/07	16/10/07								
6	16/10/07	08/11/07								
6	08/11/07	08/01/08								
6	08/01/08	07/02/08								
6	07/02/08	11/03/08								
6	11/03/08	21/04/08								
6	21/04/08	03/06/08								
6	03/06/08	14/07/08								
6	14/07/08	13/08/08								
7	03/05/07	07/06/07								
7	07/06/07	03/08/07								
7	03/08/07	12/09/07								
7	02/09/07	16/10/07								
7	16/10/07	08/11/07								
7	08/11/07	08/01/08								
7	08/01/08	07/02/08								
7	07/02/08	11/03/08								
7	11/03/08	21/04/08								
7	21/04/08	03/06/08								
7	03/06/08	14/07/08								
7	14/07/08	13/08/08								
8	24/01/07	22/02/07								
8	22/02/07	20/03/07								
8	20/03/07	03/05/07								
8	03/05/07	07/06/07								
8	07/06/07	03/08/07								
8	03/08/07	12/09/07								
8	12/09/07	16/10/07								
8	16/10/07	08/11/07								
8	08/11/07	08/01/08								
8	08/01/08	07/02/08								

Table B1 cont

Site	Date on	Date off	Na µg m^{-3}	Al µg m^{-3}	Si µg m^{-3}	P µg m^{-3}	S µg m^{-3}	Cl µg m^{-3}	K µg m^{-3}	Ca µg m^{-3}
8	07/02/08	11/03/08								
8	11/03/08	21/04/08								
8	21/04/08	03/06/08								
8	03/06/08	14/07/08								
8	14/07/08	13/08/08								
8 Cond	24/01/07	22/02/07								
8 Cond	22/02/07	20/03/07								
8 Cond	20/03/07	03/05/07								
8 Cond	03/05/07	07/06/07								
8 Cond	07/06/07	03/08/07								
8 Cond	03/08/07	12/09/07								
8 Cond	12/09/07	16/10/07								
8 Cond	16/10/07	08/11/07								
8 Cond	08/11/07	08/01/08								
8 Cond	08/01/08	07/02/08								
8 Cond	07/02/08	11/03/08								
8 Cond	11/03/08	21/04/08								
8 Cond	21/04/08	03/06/08								
8 Cond	03/06/08	14/07/08								
8 Cond	14/07/08	13/08/08								
8 Hi	21/05/07	25/06/07								
8 Hi	25/06/07	04/08/07								
8 Hi	04/08/07	12/09/07								
8 Hi	12/09/07	08/11/07								
8 Hi	08/11/07	08/01/08								
8 Hi	08/01/08	07/02/08								
8 Hi	07/02/08	11/03/08								
8 Hi	11/03/08	21/04/08								
8 Hi	21/04/08	04/06/08								
8 Hi	04/06/08	14/07/08								
8 Hi	14/07/08	13/08/08								

Table B2. Elemental concentrations of TSP and PM_{10} samples at various sites measured by PIXE analysis.

Site	Date on	Date off	Ti µg m^{-3}	V µg m^{-3}	Cr µg m^{-3}	Mn µg m^{-3}	Fe µg m^{-3}	Co µg m^{-3}	Ni µg m^{-3}	Cu µg m^{-3}
1	04/05/07	14/06/07								
1	14/06/07	02/08/07								
1	02/08/07	09/09/07								
1	09/09/07	25/10/07								
1	25/10/07	09/11/07								
1	09/11/07	09/01/08								
1	09/01/08	08/02/08								
1	08/02/08	12/03/08								
1	12/03/08	27/04/08								
1	27/04/08	04/06/08								
1	04/06/08	17/07/08								
1	17/07/08	14/08/08								
6	03/05/07	07/06/07								
6	07/06/07	04/08/07								
6	04/08/07	12/09/07								
6	12/09/07	16/10/07								
6	16/10/07	08/11/07								
6	08/11/07	08/01/08								
6	08/01/08	07/02/08								
6	07/02/08	11/03/08								
6	11/03/08	21/04/08								
6	21/04/08	03/06/08								
6	03/06/08	14/07/08								
6	14/07/08	13/08/08								
7	03/05/07	07/06/07								
7	07/06/07	03/08/07								
7	03/08/07	12/09/07								
7	02/09/07	16/10/07								
7	16/10/07	08/11/07								
7	08/11/07	08/01/08								
7	08/01/08	07/02/08								
7	07/02/08	11/03/08								
7	11/03/08	21/04/08								
7	21/04/08	03/06/08								
7	03/06/08	14/07/08								
7	14/07/08	13/08/08								
8	24/01/07	22/02/07								
8	22/02/07	20/03/07								
8	20/03/07	03/05/07								
8	03/05/07	07/06/07								
8	07/06/07	03/08/07								
8	03/08/07	12/09/07								
8	12/09/07	16/10/07								
8	16/10/07	08/11/07								
8	08/11/07	08/01/08								
8	08/01/08	07/02/08								
8	07/02/08	11/03/08								
8	11/03/08	21/04/08								
8	21/04/08	03/06/08								
8	03/06/08	14/07/08								
8	14/07/08	13/08/08								

Table	B2 cont									
Site	Date on	Date off	Ti $\mu g\ m^{-3}$	V $\mu g\ m^{-3}$	Cr $\mu g\ m^{-3}$	Mn $\mu g\ m^{-3}$	Fe $\mu g\ m^{-3}$	Co $\mu g\ m^{-3}$	Ni $\mu g\ m^{-3}$	Cu $\mu g\ m^{-3}$
8 Cond	24/01/07	22/02/07								
8 Cond	22/02/07	20/03/07								
8 Cond	20/03/07	03/05/07								
8 Cond	03/05/07	07/06/07								
8 Cond	07/06/07	03/08/07								
8 Cond	03/08/07	12/09/07								
8 Cond	12/09/07	16/10/07								
8 Cond	16/10/07	08/11/07								
8 Cond	08/11/07	08/01/08								
8 Cond	08/01/08	07/02/08								
8 Cond	07/02/08	11/03/08								
8 Cond	11/03/08	21/04/08								
8 Cond	21/04/08	03/06/08								
8 Cond	03/06/08	14/07/08								
8 Cond	14/07/08	13/08/08								
8 Hi	21/05/07	25/06/07								
8 Hi	25/06/07	04/08/07								
8 Hi	04/08/07	12/09/07								
8 Hi	12/09/07	08/11/07								
8 Hi	08/11/07	08/01/08								
8 Hi	08/01/08	07/02/08								
8 Hi	07/02/08	11/03/08								
8 Hi	11/03/08	21/04/08								
8 Hi	21/04/08	04/06/08								
8 Hi	04/06/08	14/07/08								
8 Hi	14/07/08	13/08/08								

Table B3. Elemental concentrations of TSP and PM_{10} samples at various sites measured by PIXE analysis, total elemental mass, gravimetric mass and fraction of iron in gravimetric mass.

Site	Date on	Date off	Zn $\mu g\ m^{-3}$	Br $\mu g\ m^{-3}$	Pb $\mu g\ m^{-3}$	Total elemental $\mu g\ m^{-3}$	Gravimetric Mass $\mu g\ m^{-3}$	% Total mass	% Fe
1	04/05/07	14/06/07					12.1		
1	14/06/07	02/08/07					11.6		
1	02/08/07	09/09/07					14.6		
1	09/09/07	25/10/07					21.6		
1	25/10/07	09/11/07					26.2		
1	09/11/07	09/01/08					26.9		
1	09/01/08	08/02/08					4.4		
1	08/02/08	12/03/08					14.0		
1	12/03/08	27/04/08					14.6		
1	27/04/08	04/06/08					11.8		
1	04/06/08	17/07/08					12.2		
1	17/07/08	14/08/08					14.7		
6	03/05/07	07/06/07					18.7		
6	07/06/07	04/08/07					15.6		
6	04/08/07	12/09/07					24.0		
6	12/09/07	16/10/07					32.6		
6	16/10/07	08/11/07					39.5		
6	08/11/07	08/01/08					37.8		
6	08/01/08	07/02/08					36.0		
6	07/02/08	11/03/08					28.7		
6	11/03/08	21/04/08					21.7		
6	21/04/08	03/06/08					12.3		
6	03/06/08	14/07/08					19.5		
6	14/07/08	13/08/08					24.4		
7	03/05/07	07/06/07					16.7		
7	07/06/07	03/08/07					10.3		
7	03/08/07	12/09/07					24.7		
7	02/09/07	16/10/07					44.4		
7	16/10/07	08/11/07					46.2		
7	08/11/07	08/01/08					49.1		
7	08/01/08	07/02/08					36.7		
7	07/02/08	11/03/08					35.2		
7	11/03/08	21/04/08					29.4		
7	21/04/08	03/06/08					51.6		
7	03/06/08	14/07/08					107.5		
7	14/07/08	13/08/08					12.3		
8	24/01/07	22/02/07					88.1		
8	22/02/07	20/03/07					43.2		
8	20/03/07	03/05/07					22.0		
8	03/05/07	07/06/07					17.0		
8	07/06/07	03/08/07					16.3		
8	03/08/07	12/09/07					21.2		
8	12/09/07	16/10/07					66.0		
8	16/10/07	08/11/07					55.6		
8	08/11/07	08/01/08					82.6		
8	08/01/08	07/02/08					49.8		
8	07/02/08	11/03/08					34.4		
8	11/03/08	21/04/08					22.6		
8	21/04/08	03/06/08					25.1		

8	03/06/08	14/07/08	6.5
8	14/07/08	13/08/08	20.8

Table B3 cont

Site	Date on	Date off	Zn µg m^{-3}	Br µg m^{-3}	Pb µg m^{-3}	Total elemental µg m^{-3}	Gravimetric Mass µg m^{-3}	% Total mass	% Fe
8 Cond	24/01/07	22/02/07					109.7		
8 Cond	22/02/07	20/03/07					57.4		
8 Cond	20/03/07	03/05/07					30.8		
8 Cond	03/05/07	07/06/07					33.1		
8 Cond	07/06/07	03/08/07					34.4		
8 Cond	03/08/07	12/09/07					51.9		
8 Cond	12/09/07	16/10/07					65.1		
8 Cond	16/10/07	08/11/07					75.5		
8 Cond	08/11/07	08/01/08					132.0		
8 Cond	08/01/08	07/02/08					79.3		
8 Cond	07/02/08	11/03/08					43.5		
8 Cond	11/03/08	21/04/08					31.9		
8 Cond	21/04/08	03/06/08					31.5		
8 Cond	03/06/08	14/07/08					20.4		
8 Cond	14/07/08	13/08/08					26.6		
8 Hi	21/05/07	25/06/07					90.4		
8 Hi	25/06/07	04/08/07					82.1		
8 Hi	04/08/07	12/09/07					99.9		
8 Hi	12/09/07	08/11/07					172.1		
8 Hi	08/11/07	08/01/08					112.4		
8 Hi	08/01/08	07/02/08					176.2		
8 Hi	07/02/08	11/03/08					104.8		
8 Hi	11/03/08	21/04/08					102.0		
8 Hi	21/04/08	04/06/08					171.2		
8 Hi	04/06/08	14/07/08					51.8		
8 Hi	14/07/08	13/08/08					67.4		

Table B4. Cation concentrations measured in TSP collected at various sites and pH and cation and anion sums of the TSP extracts.

Site	Date on	Date off	pH	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cation Sum	Anion Sum
				µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µeq l^{-1}	µeq l^{-1}
1	04/05/07	14/06/07		1.64	0.03	0.11	0.20	0.14	1455.0	1453.8
1	14/06/07	02/08/07		1.76	0.01	0.11	0.21	0.14	1840.5	1729.2
1	02/08/07	09/09/07		1.55	0.02	0.18	0.20	0.21	1364.5	1240.1
1	09/09/07	25/10/07		2.78	0.03	0.18	0.35	0.30	2848.6	2591.1
1	25/10/07	09/11/07		3.72	0.09	0.17	0.45	0.33	1185.0	1162.6
1	09/11/07	09/01/08		3.78	0.05	0.17	0.47	0.41	5050.0	5175.9
1	09/01/08	08/02/08		0.19	0.01	0.01	0.02	0.12	186.3	191.3
1	08/02/08	12/03/08		2.45	0.07	0.11	0.29	0.20	1746.2	1791.3
1	12/03/08	27/04/08		1.57	0.05	0.11	0.20	0.16	1623.7	1627.7
1	27/04/08	04/06/08		1.22	0.06	0.13	0.15	0.14	1073.1	998.6
1	04/06/08	17/07/08		1.81	0.04	0.08	0.21	0.15	1677.4	1528.9
1	17/07/08	14/08/08		1.98	0.03	0.11	0.24	0.19	1209.9	1191.9
3	29/01/07	22/02/07		6.35	0.05	0.27	0.79	0.96	3455.0	3352.5
3	22/02/07	20/03/07		3.08	0.06	0.16	0.38	0.45	1815.0	1729.8
3	20/03/07	04/05/07		1.29	0.03	0.13	0.16	0.15	1327.2	1238.5
3	04/05/07	14/06/07		1.35	0.02	0.08	0.16	0.14	1206.4	1106.0
3	14/06/07	02/08/07		1.74	0.01	0.11	0.21	0.16	1848.1	1761.9
3	02/08/07	09/09/07		1.36	0.01	0.18	0.17	0.25	1248.5	1124.4
3	09/09/07	25/10/07		2.81	0.03	0.18	0.35	0.36	2903.2	2725.8
3	25/10/07	09/11/07		0.93	0.02	0.03	0.11	0.08	299.6	293.4
3	09/11/07	09/01/08		1.20	0.01	0.06	0.15	0.16	1412.0	1336.0
3	09/01/08	08/02/08		6.09	0.06	0.27	0.76	0.67	4027.7	3854.2
3	08/02/08	12/03/08		3.62	0.07	0.16	0.43	0.29	1938.6	1863.7
3	12/03/08	27/04/08		0.89	0.02	0.04	0.12	0.20	83.0	80.6
3	27/04/08	04/06/08								
3	04/06/08	17/07/08		1.34	0.02	0.07	0.16	0.11	1243.7	1174.9
3	17/07/08	14/08/08		1.22	0.02	0.07	0.14	0.12	1090.3	1025.0
4	03/05/07	07/06/07		1.36	0.05	0.08	0.17	0.72	1310.2	957.6
4	07/06/07	04/08/07		1.87	0.01	0.12	0.23	0.62	2634.1	2252.4
4	04/08/07	12/09/07		1.54	0.02	0.21	0.20	0.97	1804.9	1308.5
4	12/09/07	16/10/07		2.95	0.04	0.20	0.38	1.30	2667.0	2204.5
4	16/10/07	08/11/07		2.95	0.05	0.14	0.37	1.24	1860.1	1450.3
4	08/11/07	08/01/08		4.64	0.03	0.21	0.57	1.14	6439.9	5962.5
4	08/01/08	07/02/08		4.96	0.05	0.22	0.62	1.44	3653.3	3324.1
4	07/02/08	11/03/08		3.05	0.07	0.13	0.37	0.69	2384.3	2157.3
4	11/03/08	21/04/08		0.94	0.01	0.05	0.12	0.54	1096.6	869.4
4	21/04/08	03/06/08								
4	03/06/08	14/07/08		1.56	0.04	0.09	0.19	0.34	1441.6	1264.2
4	14/07/08	13/08/08		1.87	0.04	0.11	0.23	0.74	1419.4	1137.3
5	03/05/07	07/06/07		1.12	0.03	0.07	0.14	0.29	986.7	856.3
5	07/06/07	04/08/07		1.41	0.01	0.10	0.18	0.28	1944.7	1816.3
5	04/08/07	12/09/07		1.23	0.02	0.18	0.17	0.42	1316.0	1113.0
5	12/09/07	16/10/07		2.41	0.04	0.18	0.31	0.50	1997.1	1821.2
5	16/10/07	08/11/07		3.25	0.05	0.17	0.41	0.63	1755.3	1603.4
5	08/11/07	08/01/08		3.24	0.03	0.16	0.42	0.57	4619.1	4445.4
5	08/01/08	07/02/08		2.65	0.07	0.13	0.32	0.36	1803.9	1721.0
5	07/02/08	11/03/08		4.24	0.03	0.20	0.53	0.74	3211.9	3095.7
5	11/03/08	21/04/08		1.52	0.04	0.09	0.18	0.35	1459.0	1360.8
5	21/04/08	03/06/08		0.99	0.02	0.13	0.14	0.52	1330.5	1075.2
5	03/06/08	14/07/08		1.27	0.03	0.07	0.16	0.29	1275.5	1131.3
5	14/07/08	13/08/08		1.51	0.02	0.10	0.19	0.43	1150.9	996.6

Table B4 Continued

Site	Date on	Date off	pH	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cation Sum	Anion Sum
				µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µeq l^{-1}	µeq l^{-1}
6	03/05/07	07/06/07		1.42	0.03	0.09	0.18	0.28	1180.7	1003.4
6	07/06/07	04/08/07		1.81	0.02	0.12	0.23	0.27	2403.2	2183.0
6	04/08/07	12/09/07		1.45	0.03	0.21	0.19	0.42	1506.2	1383.9
6	12/09/07	16/10/07		2.64	0.05	0.19	0.33	0.50	2149.9	2011.7
6	16/10/07	08/11/07		3.96	0.07	0.20	0.50	0.65	2085.5	2025.7
6	08/11/07	08/01/08		3.67	0.04	0.18	0.48	0.57	5138.7	5103.1
6	08/01/08	07/02/08		4.43	0.06	0.20	0.55	0.63	3009.3	2811.3
6	07/02/08	11/03/08		2.80	0.07	0.13	0.33	0.32	2046.4	1878.7
6	11/03/08	21/04/08		1.62	0.06	0.10	0.20	0.30	1590.9	1518.5
6	21/04/08	03/06/08		0.67	0.04	0.09	0.08	0.17	771.6	688.5
6	03/06/08	14/07/08		1.64	0.04	0.12	0.20	0.28	1583.1	1455.5
6	14/07/08	13/08/08		1.90	0.04	0.14	0.23	0.38	1366.5	1200.1
7	03/05/07	07/06/07		1.50	0.03	0.09	0.19	0.34	1277.6	1148.3
7	07/06/07	03/08/07		1.91	0.01	0.11	0.24	0.29	2476.9	2412.2
7	03/08/07	12/09/07		1.45	0.02	0.19	0.19	0.65	1700.9	1328.1
7	02/09/07	16/10/07		2.74	0.05	0.20	0.35	0.92	2491.4	2193.6
7	16/10/07	08/11/07		4.15	0.07	0.22	0.52	0.77	2219.8	1949.0
7	08/11/07	08/01/08		3.66	0.04	0.19	0.52	0.78	5461.3	5461.9
7	08/01/08	07/02/08		2.50	0.04	0.11	0.31	0.34	1693.0	1692.4
7	07/02/08	11/03/08		3.13	0.06	0.15	0.38	0.45	2325.0	2325.7
7	11/03/08	21/04/08		2.54	0.04	0.15	0.30	0.65	1183.0	1155.5
7	21/04/08	03/06/08								
7	03/06/08	14/07/08		12.07	0.22	0.60	1.49	1.88	2012.8	1942.6
7	14/07/08	13/08/08		1.17	0.03	0.07	0.14	0.26	855.8	772.2
8	24/01/07	22/02/07		5.42	0.05	0.22	0.68	0.95	3711.4	3797.4
8	22/02/07	20/03/07		2.59	0.04	0.14	0.32	0.52	1604.2	1511.0
8	20/03/07	03/05/07		1.27	0.04	0.07	0.16	0.27	1361.6	1248.2
8	03/05/07	07/06/07		1.04	0.05	0.07	0.13	0.34	980.7	756.9
8	07/06/07	03/08/07		1.36	0.01	0.09	0.17	0.31	1883.1	1809.1
8	03/08/07	12/09/07		0.80	0.01	0.12	0.12	0.34	939.0	753.9
8	12/09/07	16/10/07		2.41	0.04	0.17	0.31	0.50	1973.7	1743.0
8	16/10/07	08/11/07		3.32	0.07	0.16	0.42	0.52	1765.3	1636.5
8	08/11/07	08/01/08		3.49	0.03	0.16	0.45	0.61	4961.0	5057.9
8	08/01/08	07/02/08		3.90	0.06	0.18	0.50	0.57	2665.4	2452.2
8	07/02/08	11/03/08		2.29	0.06	0.10	0.27	0.28	1677.3	1572.7
8	11/03/08	21/04/08		1.28	0.05	0.08	0.16	0.25	1153.4	1043.3
8	21/04/08	03/06/08		0.82	0.12	0.12	0.11	0.40	697.7	543.4
8	03/06/08	14/07/08		0.45	0.04	0.02	0.06	0.19	559.0	418.7
8	14/07/08	13/08/08		1.15	0.07	0.08	0.15	0.52	489.5	357.3
8 Cond	24/01/07	22/02/07		5.69	0.08	0.24	0.72	1.03	2842.0	2648.3
8 Cond	22/02/07	20/03/07		3.36	0.05	0.16	0.41	0.65	1310.0	1186.2
8 Cond	20/03/07	03/05/07		1.42	0.08	0.07	0.18	0.25	583.5	526.5
8 Cond	03/05/07	07/06/07		1.09	0.11	0.06	0.13	0.23	200.2	181.2
8 Cond	07/06/07	03/08/07		1.47	0.04	0.10	0.18	0.26	329.7	321.0
8 Cond	03/08/07	12/09/07		1.41	0.14	0.19	0.19	0.47	417.2	369.4
8 Cond	12/09/07	16/10/07		1.65	0.04	0.11	0.21	0.35	1070.1	1010.8
8 Cond	16/10/07	08/11/07		3.73	0.09	0.17	0.46	0.55	1079.9	977.2
8 Cond	08/11/07	08/01/08		3.97	0.07	0.19	0.51	0.78	2841.1	2594.8
8 Cond	08/01/08	07/02/08		1.98	0.09	0.09	0.23	0.22	791.5	730.3
8 Cond	07/02/08	11/03/08		10.34	0.12	0.47	1.29	1.92	3523.7	3397.8
8 Cond	11/03/08	21/04/08		1.86	0.10	0.10	0.22	0.31	742.5	676.1
8 Cond	21/04/08	03/06/08		0.92	0.11	0.13	0.12	0.27	457.1	438.5
8 Cond	03/06/08	14/07/08		0.97	0.12	0.04	0.10	0.20	125.5	116.9

8 Cond	14/07/08	13/08/08		1.11	0.08	0.07	0.13	0.22	242.6	209.1

Table B4 Continued

Site	Date on	Date off	pH	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cation Sum	Anion Sum
				µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}	µeq l^{-1}	µeq l^{-1}
8Hi	21/05/07	25/06/07		0.94	0.11	0.05	0.11	0.25	57.8	49.9
8Hi	25/06/07	04/08/07		1.23	0.06	0.05	0.14	0.22	186.2	162.5
8Hi	04/08/07	12/09/07		0.88	0.07	0.09	0.13	0.61	278.9	193.7
8Hi	12/09/07	08/11/07		1.41	0.05	0.08	0.20	0.75	1596.2	1420.7
8Hi	08/11/07	08/01/08		1.57	0.07	0.08	0.22	0.74	1895.5	1803.8
8Hi	08/01/08	07/02/08		4.29	0.10	0.19	0.56	0.83	1354.3	1291.5
8Hi	07/02/08	11/03/08		1.97	0.14	0.09	0.24	0.31	555.7	530.5
8Hi	11/03/08	21/04/08		1.74	0.12	0.10	0.25	0.31	453.8	453.3
8Hi	21/04/08	04/06/08		1.20	0.18	0.14	0.19	0.36	228.1	205.1
8Hi	04/06/08	14/07/08		1.17	0.14	0.05	0.13	0.14	53.0	48.5
8Hi	14/07/08	13/08/08		0.64	0.10	0.04	0.08	0.10	78.3	70.9

Table B5. Anion concentrations measured in TSP collected at various sites in 2007/2008.

Site	Cl^- µg m^{-3}	NO_3^- µg m^{-3}	SO_4^{2-} µg m^{-3}	$C_2O_4^{2-}$ µg m^{-3}	PO_4^{3-} µg m^{-3}	F^- µg m^{-3}	CH_3COO^- µg m^{-3}	$HCOO^-$ µg m^{-3}	$CH_3SO_3^-$ µg m^{-3}	HCO_3^- µg m^{-3}
1	2.33	0.00	0.62	0.91	0.13	0.02	0.00	0.00	0.01	
1	2.58	0.00	0.42	0.75	0.11	0.00	0.00	0.00	0.00	
1	1.93	0.00	0.62	0.98	0.21	0.01	0.00	0.01	0.00	
1	3.67	0.00	0.94	1.50	0.21	0.01	0.00	0.00	0.00	
1	5.69	0.01	0.97	1.87	0.18	0.00	0.00	0.00	0.00	
1	5.87	0.01	1.24	2.13	0.21	0.01	0.00	0.00	0.00	
1	0.26	0.00	0.08	0.14	0.26	0.00	0.00	0.00	0.00	
1	3.37	0.00	1.23	1.52	0.15	0.01	0.00	0.00	0.00	
1	1.59	0.00	1.18	1.37	0.24	0.01	0.00	0.00	0.00	
1	1.29	0.00	0.60	1.05	0.21	0.01	0.00	0.00	0.00	
1	2.46	0.00	0.51	0.90	0.09	0.00	0.00	0.00	0.00	
1	3.09	0.01	0.55	0.94	0.09	0.00	0.00	0.01	0.00	
3	9.93	1.69	3.41	0.30	0.02	<0.01	<0.01	0.02	0.10	
3	4.47	1.18	1.62	0.25	0.02	<0.01	<0.01	0.01	0.02	
3	1.27	0.88	1.00	0.20	0.02	<0.01	<0.01	0.01	0.02	
3	1.75	0.53	0.69	0.11	0.01	<0.01	<0.01	<0.01	0.01	
3	2.60	0.43	0.78	0.11	0.01	<0.01	<0.01	0.01	0.01	
3	1.73	0.56	0.91	0.21	0.01	<0.01	<0.01	0.01	0.01	
3	3.99	0.90	1.51	0.21	0.02	<0.01	<0.01	0.01	0.02	
3	1.51	0.18	0.39	0.03	<0.01	<0.01	<0.01	0.01	0.01	
3	1.79	0.31	0.59	0.09	0.01	<0.01	<0.01	0.01	0.01	
3	8.21	2.51	3.47	0.40	0.01	<0.01	0.01	0.01	0.10	
3	4.81	1.60	1.93	0.19	0.02	<0.01	<0.01	0.01	0.03	
3	1.63	0.48	0.29	0.05	<0.01	<0.01	0.01	0.02	<0.01	
3										
3	1.82	0.44	0.73	0.08	0.01	<0.01	<0.01	<0.01	0.01	
3	1.79	0.32	0.58	0.06	0.01	<0.01	<0.01	<0.01	0.01	
4	1.76	0.75	0.86	0.14	0.00	<0.01	0.01	0.01	0.01	
4	2.95	0.56	0.99	0.11	0.00	<0.01	0.01	0.01	0.01	
4	2.05	0.86	1.14	0.16	0.01	<0.01	0.01	0.01	0.01	
4	4.39	1.26	2.01	0.18	0.01	<0.01	0.01	0.03	0.03	
4	4.68	0.70	1.39	0.15	0.01	<0.01	0.01	0.03	0.02	
4	7.27	1.47	2.69	0.14	0.01	<0.01	0.01	0.02	0.06	
4	7.14	2.35	3.32	0.25	0.01	<0.01	0.01	0.02	0.08	
4	4.29	1.35	1.81	0.17	0.01	<0.01	<0.01	0.01	0.03	
4	1.26	0.67	0.69	0.08	0.01	<0.01	<0.01	0.01	0.01	
4										
4	2.15	0.58	0.95	0.10	0.01	<0.01	<0.01	0.01	0.01	
4	2.80	0.60	1.08	0.10	0.00	<0.01	0.01	0.01	0.01	
5	1.36	0.65	0.76	0.13	0.00	<0.01	0.01	0.01	0.01	
5	2.18	0.45	0.77	0.09	0.00	<0.01	<0.01	0.01	0.01	
5	1.53	0.72	0.96	0.18	0.01	<0.01	<0.01	0.01	0.01	
5	3.27	1.04	1.60	0.21	0.01	<0.01	0.01	0.01	0.02	
5	4.91	0.91	1.75	0.22	0.01	<0.01	0.01	0.02	0.03	
5	4.82	1.18	2.08	0.14	0.00	<0.01	<0.01	0.01	0.05	
5	3.50	1.26	1.67	0.18	0.02	<0.01	<0.01	0.01	0.03	
5	5.93	1.79	2.80	0.27	0.00	<0.01	0.01	0.02	0.07	
5	1.68	1.07	1.29	0.20	0.00	<0.01	<0.01	0.01	0.02	
5	1.06	0.72	1.13	0.16	0.01	<0.01	0.01	0.01	0.01	
5	1.75	0.50	0.81	0.09	0.00	<0.01	<0.01	0.01	0.01	
5	2.24	0.51	0.88	0.09	0.01	<0.01	0.01	0.01	0.01	

Table B5 Continued

Site	Cl^- µg m^{-3}	NO_3^- µg m^{-3}	SO_4^{2-} µg m^{-3}	$C_2O_4^{2-}$ µg m^{-3}	PO_4^{3-} µg m^{-3}	F^- µg m^{-3}	CH_3COO^- µg m^{-3}	$HCOO^-$ µg m^{-3}	$CH_3SO_3^-$ µg m^{-3}	HCO_3^- µg m^{-3}
6	1.73	0.00	0.68	0.81	0.14	0.00	0.00	0.00	0.00	0.01
6	2.67	0.00	0.47	0.89	0.12	0.00	0.00	0.00	0.00	0.01
6	1.93	0.00	0.84	1.15	0.24	0.01	0.00	0.01	0.01	0.01
6	3.64	0.00	1.14	1.75	0.23	0.01	0.00	0.01	0.00	0.02
6	6.30	0.01	1.06	2.17	0.26	0.01	0.00	0.00	0.00	0.03
6	5.65	0.00	1.31	2.23	0.17	0.01	0.01	0.02	0.01	0.01
6	5.73	0.01	1.95	2.77	0.33	0.01	0.00	0.00	0.00	0.02
6	3.59	0.01	1.18	1.61	0.16	0.02	0.00	0.00	0.00	0.01
6	1.80	0.00	1.12	1.35	0.22	0.01	0.00	0.00	0.00	0.01
6	0.71	0.00	0.47	0.62	0.15	0.00	0.00	0.00	0.00	0.01
6	2.37	0.00	0.55	0.95	0.11	0.01	0.00	0.01	0.00	0.01
6	2.80	0.00	0.55	0.98	0.10	0.01	0.00	0.01	0.01	0.02
7	2.11	0.00	0.67	0.82	0.13	0.00	0.00	0.01	0.01	0.01
7	3.09	0.01	0.50	0.92	0.12	0.00	0.00	0.01	0.00	0.01
7	1.91	0.00	0.77	1.01	0.18	0.01	0.00	0.01	0.01	0.02
7	4.01	0.00	1.31	1.80	0.23	0.01	0.00	0.02	0.01	0.03
7	6.11	0.01	1.02	2.02	0.25	0.01	0.00	0.02	0.01	0.03
7	5.91	0.01	1.53	2.48	0.17	0.01	0.01	0.03	0.02	0.02
7	3.41	0.00	1.24	1.64	0.23	0.00	0.00	0.01	0.01	0.01
7	4.54	0.01	1.48	1.88	0.19	0.02	0.00	0.00	0.00	0.01
7	3.52	0.01	1.56	1.77	0.31	0.01	0.00	0.01	0.01	0.02
7	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
7	18.29	0.02	3.99	6.91	0.71	0.03	0.00	0.02	0.02	0.04
7	1.86	0.00	0.34	0.57	0.06	0.00	0.00	0.01	0.01	0.01
8	8.91	0.01	1.53	3.45	0.28	0.00	0.00	0.01	0.01	0.02
8	3.65	0.01	1.14	1.59	0.25	0.01	0.00	0.01	0.01	0.02
8	1.29	0.00	0.92	1.11	0.17	0.01	0.00	0.00	0.00	0.01
8	1.20	0.00	0.56	0.68	0.12	0.00	0.00	0.01	0.01	0.01
8	2.16	0.00	0.48	0.79	0.11	0.01	0.00	0.00	0.00	0.01
8	1.01	0.00	0.45	0.61	0.14	0.01	0.00	0.01	0.01	0.02
8	3.26	0.00	0.98	1.43	0.20	0.00	0.00	0.01	0.01	0.02
8	4.98	0.01	0.84	1.79	0.22	0.00	0.00	0.01	0.01	0.03
8	5.62	0.00	1.23	2.22	0.19	0.00	0.00	0.01	0.01	0.01
8	4.95	0.01	1.76	2.41	0.33	0.00	0.00	0.01	0.00	0.02
8	3.10	0.00	1.01	1.24	0.12	0.00	0.00	0.01	0.01	0.01
8	1.24	0.00	0.91	1.09	0.20	0.00	0.00	0.00	0.00	0.01
8	0.75	0.00	0.65	1.03	0.22	0.00	0.00	0.01	0.01	0.02
8	0.62	0.00	0.19	0.28	0.03	0.00	0.00	0.01	0.00	0.01
8	1.64	0.00	0.43	0.66	0.07	0.00	0.00	0.02	0.01	0.02
8 Cond	8.56	0.01	1.43	3.40	0.28	0.00	0.01	0.01	0.01	0.03
8 Cond	4.75	0.01	1.27	1.82	0.23	0.00	0.00	0.00	0.00	0.03
8 Cond	1.31	0.00	1.07	1.28	0.21	0.00	0.00	0.01	0.01	0.01
8 Cond	1.28	0.00	0.84	0.82	0.11	0.00	0.00	0.03	0.03	0.04
8 Cond	2.28	0.00	0.57	0.86	0.11	0.01	0.00	0.02	0.02	0.03
8 Cond	1.87	0.00	0.92	1.27	0.23	0.01	0.00	0.03	0.03	0.04
8 Cond	2.42	0.00	0.66	1.09	0.14	0.00	0.00	0.01	0.01	0.02
8 Cond	5.46	0.01	0.91	1.90	0.21	0.00	0.00	0.02	0.02	0.04
8 Cond	5.78	0.01	1.27	2.36	0.27	0.00	0.00	0.01	0.01	0.02
8 Cond	2.36	0.00	1.09	1.26	0.13	0.01	0.00	0.00	0.00	0.01
8 Cond	14.52	0.03	5.01	6.69	0.58	0.01	0.01	0.01	0.01	0.04
8 Cond	2.15	0.00	1.23	1.27	0.19	0.00	0.00	0.00	0.00	0.02
8 Cond	0.96	0.00	0.78	1.18	0.25	0.00	0.00	0.01	0.00	0.01
8 Cond	1.31	0.00	0.64	0.73	0.08	0.00	0.00	0.01	0.01	0.03
8 Cond	1.40	0.00	0.58	0.73	0.08	0.00	0.00	0.01	0.01	0.02

Table B5 Continued

Site	Cl^- µg m^{-3}	NO_3^- µg m^{-3}	SO_4^{2-} µg m^{-3}	$C_2O_4^{2-}$ µg m^{-3}	PO_4^{3-} µg m^{-3}	F^- µg m^{-3}	CH_3COO^- µg m^{-3}	$HCOO^-$ µg m^{-3}	$CH_3SO_3^-$ µg m^{-3}	HCO_3^- µg m^{-3}
8Hi	1.29	0.00	0.45	0.79	0.08	0.00	0.01	0.02	0.02	0.07
8Hi	1.82	0.00	0.29	0.67	0.05	0.00	0.00	0.00	0.00	0.04
8Hi	1.22	0.00	0.39	0.77	0.12	0.00	0.00	0.01	0.01	0.03
8Hi	2.06	0.00	0.35	1.83	0.19	0.00	0.00	0.01	0.00	0.02
8Hi	2.32	0.00	0.44	2.22	0.17	0.00	0.00	0.01	0.00	0.01
8Hi	6.19	0.01	1.61	3.03	0.30	0.00	0.00	0.00	0.00	0.03
8Hi	2.66	0.00	1.02	1.47	0.12	0.00	0.00	0.01	0.00	0.02
8Hi	2.63	0.00	1.05	1.23	0.16	0.00	0.00	0.01	0.00	0.03
8Hi	1.44	0.00	0.80	1.44	0.27	0.00	0.00	0.01	0.01	0.03
8Hi	1.65	0.00	0.59	0.73	0.07	0.00	0.00	0.04	0.03	0.07
8Hi	0.82	0.00	0.38	0.60	0.05	0.00	0.00	0.01	0.01	0.03