Identification of Atmospheric Pollutant Sources Across Newcastle (N.S.W) A Pilot Study

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SUMMARY

Air quality is an issue that is of continued interest particularly in urban centres with specific concern regarding its impact on human health and quality of life. Concerns about Newcastle's air quality are regularly expressed and typically linked to its industrial activities. Studies previously undertaken in this area have focused mainly on the industrial pollutant sources and their impact on the inner city suburbs. Research lacking in the air quality of the outer lying suburbs led to the establishment of this study, whose desire it was to construct an assessment of atmospheric particulate movements across the city of Newcastle with an interest in the major urban potential source. Through factor analysis this study aims to identify the major atmospheric particulate sources impacting on the 6 representative. (This study is currently incomplete and is therefore a 'paper in progress').

INTRODUCTION

The necessity to not only study, but monitor and reduce atmospheric particulate levels is evident through its impact on society. At sufficiently high levels, dust can affect any aspect of the community both socially and economically[19,27] (a) through its impact on health, particularly in the young, old, and suffers of chronic bronchitis, asthma, and allergies[19], (b) by impacting on visibility, where by increases in particulate size and concentration decrease visibility distance and clarity[19], and (c) by way of incurring a nuisance value, which is always perceived greater in those who have only recently experienced air quality deterioration than in those subject to it over a longer period[19].

Urban areas, exhibit a multitude of atmospheric particulate sources predominantly anthropogenic where characteristic trace elements are propelled into the atmosphere to be transported a distance away from their source depending on (a) the size and consequently weight of the particulate, and (b) the prevailing meteorological conditions. Table 1 shows the major urban sources and their characteristic trace elements.

LOCATION

Newcastle (N.S.W) is located ~170km north of Sydney (see insert map in figure 1) and is situated at the mouth of the Hunter River on the east coast of New South Wales. The city itself covers ~214km^2 and with a population of 130,940 (as of June 30, 1989) acts as the regional centre for the Hunter Valley[7].

Sampling Sites

The most manageable way to study all aspects of the city was by way of a transect which ran east to west from Stockton, through the industry at Mayfield, and dense residential at Waratah, Jesmond, and Wallsend, to the relative rural outskirts of Minmi on the cities western boundary. Figure 1 shows the location of the 6 samplers, 4 of which were permanently maintained. These 4 sites were at Stockton maintained by Incitec, Mayfield and Waratah by BPH, and Wallsend by Newcastle City Council. The two university samplers at Jesmond and Minmi were installed for the purposes of this study, and were removed following the sampling period.

Meteorological Sites

An intimate relationship exists between particulate emission and deposition[17], thus to pin point particulate sources, the prevailing meteorology needs to be understood. The parameters of interest were wind speed and direction, temperature, rainfall, and humidity[18,26,28,32,34], which were collected at 3 sites across the city. The 3 sites were at Stockton again maintained by Incitec, Mayfield by BPH, which was also used for Waratah, and Wallsend by EPA, which was used for Jesmond, Wallsend, and Minmi.

METHODOLOGY

Sample Collection and Analysis

Air samples were collected at each site by way of a high volume air sampler at a rate of between 1.5-2.0 m^3/min. The decision to use high volume air samplers was due to their availability. They exhibit both advantageous and disadvantageous characteristics, acknowledged by many authors[3,4,19,25,32,36]. Nevertheless, the decision for use was based on their simplicity and inexpense. Sampling was performed in accordance

with the Environment Protection Authority (EPA) atmospheric particulate sampling regime, of every 6th day for a 24 hour period, over 25 weeks.

Prior to and following sample collection, the filters were dried for 24 hours at 110°C and weighed, and the increase in weight from the clean to the sampled filter was assumed as the amount of particulate material collected.

One quarter of each filter was used for analysis, which was cut into pieces ~1cm^2 and fed into a 100ml boiler. 40ml of concentrated HNO_3 was added to each boiler, which were covered with watch glasses and boiled gently for 30 minutes. The watch glasses were then removed, and the boilers continued to boil until the liquid had reduced to ~20ml, at which point they were removed from the heat, allowed to cool to room temperature and the liquid transferred to 100ml volumetric flasks. 30ml of distilled water was added to each boiler, which was agitated, placed on the heat for 10 minutes, removed from the heat and allowed to stand for at least 30 minutes to allow any trace elements trapped in the filter to diffuse into the rinse water. This remaining solution was added to the 100ml volumetric flasks using two washings. The flasks were then made up to the 100ml mark with distilled water. This solution was centrifuged (3300 rpm, 300 seconds), the superant decanted, and stored in plastic vials awaiting analysis.

Trace element measurement was done by a Varian Atomic Absorption Spectrophotometer (AAS). Standard preparation, instrument optimisation, and operating procedures were all carried out in accordance with specifications as per the manufacturer's operating manual[37].

Through a regression and quadratic equation performed by the AAS a value was given which corresponded to the amount of each element in 1/4 of each filter. This value was multiplied by 4 to give a value for the entire filter, which was divided by the amount of air that passed across the filter, giving an elemental concentration at each site for each sampling day in ug/m^3.

Quality Assurance Measures and Errors

1. The high volume air samplers were calibrated periodically through out the 25 week sampling period using a 'top loading orifice plate' and 'differential monometer' both constructed to the Australian Standard: AS2724-3.
2. The glassware was all washed in a nitric acid bath prior to use, and all water used in analysis was triple deionised.
3. Every 25th filter was prepared as a 'reagent blank', which was not used in sample collection but still underwent the full trace element extraction procedures and AAS analysis.
4. Trace element readings from the reagent blanks were subtracted from the respective sampled readings, and this value was taken as the true amount of each trace element sampled.
5. During analysis the AAS program prompted quality control solutions for deviation. Excessive deviation resulted in analysis batch rejection.
6. Most samples were analysed on at least two separate occasions, and often up to six independent readings were obtained. The average standard deviation between readings was 4%.
7. The raw ug/m3 readings for each element was assessed relative to both the lower detection limit (LDL) and sensitivity of the AAS. Readings either below the LDL or below the sensitivity limit once the blank was subtracted, were treated for the purposes of statistical analysis as zero.

Statistical Analysis

The multivariate statistical technique of factor analysis[1,8,9,12,16,20,23] was used to identify relationships between elemental concentrations and meteorological data. Analysis performed on the data was similar to that used by Gatz[12], where a matrix of correlation coefficient between variables was calculated. The initial number of factors was extracted through principal component analysis, where factors with values greater than or equal to 0.9 were kept and rotated to a final reading using a varimax rotation. From these results factor values greater than 0.5 were taken as valid correlation readings from which relationships between the variables was established and potential sources of atmospheric pollutants identified. The entire factor analysis procedure was performed on the statistical computer package 'Minitab for Windows'.

RESULTS/DISCUSSION

Of the 9 elements tested for, only 5 gave values above either the LDL or sensitivity limit of the AAS and were therefore the only elements that could be further analysed. The 5 elements were calcium, iron, magnesium, manganese, and potassium. Histograms were created to identify the relative significance of each element at each site (see graphs 1-5).

Graph 1 shows the average ug.m^{-3} of calcium, which is characteristic of ground disturbance activities. Mayfield recorded the

highest concentration typically because of the magnitude of ground disturbance activities that occur in and around the industrial area, predominantly on internal unpaved roads. Calcium concentrations decreased away from Mayfield which has a two fold explanation, (1) the impact of industrial ground disturbance activities decreases as distance from that source increases, and (2) the types of ground disturbance activities at the other sites generated fewer atmospheric particulates than activities surrounding Mayfield. Minmi showed an increase in calcium concentration from Wallsend most likely due to the housing development under way east of the Minmi sampler.

Graph 2 shows the average $ug.m^{-3}$ of iron, which is most characteristic of general industrial activities. Clearly, Mayfield experienced the greatest impact of iron particulates due to its location as being the closest sampler to the industry. Iron concentrations drop off rapidly at the other sampling sites exhibiting an inverse relationship to distance from the industry. Mayfield exhibited 11.5 times greater concentrations of iron than Minmi which not only reinforced the previous statement but indicated that the weight of industrial iron particulates are relatively large and exhibit a short residence time in the atmosphere.

Graph 3 shows the average micrograms/cubic metre of manganese, and like iron recorded the highest concentrations at Mayfield, decreasing as distance from the industry increased. Graphically, the trend of manganese may be the same as iron but the concentrations are much smaller. Iron concentrations exceed manganese by between 5 and 22 times for each site. The most likely explanation is that manganese is characteristic of a specific industry constituting a very small portion of Newcastle's total industrial activities, mostly of which iron is characteristic.

Graph 4 shows the average $ug.m^{-3}$ of magnesium, which is characteristic of the ocean, reinforced by the obvious trend of the highest concentration recorded at Stockton, decreasing with increased distance from the coast.

Graph 5 shows the average $ug.m^{-3}$ of potassium which is characteristic of soil disturbance. Potassium was only recorded at Jesmond and Minmi with higher concentration recorded at Minmi due to the housing and estate development east of the Minmi sampler.

Factor analysis was performed for each site on the elements and the meteorological variables previously identified. Two examples of the results are shown in table 2 and 3 which represent the Mayfield and Minmi sites respectively.

Correlations from tables 2 and 3 were assessed with respect to table 1 and the following identifications were made. Four factors were identified at Mayfield (table 2), three contributing to the trace element concentrations. Factor 1, which contributed 23.9% to the relationships identified, showed a correlation between calcium, iron and north east wind indicating calcium to be a result of industrial unpaved road disturbance and particulate suspension, while iron was purely from industrial activities. Factor 2, contributed 18.7%, and showed a correlation between magnesium and easterly wind indicating this to be from an ocean source. Factor 4, which contributed 14.1%, showed a correlation between manganese, maximum wind speed, and northerly wind indicating another industrial source, possibly the manganese plant.

Five factors were identified at Minmi (table 3), again only three contributing to trace element concentrations. Factor 1, which contributed 20.9% to the relationships identified, showed a correlation between potassium, magnesium, minimum temperature, and south easterly wind. Potassium was identified as having come from soil disturbance activities such as housing construction to the east of the sample, while the magnesium was undoubtedly a derivative of the ocean. Factor 2, which contributed 19.1%, showed a correlation between iron and easterly wind indicating this to have derived from the industry. Factor 3, contributed 14.2%, and showed a correlation between calcium and north east wind potentially having derived from ground disturbance activities occurring at building sites to the north east of the sampler.

The results of factor analysis have allowed the identification of potential sources, but the relative impact or significance of each source was assessed with respect to the elemental concentrations indicated in graphs 1-5 allowing the following conclusions to be made. Clearly iron, magnesium, and manganese have been identified at Mayfield and Minmi and it would appear have derived from the same sources, but elemental concentrations at Minmi are a magnitude less than those at Mayfield, indicating the relative impact at Mayfield to be more significant. Factor analysis shows the sources of calcium and potassium to be localised at both sites which is reflected in graph 1 where calcium concentrations are high at both Mayfield and Minmi, and graph 5 where potassium was recorded at intermittent sites.

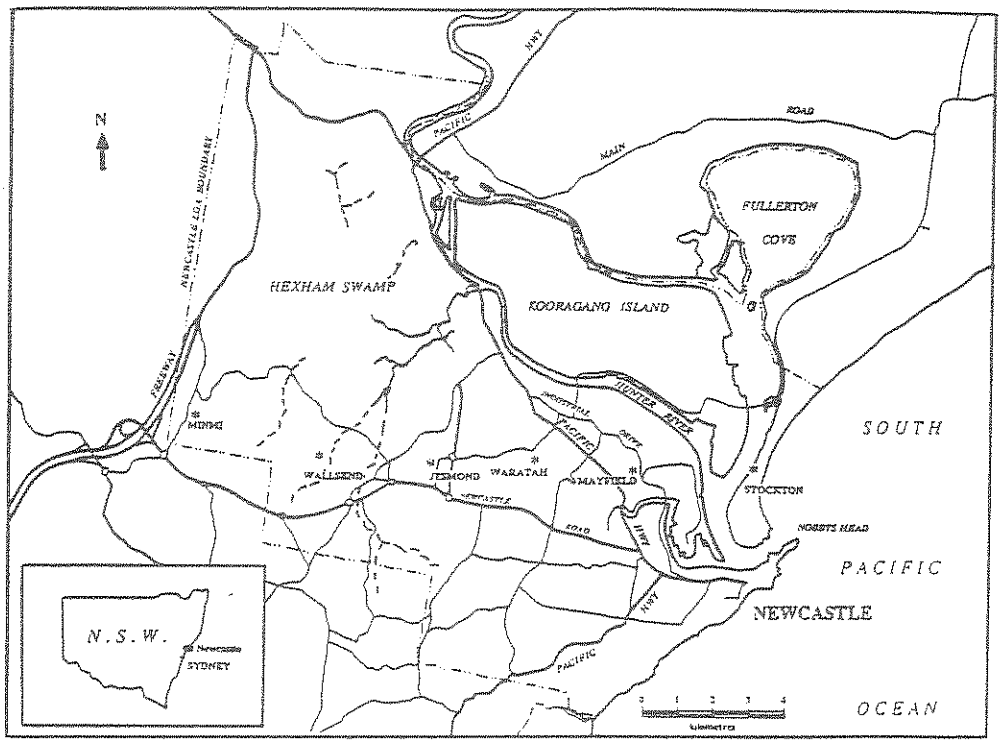


Figure 1: Location of Newcastle and the Sampling Sites

Table 1: Urban Suspended Particulate Sources and the Trace Elements Characteristic of Each

SOURCES	Ca	Cd	Cu	Fe	K	Mn	Mg	Pb	V
Agriculture	*		*	*	*	*	*	*	
Construction	*	*	*	*		*			*
Domestic Heating			*	*				*	
Industry		*		*		*	*	*	
Street Dust	*	*	*	*				*	
Vehicular		*		*				*	
Ocean	*				*		*		

(2,5,6,10,11,13,14,15,21,22,24,27,28,29,30,31,32,33,35,36)

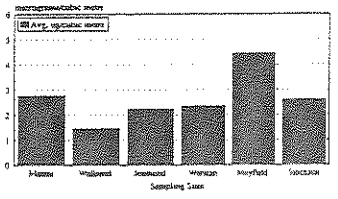
Table 2 : Factor Analysis Correlations for Mayfield

Variables	Factor 1	Factor 2	Factor 3	Factor 4
Ca	**0.827**	0.113	0.281	0.221
Fe	**0.864**	0.344	0.181	-0.101
Mn	0.073	-0.263	0.072	**0.672**
Mg	0.336	**0.692**	-0.107	-0.230
TSP	**0.740**	0.332	0.340	0.025
Min. Temp	0.009	**0.828**	0.210	-0.339
Max. Temp	0.309	0.482	0.413	0.091
Max. Wind Speed	-0.096	-0.178	-0.040	**0.852**
Rainfall	0.159	0.094	0.064	-0.419
North	0.316	-0.092	0.246	**0.736**
North East	**0.817**	0.257	0.173	-0.060
East	0.317	**0.613**	0.195	-0.180
South East	**-0.821**	0.332	0.215	-0.210
South	-0.153	0.041	**-0.928**	-0.116
South West	-0.162	-0.102	**-0.865**	-0.024
West	0.002	**-0.817**	0.101	-0.165
% of Variance	23.9	18.7	14.1	14.1

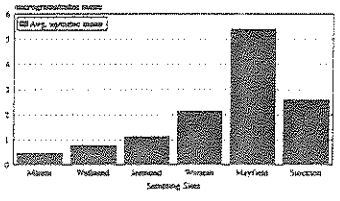
Table 3 : Factor Analysis Correlations for Minmi

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Ca	0.373	0.059	**0.812**	0.063	-0.007
Fe	-0.075	**-0.911**	0.198	0.025	-0.035
K	**0.777**	0.214	0.337	-0.024	-0.274
Mn	-0.187	**-0.783**	0.189	-0.019	0.159
Mg	**0.864**	-0.319	0.136	-0.082	-0.002
TSP	0.253	**-0.806**	-0.152	-0.027	-0.241
Min. Temp.	**0.768**	0.000	-0.300	-0.079	0.165
Max. Temp.	0.158	-0.412	-0.146	-0.181	**-0.638**
Max. Humidity	0.290	-0.090	-0.236	**-0.834**	0.054
Max. Wind Speed	0.487	-0.124	0.107	**0.707**	0.007
North	-0.381	0.180	0.286	**-0.504**	**-0.506**
North East	-0.314	-0.095	**0.706**	0.182	-0.166
East	-0.010	**-0.764**	0.065	0.011	0.044
South East	**0.790**	0.184	-0.060	0.113	-0.039
South	0.001	-0.126	-0.271	-0.234	**0.842**
South West	0.037	0.235	**-0.716**	-0.009	0.069
West	-0.383	0.275	-0.406	0.445	-0.265
% of Variance	20.9	19.1	14.2	10.6	9.8

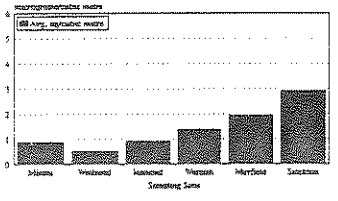
Graph 1: Calcium Concentrations at each Sampling Site



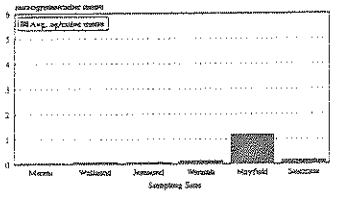
Graph 2: Iron Concentrations at each Sampling Site



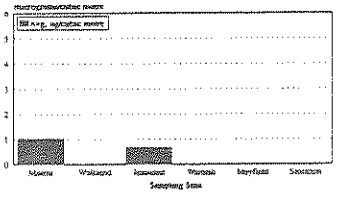
Graph 3: Magnesium Concentrations at each Sampling Site



Graph 4: Manganese Concentrations at each Sampling Site



Graph 5: Potassium Concentrations at each Sampling Site



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