

CHARACTERISATION AND HEALTH IMPACTS OF THE OCTOBER 2002 DUST EVENT IN QUEENSLAND: A PRELIMINARY INVESTIGATION

Shannon Rutherford¹, Karen I. Macintosh², Kari A. Jarvinen¹, Grant H. McTainsh³, Andrew Chan³

¹ Environmental Health Unit, Queensland Health, GPO Box 48 Brisbane, Qld, 4001, ² Air Services, Environmental Protection Agency, PO Box 155 ALBERT STREET, Qld, 4002, ³ Faculty of Environmental Sciences, Griffith University, Nathan, Qld, 4111.

Summary

This paper describes the characteristics of the October 23 2002 dust event and the results of a preliminary investigation into the health impacts of the event. The event was associated with significantly elevated PM₁₀ and PM_{2.5} levels in several coastal cities of Queensland.

Preliminary statistical analysis has indicated that despite the elevated levels of both PM₁₀ and PM_{2.5}, no detectable change in respiratory admissions or emergency department attendances was found. A statistically significant change was observed for cardiovascular admissions and this requires further investigation.

Keywords: particles, dust, respiratory, cardiovascular, asthma, Queensland, hospital admissions

1. Introduction

Beginning on Wednesday 23 October 2002 Queensland experienced a dust storm that affected visibility across the state. The dust storm originated in South Australia and moved across eastern Queensland and New South Wales, reaching the eastern coast of Australia on the morning of the 23rd October and clearing in Mackay, Queensland on the 26th October 2002.

Dust storms of this magnitude are rarely experienced in the highly populated urban coastal areas of Queensland. The event provided an opportunity to study the characteristics of the dust storm and its impacts on the environment and health of the exposed population.

This descriptive study reports the particle levels and size distribution before and during the dust storm event and examines hospital admissions and emergency department attendances for relevant health outcomes before and after the event.

2. Background

The relationship between particles and health has been studied extensively around the world. Time-series studies have been useful in establishing dose-response relationships between particles and health outcomes such as respiratory and cardiovascular mortality and hospital admissions. In parallel, toxicological studies

continue to answer questions regarding mechanisms of action and systemic effects associated with particles.

Most epidemiological studies have focussed on particle mass either as PM₁₀, and to a lesser extent, PM_{2.5}. An increasing number of epidemiological studies have shown that the finer particles (PM_{2.5}) have stronger associations with health outcomes such as cardiovascular and respiratory mortality and morbidity (Schwartz et al., 1996, Victoria EPA, 2001). Epidemiological studies that have examined the elemental composition of particles and their impacts on health have not shown consistent or convincing results (Roemer et al., 2000; Tolbert et al., 2000). However, toxicological studies in animals indicate that exposures to urban particles are associated with respiratory and cardiovascular changes (HEI, 2002).

Dust storms occur reasonably frequently in inland Australia (McTainsh et al., 2001) and regularly impact upon the air quality of inland cities such as Mildura. However, it is rare that a dust plume engulfs a coastal city. The best documented recent events were in Melbourne on 8 February 1983 (Raupach et al., 1994), in Brisbane on 1 December, 1987 (Knight et al., 1995) and Adelaide on 24 and 25 May, 1994 (McGowan et al., 2000). Small incursions of rural dust into coastal Australia are more common, particularly in late winter/spring in southern Queensland and New South Wales, and during summer in Victoria and South Australia. These small events frequently go unnoticed by city dwellers, as they are difficult to distinguish from urban-derived particle

pollution. Dust events are commonly associated with elevated particle levels in both the fine and coarse fractions, with most elevation in the coarse fraction (Chan et al., 1999).

Very few studies have examined the impact of rural dust on health in urban communities. A descriptive study by Rutherford et al (1999) found that a number of dust events in south-east Queensland were associated with a decline in lung function (peak expiratory flow) and an increase in asthma severity in a self-selected panel of asthmatics. A Kuwait study found no effect of dust storm activity on the frequency of attendances or admissions for asthma in children (Strannegard and Strannegard, 1990), while Hefflin et al. (1994) concluded that naturally occurring particles associated with dust events in Washington State had only a small effect on the respiratory health of the population, even when 24-hour average PM₁₀ levels exceeded 1000 µg/m³. An investigation of the effect of elevated particle levels associated with dust storms on mortality revealed that there was no increased risk of mortality on dust episode days compared with non-dust episode days (Schwartz et al., 1999). Taken together, these studies do not provide a clear or consistent picture of the potential impact of elevated particle levels associated with dust storms on public health. However, other studies that have specifically investigated the coarser fraction of PM₁₀, ie. those particles with an aerodynamic diameter greater than 2.5 µm, indicate that this size fraction is more strongly associated with respiratory mortality than the PM_{2.5} fraction (Castillejos et al., 2000) and that particle composition may also be playing an important role in this size fraction, particularly for cardiovascular mortality (Ostro et al. 2000).

3. Methods

3.1. Air quality data

PM₁₀ and PM_{2.5} data (either from High-Volume or TEOM samplers) routinely collected by the Environmental Protection Agency were available for a number of monitoring sites in south-east Queensland, Gladstone and Mackay during the dust event. PM_{2.5} data collected and analysed by the Australian Nuclear Science and Technology Organisation (ANSTO) (ERDC 1995) were also available for two sites during the dust event. The method of analysis for PM_{2.5} provides information on the composition of the particles collected and hence an insight into sources (Cohen et al., 1995).

The 24-hour PM₁₀ and PM_{2.5} concentrations during the October dust storm event were compared to average October levels from 1997-2001. South-east Queensland values were also compared to a dust storm occurring in the region on 4 July 2002.

To determine particle-size distribution characteristics for a day before the event (17/10/2002) and on the first

day of the event (23/10/2002), two Total Suspended Particulate (TSP) filter samples from a site dominated by motor vehicle emissions were analysed using a Coulter Multisizer (Kiefert, 1995). This method requires only small amounts of sample to produce a very high-resolution particle-size distribution presented in 256 size-classes. Particle-size data are expressed as volume per cent particle-size frequency distributions. Temperature, ozone and pollen levels were reviewed for the October dust event to determine any other factors that may contribute to any identified health effects.

3.2 Health data

Non-identifying individual patient health data were obtained from hospitals within areas from where air quality data were available. Hospital admissions (HA) data were extracted from the Queensland Health central database for the Brisbane Statistical Division as well as the Local Government Areas of Caloundra, Maroochydore, Noosa, Gladstone and Mackay. Less severe health effects, measured by respiratory Emergency Department (ED) attendances were also examined to complement hospital admissions data. ED data were requested separately from individual hospitals in the Brisbane metropolitan area. For both data sources the requested data fields included date and time of presentation, age, gender and diagnostic code. Data were obtained for the period between October 1st and November 30th for the study year of 2002 as well as for the same period in 1997-2001 to act as control years. ED data were not available from all hospitals for the full control period. Table 1 summarises the diagnostic groupings extracted for analysis, indicating whether the groups were included in the admissions or ED datasets.

Table 1 – Disease groups analysed using hospital admissions (HA) and Emergency Department (ED) data, with International Classification of Diseases (ICD) coding

Disease group	ICD-9 Code	ICD-10 Code	HA	ED
Bronchitis, chronic bronchitis, emphysema	490–492.99	J40–J43.9	✓	✓
Asthma	493–493.99	J45–J46.9	✓	✓
Ischaemic heart disease	410–414.99	I20–I25.9	✓	
Heart failure	428–428.99	I50–I50.9	✓	
Stroke	430–438.99	I60–I69.9	✓	

A staged analysis was carried out on the obtained data, commencing by comparing daily admissions or ED presentations for the entire Oct-Nov 2002 period against the daily means for the same period during 1997-2001. This was followed by comparing 2002 data for the 7 and

10-day periods from October 23 onwards against the same average 7 and 10-day periods for 1997-2001. Further analyses were then performed on 2002 data by comparing a 7 and 10-day average period after the dust event against the corresponding period before the event. Analyses were carried out for combined respiratory and combined cardio-vascular diseases as well as for individual disease categories. Sub-group analyses were performed by location and also by gender and age group where significant post-dust event elevations were noted. All analyses were carried out using MS-Excel-97[®] testing means by the two-sample t-test assessing significance at the 0.05-level. Unequal variances were assumed when comparing 2002 data against the previous years, while equal variances were assumed when comparing 2002 pre- and post-event data.

4. Results

4.1 Characteristics of the October 2002 dust event

On the morning of 23 October, 2002 the dust storm swept across eastern Australia, extending along a 2,900km front, from the northern Victoria to beyond Mt Isa, in north west Queensland. As it moved across eastern Australia the dust storm swept up large quantities of topsoil from the drought-affected rangelands of Queensland and New South Wales.

This dust storm is typical of a large number of dust storms that are associated with westerly winds that accompany frontal systems travelling west-east across the continent. However, both the large scale and severity of the event make it possibly the largest dust storm in eastern Australia in the past 40 years (McTainsh et al. 2003).

Elevated air temperatures were observed at the Rocklea monitoring site in south-east Queensland on October 23rd, with a peak of 37°C at 5pm, approximately 10°C higher than the previous day's maximum at 2pm.

Queensland Health released a media statement in the afternoon prior to the event reaching Brisbane, advising of the event and recommending precautions for sensitive populations.

4.2 Air quality during the October 2002 dust event

Table 2 shows the maximum PM₁₀ concentrations recorded during two dust storm events in 2002 and average concentrations derived from 1997-2001 data. The 23 October 2002 dust storm was recorded at air quality monitoring stations in south-east Queensland, Gladstone and Mackay. The 4 July 2002 dust storm passed through only the south-east Queensland region.

Maximum PM₁₀ concentrations at least three times the 24-hour average Air NEPM standard of 50 µg/m³ were measured during the October dust storm. PM₁₀ levels

measured in the south-east Queensland region were lower than those measured in the Gladstone and Mackay regions. The maximum south-east Queensland measurements were recorded on 23 October while maximum concentrations in Mackay occurred on 24 October and in Gladstone on 26 October. In general, for each region, the monitoring stations located closer to the coastline (e.g. Mountain Creek and Eagle Farm) recorded lower PM₁₀ levels than stations further inland (e.g. Targinie).

Table 2- 24-hour average values (µg/m³) for PM₁₀ concentrations (standard deviations included in brackets)

Location	Maximum PM ₁₀ (October event)	Average October PM ₁₀ (1997-2001)	PM ₁₀ (July event)
South-east Queensland ^a			
Mountain Creek ^b	147	17.2	76
Eagle Farm	147	22.7(1.3)	108
Brisbane CBD	162	18.8(2.2)	96
South Brisbane ^c	170		100
Woolloongabba	176	30.8(7.1)	114
Rocklea	177	20.0(2.9)	95
Springwood	140	17.1(2.3)	88
Helensvale	Nd	17.5(1.9)	82
Flinders View	197	17.6(2.9)	100
Gladstone ^d			
South Gladstone	197	23.7(3.8)	
Clinton ^b	185	25.1	
Targinie ^b	204	24.7	
Mackay ^e			
West Mackay	475 *	21.6(4.7)	

nd – no data available

^a Highest PM₁₀ concentrations during the October dust storm were recorded on 23/10/02 for south-east Queensland (except Mountain Creek (maximum 26/10/02))

^b Monitoring only commenced at Mountain Creek, Clinton and Targinie stations in 2001

^c Monitoring only commenced at South Brisbane station in 2002

^d Highest PM₁₀ concentrations during the October dust storm were recorded on 26/10/02 for Gladstone.

^e Highest PM₁₀ concentrations during the October dust storm were recorded on 24/10/02 for Mackay.

At the three south-east Queensland sites where PM_{2.5} is measured, the maximum PM_{2.5} concentrations during the October dust storm event were 34, 47 and 39 µg/m³ at the Brisbane CBD, Rocklea and Springwood monitoring sites, respectively. These exceeded the Air NEPM advisory standard of 25µg/m³. These values are

significantly higher than the average PM_{2.5} for the 1997-2001 period of 10 µg/m³. The July dust storm produced PM_{2.5} levels around 15 µg/m³, considerably lower than those measured during the October event.

The contribution of soil to PM_{2.5} samples taken twice weekly at the Brisbane CBD and Rocklea stations is routinely analysed by Australia Nuclear Science and Technology Organisation (ANSTO). On average, soil contributes 7-9% of the PM_{2.5} mass collected from non-dust storm October 2002 samples. For the first day of the dust event, 55% of the PM_{2.5} has been attributed to windblown soil.

No noticeable change in other air pollutants such as ozone and pollen was observed during the dust event period.

Figure 1 shows the particle size distributions for the two days investigated. The pre-event sample has a mode of 20 µm compared with the event sample which has a mode of 6.4 µm. Previous studies have indicated significant variability in modal sizes ranging from 4.0 to 14.4 µm for Brisbane urban dust samples and 4.8 to 12.1 µm for Brisbane rural dust samples (Clark, 1995). Figure 1 indicates that the modal size of the urban dust prior to the event is greater than that previously reported and the size distribution for the event is at the finer end of the rural dust range.

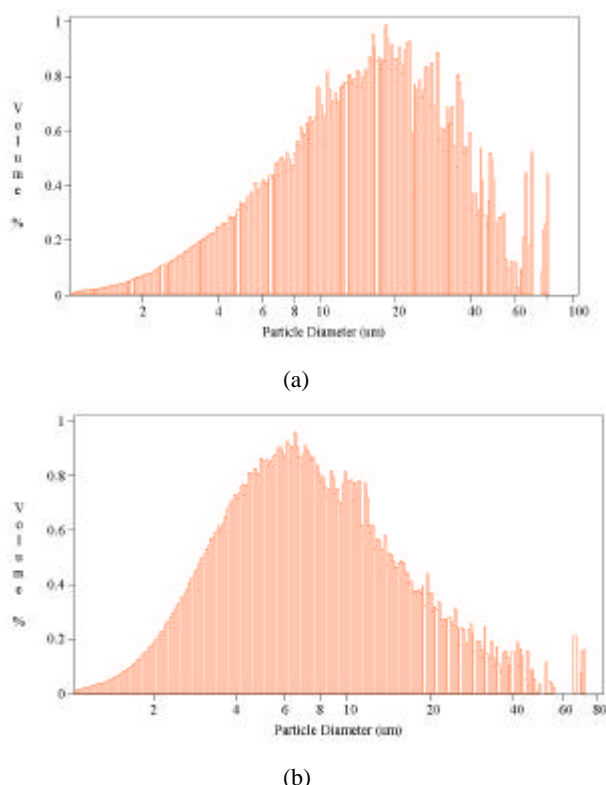


Figure 1 – Particle size distribution for a pre-dust event day 17/10/02 (a) and the first day of the dust event 23/10/02 (b)

4.3 Hospital admissions and emergency department attendances

Hospital Admissions

Daily admissions for combined cardio-vascular diseases were elevated during the ten days following the 2002 event in comparison with the preceding ten days. However, this difference was not statistically significant (Table 3). The average of the daily admissions for ischaemic heart disease for the 10 days after the event was significantly higher than the average of the ten days before the dust event. Analyses by gender showed ischaemic heart disease admissions to be significantly elevated only for females for both the seven ($p=0.03$) and ten-day average periods ($p = 0.005$). The overall patterns of ischaemic heart disease admissions are summarised in Figure 2. While a significant change has been detected statistically, this change is not easily observed when charted. Stroke admissions were elevated for the average of the seven days after the dust event ($p=0.02$), with increased significance for the Brisbane data alone ($p=0.007$). The lack of appreciable impact of the dust event on respiratory diseases is demonstrated in Figure 3.

Table 3 - Mean hospital admissions and ED presentations before and after the October 2002 dust event for 7 and 10-day averaging periods

Means	2002 pre- and post-event					
	7 days			10 days		
	Pre-	Post-	$p(t)$	Pre-	Post-	$p(t)$
Hospital Admissions						
Combined Respiratory	7.4	6.3	0.22	7.2	6.4	0.26
Asthma	7.0	6.1	0.35	6.8	6.3	0.46
COPD/ Bronchitis	1.0	1.0	-	1.0	1.0	-
Combined Cardiovascular	32.6	36.3	0.15	32.6	36.2	0.08
IHD	21.0	23.0	0.33	19.8	23.7	0.03
Heart failure	7.1	6.1	0.40	7.7	5.6	0.12
Strokes	4.4	7.1	0.02	5.1	6.9	0.11
ED Presentations						
Combined Respiratory	11.3	9.6	0.38	12.6	9.0	0.03
Asthma	8.1	7.1	0.56	9.0	6.7	0.11
COPD	2.0	2.0	1.00	2.5	2.2	0.68
Acute Bronchitis/- iolitis	2.0	1.3	0.39	2.1	1.2	0.16

Comparing data for 2002 against the means for 1997-2001 for the 7- and 10-day averaging periods from October 23rd, there was no significant increase in admissions during 2002 for most of the studied diseases. Admissions were higher in 2002 only for females with ischaemic heart disease. Combined respiratory, asthma as well as gastroenteritis admissions were significantly

lower in 2002 compared with the previous years for this period. This reduction in 2002 could reflect changes in hospital admissions procedures.

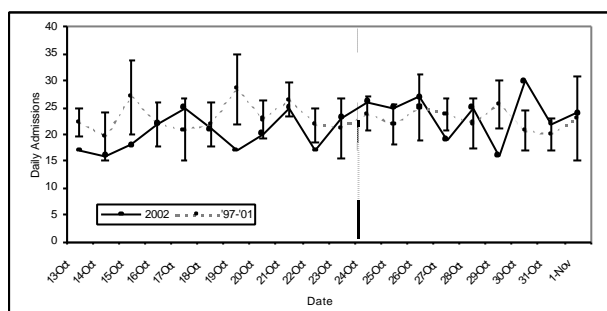


Figure 2 – Daily admissions for Ischaemic Heart Disease for the 10-day period before and after 23 Oct 2002 and the average of the previous 5 years (with 95% confidence intervals)

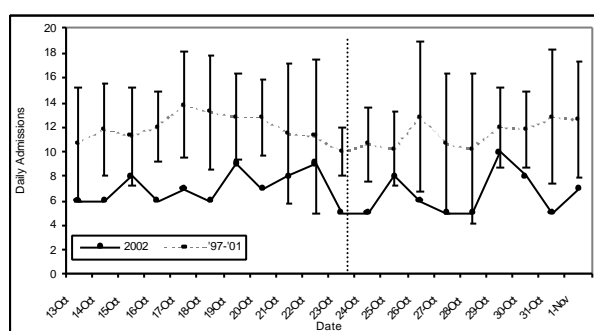


Figure 3 –Daily admissions for respiratory conditions for the 10-day period before and after 23 Oct 2002 and the average of the previous 5 years (with 95% confidence intervals)

Emergency Department Attendances

Supplementary analyses of daily Emergency Department respiratory disease presentations generally revealed no significant increases following the dust event (Table 3). Presentations for acute bronchitis were significantly higher during Oct-Nov 2002 in comparison with the corresponding period over the preceding five years ($p = 0.02$), but the presentations were not significantly elevated on comparing the period after the dust event with periods prior to it. Similarly, presentations for chronic bronchitis / emphysema were significantly higher during Oct-Nov 2002 in comparison with the corresponding period over the preceding five years ($p = 0.01$), the association being even more marked for females ($p < 0.001$). There were no significant increases in asthma presentations.

5. Discussion and recommendations

The question of whether dust events of this magnitude have a significant impact on public health is frequently asked of health and environment agencies. The aims of this descriptive study were to describe the characteristics and investigate the health impacts of the October 2002

dust event. Hospital admissions and emergency department attendance data were used as markers of impact. Other more sensitive markers of adverse respiratory impacts were not available for this study.

This dust event was associated with levels of PM_{10} between 3 and 5 times higher than the 24-hour average NEPM value of $50 \mu\text{g}/\text{m}^3$, with $PM_{2.5}$ levels recorded up to twice the current NEPM advisory standard of $25 \mu\text{g}/\text{m}^3$. Despite significantly exceeding ambient air standards, no significant changes in respiratory hospital admissions and emergency department attendances were observed after the event. This is consistent with previous studies by Hefflin et al (1994), Strannegard and Strannegard (1990) and Schwartz et al (1999) who examined hospital outcomes and mortality associated with dust events.

One possible reason for the absence of the effect is the particle composition for the dust event. Limited available data indicated that 55% of the finer particles ($PM_{2.5}$) were of soil origin. The urban particle mix has been found to be associated with respiratory and cardiovascular impacts and is predominantly characterised by organic compounds, metals and sulfate and nitrate aerosols.

Other factors that may have contributed to the absence of respiratory impact are exposure and sensitivity of health outcome. Factors that may have reduced exposure are the timing of the event (the event occurred late afternoon when outside activities, particularly for those most susceptible groups, are less likely) and health advisory statements made by Queensland Health recommending that people with respiratory and cardiovascular conditions should remain indoors and avoid exertion.

Though no significant changes were observed for respiratory admissions or ED attendances, more sensitive markers of respiratory change may have been experienced in the community. A previous study of individuals with asthma has reported changes in peak expiratory flow and asthma symptoms after a number of significant dust events in Brisbane (Rutherford et al., 1999).

A significant increase in cardiovascular admissions, particularly ischaemic heart disease, after the dust event was found in this study. There is increasing epidemiological evidence of an association between particles and changes in cardiovascular function as well as cardiovascular admissions and mortality. As well, numerous animal studies have suggested mechanisms for cardiovascular impacts from urban particle exposure. However, the authors recognise the limitations of the data available and the preliminary nature of the analysis. Further investigation of the cardiovascular impacts is required.

This preliminary investigation has indicated that despite elevated particle levels associated with the dust event, no changes in respiratory admissions or ED attendances and only small changes in cardiovascular

admissions were detected. Given the limited data, statistical design, and choice of outcomes used for the study, health agencies should continue to provide advisory warnings to the public for major dust events, particularly targeting those with existing respiratory and cardiovascular conditions.

Further investigation of the regional data and lag effects is being planned, as well as an investigation of impacts from dust events compared with bush fire events associated with similar particle level increases.

Acknowledgments

The authors wish to thank the hospital emergency departments of the Mater Childrens, Mater Adults, Royal Childrens, Royal Adults, and Logan and Queensland Health Information Centre for supply of data. Thanks also to Professor Charles Mitchell, University of Queensland for advice, and colleagues within Queensland Health and the Environmental Protection Agency for comment and support.

References

- Castillejos M., Borja-Aburto, V.H., Dockery, D.W., Gold, D.R., Loomis, D. 2000, 'Airborne coarse particles and mortality', *Inhalation Toxicology*, **12**(Supp 1): 61-72.
- Chan Y.C., Simpson R.W., McTainsh G.H., Vowles P.D., Cohen D.D. and Bailey G.M. 1999. 'Source apportionment of PM_{2.5} and PM₁₀ aerosols in Brisbane (Australia) by receptor modelling', *Atmospheric Environment* **33**: 2151-3268.
- Clark E. 1995, 'The impacts of rural dust on air quality in Brisbane', B.Sc. (Honours) Dissertation, Griffith University, Brisbane.
- Cohen D., Kondepudi R., Hyde R., Young M., Crisp P., 1995, 'Meteorological and chemical interpretation of air pollution by fine-aerosol particles in the region 200km around Sydney', *Final report*. Australian Nuclear Science & Technology Organisation. Lucas Heights, New South Wales.
- EPA Victoria, 2001, 'Ambient Air Pollution and Daily Hospital Admissions in Melbourne, 1994-1997', EPA Publication 789.
- ERDC 1995, 'Contributions of Fuel Combustion to Pollution by Airborne Particles in Urban and Non-Urban Environments'. ANSTO, UNSW, Macquarie University. Report no: ERDC 259.
- Hefflin B. J., Jalaludin B., McClure E., Cobb N., Johnson C. A., Jecha L., Etzel R.A. 1994. 'Surveillance for dust storms and respiratory diseases in Washington State, 1991'. *Archives of Environmental Health*, **49**(3): 170-174.
- HEI – Health Effects Institute. 2002 'Understanding the health effects of components of the particulate matter mix: progress and next steps', HEI Perspectives, April 2002, www.healtheffects.org.
- Kiefert L. 1995. 'Characteristics of wind transported dust in Eastern Australia'. Ph.D Thesis, Griffith University.
- Knight A.W., McTainsh G.H. & Simpson R.W. 1995, 'Sediment loads in an Australian dust storm: Implications for present and past dust processes'. *Catena* **24**: 195-213.
- McGowan H.A., McTainsh G.H. and Peyman Zawar-Reza.2000, 'Identifying regional dust transport pathways: application of kinematic trajectory modelling to a trans-Tasman case', *Earth Surface Processes and Landforms* **25**: 633-647.
- McTainsh G.H, Leys J.F. & Tews E.K. 2001, 'Wind erosion' in, *Australia: State of the Environment*, CSIRO Publishing, Melbourne: 24-27.
- McTainsh G.H, McGowan H.A. Chan, A and Leys J.F. 2003, 'The 23rd October, 2002 dust storm in eastern Australia: characteristics and meteorological conditions', *Atmospheric Environment* (submitted)
- Ostro B. D., Broadwin R., Lipsett M.J. 2000., 'Coarse and fine particles and daily mortality in the Coachella Valley, California: a follow-up study', *Journal of Exposure Analysis and Environmental Epidemiology* **10**(5): 412-419.
- Raupach M.R., McTainsh G.H. & Leys J.F. 1994, 'Estimates of dust mass in some recent major Australian dust storms', *Australian Journal of Soil and Water Conservation*, **7**(3): 20-24.
- Roemer W., Hoek G., Brunekreef B., Clench-Aas J., Forsberg B., Pekkanen J., Schutz A. 2000, 'PM₁₀ elemental composition and acute respiratory health effects in European children (PEACE project)', *European Respiratory Journal* **15**: 553-559.
- Rutherford S., Clark E., McTainsh G., Simpson R., Mitchell C. 1999, 'Characteristics of rural dust events shown to impact on asthma severity in Brisbane, Australia', *International Journal of Biometeorology* **42**: 217-225.
- Tolbert P. E., Klein M., Metzger K.B., Peel J., Flanders W.D., Todd K., Mulholland J.A., Ryan P.B., Frumkin H. 2000, 'Interim results of the study of particulates and health in Atlanta (SOPHIA)', *Journal of Exposure Analysis and Environmental Epidemiology*, **10**: 446-460.
- Schwartz J., Dockery D.W., & Neas L.M. 1996, 'Is daily mortality associated specifically with fine particles' *Journal of the Air and Waste Management Association* **46**: 927-939.
- Schwartz J., Norris G., Larson T., Sheppard L., Claiborne C., Koenig J. 1999, 'Episodes of high coarse particle concentrations are not associated with increased mortality', *Environmental Health Perspectives* **107**(5): 339-342.
- Strannegard I. L., Strannegard O. 1990. 'Childhood bronchial asthma in a desert country'. *Allergy*, **45**: 327-333.