HEALTH EFFECTS OF COARSE PARTICLES
Vicky Sheppeard, Otto Puntsag and Adam Capon
Environmental Health Branch, NSW Health

Summary
Recent research on the adverse health effects of particulate matter (PM) in ambient air is focussing on elucidating the role of particle size and source in eliciting health effects. In settings influenced by the coarser fraction of particles, such as around mines, there has been some question as to whether exposure standards based on urban air pollution are appropriate for health protection.

In this paper we review the literature on health effects of PM ranging from 2.5 – 10 microns, with an emphasis on studies conducted around mining communities. We also include recent reviews of health effects from community exposure to silica dust in particular.

The literature suggests that there are significant respiratory health effects associated with the coarser fraction of PM10 and that it is important to minimise any incremental exposure to PM from developments such as mines. In most situations, and where PM concentrations comply with standards, it is unlikely that silica represents any additional risk to health for nearby communities.

An outcome of this review was a brochure for mine dust affected communities, developed jointly by NSW Health Department, NSW Department of Environment and Conservation and the NSW Minerals Council.

Keywords: air pollution, PM10, coarse particles, mine dust.

1. Introduction
Adverse health effects of particulate matter (PM) in ambient air have drawn considerable research and policy attention. Particulate matter has proven to cause a range of health effects, such as:
- increases in total mortality (all causes),
- increases in hospital admissions for respiratory and cardiovascular conditions,
- increases in the daily prevalence of respiratory symptoms,
- increases in hospital emergency and medical surgery visits for asthma and other respiratory conditions,
- small decreases in the level of pulmonary function.

Inflammation appears to be the major determinant in inducing these effects, with the immune response dependant on particle constitution and size.

Studies on health effects of airborne PM initially looked at health effects from the full range of suspended particulate matter (TSP). With advancing measurement techniques and the understanding that particles larger than around 10 microns in diameter did not enter the lower respiratory tract, research focussed for many years on inhalable particles (PM10). As measurement technology again improved and with an understanding that the fine fraction of PM10 (i.e. PM2.5) could penetrate to the alveoli, research from the latter part of the 1990’s started to document health effects from this size fraction. More recently there has been renewed attention about health effects of the coarse fraction of PM10 i.e. particles >2.5µm, referred to as PM2.5.

From a policy perspective this range of PM is of particular relevance to mining developments.

2. Literature Review
In 2006 an extensive review was undertaken by Schwarze et al who examined epidemiological and toxicological evidence for PM with a specific focus on particle properties, health effects and consistency between the study disciplines.

With regard to particle size, epidemiological evidence showed acute exposure to coarse PM may be significantly associated with mortality and morbidity, but not for long term exposure. Toxicological evidence on the issue is mixed. Toxicological studies using uniform model particles, such as polystyrene, carbon black and titanium oxide showed that smaller particles induced stronger inflammatory responses than larger particles due to their larger surface area. However when ambient PM was used, it was determined that the coarse fraction was the most potent, even at the same mass, due to its constitution. The authors concluded that size alone
is not the critical determinant of PM induced health effects.

With regard to PM metal content the authors noted that current epidemiological studies indicate some importance for the presence of metals in air pollution mortality, which was consistent with toxicological evidence that showed that metals play an important role in both pulmonary inflammation and cardiovascular effects. Metals are also believed to be involved in allergic responses. The authors document one study which demonstrated that the coarse fraction of PM, in general, contained more metals and induced a greater immune response than fine fractions, although the metals alone could not account for the level of the immune response.

With regard to biological content of particles the authors note that toxicological studies suggest a higher concentration of biological content is found on coarse particles when compared to fine particles, and this biological content is a major inducer of inflammation by PM.

With regard to crustal particles the authors conclude that epidemiological studies, in which crustal particles dominate, generally show that these particles may elicit adverse effects on respiratory morbidity. This is consistent with toxicological data showing the potential for mineral particles to induce inflammation.

In 2005 Brunekreef and Forsberg, undertook a systematic review of ecological studies looking at health effects of coarse particulate air pollution. The conclusion of the article was that the time-series studies relating ambient PM to mortality have in some places provided evidence of an independent effect of coarse PM$_{2.5-10}$ on daily mortality, but in most urban areas, the evidence is stronger for fine particles. In studies of chronic obstructive pulmonary disease, asthma and respiratory admissions, coarse PM$_{2.5-10}$ has a stronger or as strong short-term effect as fine PM, suggesting that coarse PM$_{2.5-10}$ may lead to adverse responses in the lungs triggering processes leading to hospital admissions. There is also support for an association between coarse PM$_{2.5-10}$ and cardiovascular admissions.

Toxicological studies concerned with particulate matter assess the immune response to particulate matter. A particulate matter immune response is initiated when the particles reach the lower respiratory tract where they are phagocytosed by alveolar macrophages and neutrophils. The macrophages may produce inflammatory mediators. Toxicological studies that investigated the response of human alveolar macrophages exposed to ambient particulate matter found that the coarse particle fraction was more potent in inducing inflammatory mediators (Becker 2004 & 2005, Hetland 2005, Pozzi 2003). Becker showed that cytokine production of macrophages was especially enhanced by coarse PM$_{2.5-10}$ and particularly by bacterial endotoxin content of coarse PM$_{2.5-10}$ (Becker 2004). Another study by the same author suggested that the potency for inducing the release of inflammatory mediators may be related in part to the elemental constituents of PM of crustal origin (Becker 2005). In a further study Alexis et al showed that the biological component of coarse PM$_{2.5-10}$ was important in mediating specific macrophage responses but not neutrophil responses.

Ecological studies from Toronto found a significant association between coarse particles and hospitalisation for asthma and respiratory infections, respectively, among children younger than 15 years (Lin 2002 & 2005). Gordian assessed the effects of exposure of PM$_{10}$ from road sanding and re-entrained volcanic ash on asthma medication administered to schoolchildren. There was an observed increase in asthma medication administered to schoolchildren with increased PM$_{10}$ (Gordian 2003).

Several studies have been conducted to look at the question of how exposure to mining dust may impact on local communities:

Brabin et al. in a cross sectional study in Merseyside, UK found respiratory symptoms were more common in coal mining dust exposed areas, including wheeze, excess cough in primary school children and school absences for respiratory symptoms (Brabin 1994).

Pless-Mulloli recruited 4860 children aged 1-11 from 5 socioeconomically matched pairs of communities close to active opencast coal mining sites and control sites away from them in rural England (Pless-Mulloli 2000 & 2001). The studies concluded that children in opencast communities were exposed to a small but significant amount of additional PM$_{10}$ to which the opencast sites were a measurable contributor. Past and present respiratory health of children was similar, but General Practitioner consultations for respiratory conditions were higher in opencast communities. However we note that there was little difference in PM$_{10}$ levels between opencast and control communities. (17.0 versus 14.9 µg/m³).

Howel studied a sub-group of children from the communities in the Pless-Mulloli research (Howel 2001). The associations found between daily increases in PM$_{10}$ levels and respiratory symptoms were positive but varied between communities.

A study conducted in Brisbane, Australia by Rutherford, examined the particulate characteristics of 11 dust events in Brisbane and associations with daily diary records of people with asthma, and hospital emergency attendances for asthma during 1992-94 (Rutherford 1999). The results indicate that a number of dust events were significantly
associated with changes in asthma severity, but general relationships could not be determined.

The findings of the above studies confirm that there are health effects of the coarse fraction PM$_{2.5}$, $10$ and that coarse PM$_{10}$ from mining activities could be associated with adverse health effects, predominantly respiratory conditions.

The importance of taking account of coarse particles was again confirmed in the review of consistency of epidemiological and toxicological studies for particulate matter properties and health effects (Schwarze 2006). This review concluded that there is a certain consistency between epidemiological and experimental data with respect to the health effect of the coarse fraction PM$_{2.5,10}$ that should not be neglected. The magnitude of the effect may differ with the type of coarse particle.

3. Health effects of silica dust

The occupational health effects of exposure to silica dust are well-recognised, and characterised as acute silicosis (cough, shortness of breath and pulmonary lipoproteinosis) and chronic silicosis (characterised by lung nodules and scarring). Respirable silica is also classified as a known carcinogen by the International Agency for Research on Cancer. Communities potentially exposed to silica dust have been concerned that the lesser exposures outside the mine environment may also result in significant lung disease.

There is no evidence that people outside of occupational settings have developed respiratory disease from silica exposure.

In 2005 the California Office of Environmental Health Hazard Assessment established a chronic reference exposure level for inhaled crystalline silica of 3 micrograms/cubic metre. This was set after review of occupational health studies at a level of lifetime exposure that is not expected to result in respiratory effects.

The USEPA have taken a slightly less stringent position on inhaled silica. Based on available medical evidence, the US EPA considers that its annual average PM$_{10}$ standard of 50 $\mu$g/m$^3$ is sufficiently adequate to protect the general population from the risk of silicosis if silica comprises less than 10% of particulate mass$^\prime$.

Epidemiological evidence suggests the range of health effects from coarse PM$_{10}$ does appear to differ from those expected from exposure to the finer fraction. Toxicological evidence suggests particulate size as well as particulate constitution is responsible for immune responses to particulate matter.

Thus it remains important to regulate sources of coarse particulate matter and reduce population exposure where possible.

5. NSW Health policy response

Communities near mines are often exposed to increased concentrations of coarse PM$_{10}$. This exposure may vary over the life of the mine as the operation evolves.

In providing advice about potential health effects from a new mine it is important to consider the range of positive and negative health impacts that could arise. The Environmental Assessment should provide predictions of expected incremental and total exposure to PM. It is also important to consider the adverse health impact on communities if forced relocations of some households in response to expected PM exposure result in a non-viable community. Other considerations are the potential for varying sensitivity to respiratory effects from exposure to coarse PM, any synergistic effects from smoking, and the positive impact on health from increased local employment provided by the mine.

Providing communities with evidence-based information about PM exposure and ways to reduce exposure may assist in reducing some of the adverse impact of mining activities. We developed a fact sheet about mine dust in liaison with the NSW Minerals Council and the Departments of Environment and Conservation and Planning that is provided to communities affected by mine dust and available on the NSW Health website: [www.health.nsw.gov.au/pubs/ 2005/mine_dust.html](http://www.health.nsw.gov.au/pubs/ 2005/mine_dust.html)

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