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Fine Particulates (PM2.5) Air Pollution Australia

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See www.3sc.net/airqual/

Fine particle pollution

A lot of attention was recently given to the dangers of fine particle air pollution during the GST debate. And rightly so. A recent study by NSW Health estimated that, every year, approximately 400 Sydneysiders die prematurely from the effects of air pollution. The pollutant most significantly related to premature mortality, and the only one to remain significant in the multi-pollutant models, was fine particulate pollution, measured by a device known as a nephelometer.

Nephelometers measure very small particles - less than about 2.5 microns (m , or millionth of a metre) in aerodynamic diameter, by their ability to scatter light. This is known as PM2.5 pollution - particle matter less than 2.5 microns. Such particles are so small, a million or so would fit on the dot over this i. According to a New Scientist article (Inside Science, No 84, 1995) large particles are filtered out by the nose. Middle size particles deposited in the airways are trapped on a layer of mucus which sweeps them to the throat, where they are coughed up or swallowed. Only particles less than 2 microns reach the alveoli, where they must be dealt with by macrophages from the immune system. The article continues "*It is important to remember that even those industrial and traffic pollutants that only mildly irritate lungs can make us more vulnerable to infection*."

Immediate effects

The NSW Health study investigated only the *immediate* effects of air pollution in Sydney. Air pollution measurements were compared with the number of people dying or admitted to hospital for heart or respiratory disease either on the day, or day following, the pollution. Most people who died would have been sick for some time; air pollution created additional stress exacerbating the situation.

Animal experiments are now shedding light on how this happens. Researchers at Harvard University exposed rats with bronchitis either to filtered air or, for 6 hours a day, to the PM2.5s present in the air at Harvard, concentrated 30 fold to simulate a pollution event. Within three days, 37% of the rats breathing PM2.5s were dead, but none of those breathing filtered air. Deaths occurred without visible changes in behaviour, or signs of irritant inhalation such as rubbing of eyes or nose, coughing or sneezing.

There is no reason, however, to believe these immediate effects represent the total effect of air pollution. As the New Scientist article suggested, air pollution can increase the risk of infection. Thus one pollution event may increase the risk of getting sick, another may make the situation worse, then finally, especially if you are old and frail, (or young and vulnerable) the next may load the system beyond its limits. Put simply, total exposure over a year, or even several years, may be a more important measure than the amount of pollution received the day before death.

Imagine a study relating mortality to the number of cigarettes smoked just on the day before death. Because smoking reduces life expectancy, it is highly likely that an association would be found. However, this association would be much smaller than for the average number of cigarettes smoked over the past several years. The latter indicator of smoking would give a much larger estimate of the effect on mortality. The same appears to be true for PM2.5 pollution.

Effects measurable after longer-term (annual) exposure

No studies of total or annual effects of air pollution on mortality have yet been done in Australia, but they have in the US. The most famous is known as the 'Six Cities Study', in which 8111 subjects (average age 50 years) from six cities were

studied between 1974 and 1991. Age, sex, weight, height, education, occupational exposures, smoking and medical history of each subject were recorded. The six cities were chosen to be representative of the range of air pollution in the US and had a comprehensive range of air pollution measurements, including total suspended particles, PM2.5s, SO_2, sulphate particles, aerosol acidity and ozone.

As might be expected, smoking had a large effect on mortality, increasing the risk of death in the subjects studied by 59%, plus a further increase depending on the amount of smoking, eg 26% for 25 years of 1 pack per day. Body mass index, education level and being a former smoker were also significant. So was city of residence; the city with the highest air pollution had 26% greater mortality, than the least polluted one. When mortality was graphed against PM2.5 pollution, the effect was almost linear (see graph 1). There was no clear relationship for ozone, SO_2, total particles or aerosol acidity. The second closest relationship was with sulphate particles which, in these cities, averaged 42% of the fine particle mass. Overall, mortality increased by 14% for each additional increase of 10 $\mu g/m^3$ of PM2.5 pollution.

A second study using death rates and fine particle measurements in 50 cities was published some time later. Unfortunately, in this study, air pollution measurements were recorded from 1979-83 but mortality from 1982-89. The non simultaneity of the two sets of measurements may have caused a downward bias in the results - a 17% increase in risk of mortality for the least polluted versus the most polluted city, equivalent to a 7% increase in mortality for each additional 10 µg/m3 of PM2.5 pollution.

Both studies therefore found PM2.5 increased death rates. A simple average of the two studies - a 10% increase in mortality for each additional 10 µg/m3 of annual PM2.5 pollution would appear to be the most plausible estimate of the overall effect. Note this is five times higher than the short-term effect observed in Sydney. Immediate short-term effects, observed on the day, or day following increased air pollution appear to represent the tip of an iceberg. Confirmation of this comes from Australian research in the Hunter and Illawarra, which found each increase of 10 µg/m3 of annual PM10 pollution increased the risk of chest colds by 43% and night time coughs by 34%. In contrast, each additional increase of 10 µg/m3 in *daily* PM10 pollution has been found in several overseas studies to increase *daily* hospital admissions for lower respiratory symptoms or cough by about 0.7 to 1.2%. Again, observed daily effects seem to represent the tip of an iceberg.

Are health effects related to PM2.5 or PM10 pollution?

PM10 means particle matter less than 10 microns, of which PM2.5s are a subgroup. Very recent research from the US has found that daily mortality is linked only to PM2.5 pollution, but not particles between 2.5 and 10 microns. Based on the long term estimates, PM2.5 air pollution in Sydney is likely to be responsible, not just for the estimated 400 deaths each year, but five times as many ie about 2,000 deaths every year and 5,000 deaths Australia wide, compared with the ideal case of little or no pollution.

Current PM2.5 measurements in Australia

Nonetheless PM2.5 measurements, especially in summer, in Australia compare quite favourably to other parts of the world. According to the July 1997 VIC EPA Air Quality Management Plan, annual PM2.5 concentrations in Australian capital cites in 1994 ranged from about 6 µg/m3 of PM2.5 in Brisbane to 8.5 in Perth. However, a very recent study by CSIRO (www.cmar.csiro.au/e-print/open/CSIRO_AFP.pdf) suggests a worse picture, especially in winter in areas where wood heaters are common. Launceston, (measured in June & July 1997), averaged 49.3 µg/m3 of PM2.5; Canberra (May 97, Monash) 34.3; Melbourne (April 97) 14.8, Brisbane (Sept, Oct & Nov 96) 11.2, Sydney (Aug 96) 18.5 and Adelaide (Aug 97) 15.8. Thus PM2.5 pollution in winter in Monash, ACT and Launceston, Tasmania not only exceeds the recently set NEPM standards, but is also considerably worse than the annual average of 29.6 µg/m3 in the worst of the six US cities. The circles on Graph 1 show the increase in mortality in these cities in winter, if the relationship between mortality and PM2.5 pollution holds not just for entire years, but for seasons within years. These values are, of course, hypothetical, based only on measured wintertime pollution and the relationship between annual pollution and annual mortality in the US cities.

No evidence wood smoke less harmful than other PM2.5

While many people have expressed the view that wood smoke is natural, so not harmful, this is contradicted by a wealth of scientific evidence. Over 40 papers linking adverse health effects to wood smoke are listed on the web at: www.3sc.net/airqual/smog_refdescr.htm#CityWide

The American Lung Association (ALA) of Washington, on the web at: http://www.alaw.org/ tells us that "*Air pollution from fireplaces and wood stoves contains particulate matter and more than 100 other chemical compounds and pollutants. Particulates can lodge deep in the lungs, causing structural damage while reducing resistance to infection. Long-term exposure may lead to chronic obstructive lung disease and an increased risk of cancer.*" The ALA's first suggestion under "*what you can do*" is: "*Don't burn wood!*" and the second is: "*Convert your wood-burning fireplace to use natural gas or propane.*" Education programs in Washington emphasize: "*Wood smoke is more than a nuisance, it is a*

health hazard. This health hazard does not exist in a far away industrial area, it exists in residential neighbourhoods, where people live and spend time with their families."

Wood smoke and cancer

Indeed, tumour initiation tests on mice and Ames tests on bacteria suggest wood smoke is 12 times more carcinogenic than the same amount of cigarette smoke. Epidemiological studies in Brazil, have recently linked wood smoke to mouth and throat cancer, suggesting that it may be responsible for 30% of these cancers. Known carcinogenic PAHs in wood smoke include bezo(k)- fluoranthene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene and benzo(a)pyrene. The latter is also a constituent of cigarette smoke, made famous by the "*every cigarette is doing you damage*" adverts. Zeedik found that an enclosed wood stove emitted 22, 17, 43 and 12 times the amount of these toxic PAHs as an open wood fire.

In Santa Clara County, California, and Seattle, Washington, wood smoke is the predominant air pollutant (up to 90%). In both places daily PM pollution was found to be significantly linked to hospital admissions for respiratory infections, just like PM pollution from other sources.

In Armidale, a rural city of 22,000 with virtually no air pollution in summer but high reliance on wood heaters in winter, PM2.5 measurements were taken in a residential area to the east of the CBD. Graph 2 shows measurements, compared with the concentration of PM2.5s administered to the rats with bronchitis in the Harvard Experiment. Unfortunately, nobody in Armidale appears interested in repeating the Harvard experiment, but using ordinary air which reaches the same PM2.5 concentrations without the need of fancy equipment to concentrate it 30-fold.

Particulate pollution and cot deaths

Particulate pollution is also linked to SIDS or cot deaths. A study published in 1997 found that for each additional 10 µg/m3 of PM10 air pollution in the first two months of a normal birth weight baby's life, cot deaths increase by 12% and respiratory deaths by 20%. So, a normal birth weight baby in East Armidale whose first two months of life were June and July 1997 (average PM2.5 pollution 55 µg/m3), would experience a 66% increase in risk of cot death and 110% (ie 2.1 times) increased risk of respiratory death. For comparison, a 1 pack per day smoking father increases indoor pollution by 30 µg/m3, equivalent to a 36% increased risk of cot death. Independently, a New Zealand Study looked at the effect of smoking by the father and found a 37% increase in risk of cot death. Fortunately, such deaths are fairly rare. The vast majority of babies survive. Having a father who smokes is not generally considered a reason for excessive alarm, and living in a high wood smoke area should be considered in the same light. But in both cases, all reasonable steps should be taken to minimize the risk. If the Australian findings of a 43% increase in chest colds and 34% increase in night time coughs for each additional 10 µg/m3 of average annual PM10 also applies to monthly or quarterly pollution, averages of 55 µg/m3 PM2.5 over June and July are clearly significantly detrimental to health.

Contribution of Wood smoke to PM2.5 pollution

Wood smoke is, in fact, a major component of PM2.5 pollution in most Australian capital cities. Even in Sydney, where roughly 13% of households use wood heating, carbon dating of PM10 particles (sampled overnight on various days in July and August 1993 from 4 pm to 8 am the following morning) found that 67% of carbon in PM10s from inner Sydney originated from wood, not coal, oil or diesel. In the Blue Mountains, the proportion was 81%. A study by the NSW EPA of emissions in Sydney found that, despite only 13% of households burning wood, wood heaters emitted an estimated 38 tonnes of fine particulates per day in winter, compared with only 2 tonnes for all passenger vehicles on Sydney's roads and 15 tonnes for other mobile sources (mainly diesel). The NSW Health study noted that both deaths and particulate pollution in Sydney peaked significantly every winter.

In Perth, wood heaters emit an estimated 28 tonnes of particulates per day in winter, compared with 4 tonnes for diesel trucks and 0.5 tonnes for buses. In Melbourne and surrounding Port Philip region, vehicle exhausts emit an estimated 2,800 tonnes of PM2.5 every year, but domestic solid fuel combustion emits 5,200 tonnes annually, nearly twice the contribution, not just in winter, but averaged over the whole year.

In Brisbane, diesel particulates are probably greater than wood smoke, but the latter are nonetheless increasing. When a neighbour installed a new AS4013 wood heater, a family in Brisbane had to move house to escape the noxious emissions which affected their health. The family were told that wood heater sales in Brisbane were now greater than in Melbourne. Roughly 7% of houses in SE Qld now have wood heaters, the majority installed in the last 5 years.

In fact, wood heater use and wood smoke emissions are increasing in most of Australia. ABS figures from 1983 to 1994 show wood consumption changed little in the ACT, but rose 70% in NSW, 20% in Vic, 22% in SA, 58% in WA and a massive 227% in Qld. The NSW EPA predict that, despite new standards for wood heaters, PM2.5 emissions from wood heaters will rise by about 25% from 1996-2012, an increase of about 10,000 tonnes per year in NSW alone. This compares with Clive Hamilton's estimate of 1,520 tonnes more PM2.5 pollution for the GST package. Thus, the potential for increased PM2.5 pollution from increasing wood heater use is considerable. Furthermore, new technology such as particle traps for diesel engines (New Scientist, 21 Feb 98) or diesel/water or diesel/alcohol mixtures have the potential to slash emissions from the existing diesel fleet by 90-95%. There is no equivalent technology to reduce wood heater emissions.

Will new wood heaters help?

New AS4013 wood heaters produce about half the PM2.5 pollution of older models - but this still represents a considerable amount, about 150 to 200 grams of PM2.5s every single day, if correctly operated, and much more (in excess of half a kilo-gram) if crammed full of wood then the air control turned down immediately for an overnight burn.

The photo (above) shows typical emissions from an AS4013 heater rated at 3.2 g/kg (better than the average of models currently on sale) when turned down for the night.

The average diesel truck is no worse than the average wood heater. US figures for a 1987 GMC heavy diesel 2-axle truck and a 1987 Ford 3-axle dump truck are 0.4 g/km. So, if the truck is driven at 80 km/h for 10 hours, it produces 320 g. This seems like an horrific figure, but a lot of brand new wood heaters installed this winter will produce more pollution than this, every single day they are used! Furthermore 25% of Australian households now use wood heating. Imagine how we'd feel pollution-wise if one household in every four used a diesel truck for several hours a day!

If we don't want this increase in heater sales and wood heater PM2.5 emissions to continue, we must also do a better job of publicising the health effects of wood smoke and, as in the US, encourage or mandate people to seek less polluting forms of heating. A flued natural gas heater, for example, emits significantly less greenhouse gases under normal use and virtually no PM2.5 pollution. We also have to think about alternatives, such as home insulation (to reduce heating needs and so greenhouse gases) as well as solar heaters (see the latest issue of ReNew magazine www.ata.org.au) and passive solar home design. Correctly sized eaves and north facing living areas can create a home that is bright, warm and sunny in winter, but which received no direct sun in summer - a far more attractive proposition than chopping wood to light the fire.

Do we need Smokeless Zones?

Most residential areas of the UK have been declared as 'smokeless zones' to protect the health of the people and provide a pleasant environment. Those affected by wood smoke in Australia have no choices. One family, who moved house to escape health problems caused by a neighbour's newly installed woodstove, deliberately chose a coastal suburb of Brisbane where there were no chimneys and the climate seemed far too mild for anyone to want a wood heater. But soon afterwards, wood heaters were installed near their home and the air has changed from fresh to smoky. For four months of the year, regardless of how mild the weather, windows now have to be kept closed in an effort to keep out the smoke. The health problems continue. The family want to know where they can go to escape this form of pollution.

Indeed, a NSW EPA study found that, of those who had sometimes or often experienced problems from other people's smoke, only 6% had complained. Perhaps this is because, as in the case above, local authorities appear unwilling to take effective action. State EPAs act upon reports of a vehicle seen smoking for 10 seconds or more. But complaints about a domestic chimney producing 10 times the quantity of smoke, not for 10 seconds, nor 10 hours but even continuously for 10 months appear to result in little more than the local council providing information to the owner about correct operation of the heater. If this has happened to you, or you have had the opposite experience of successful action being taken, or you felt discouraged from complaining in the first place, let us know. We would like to compile a list of such experiences. People concerned about wood smoke should also write to their Local Council and the Minister of Health asking whether families would be informed under the planning process about an application to install a wood heater close (say within 50 metres) of their home, why there are no smokeless zones in Australia, and why the complaints procedure has to be handled, not by the EPA, but by local authorities, who have no training in air pollution.

We need a realistic assessment of the costs and benefits of wood heating in urban areas. There are many renewable, greenhouse and environmentally friendly uses for all the wood we will ever be able to grow, including wood fired heat and power plants (needed to replace coal fired plants) as well as production of ethanol needed to replace dwindling petrol supplies.

Conclusions: PM2.5 pollution is known to be have significant health impacts, including exacerbation of asthma and increased risk of premature mortality, especially in the very young and the elderly. Environmental groups were rightly concerned over increased PM2.5 pollution from increased diesel use. But new technology could reduce PM2.5 emissions from the diesel fleet by 90-95%, if there is a will to insist on its use. In contrast a state of the art AS4013 wood heater operated continuously for a day, will emit more PM2.5 particles than driving a new car 15,000 km, or if carelessly operated produce more PM2.5s than a new car in its entire lifetime. Though used by only a small proportion [25%] of households, wood heaters now produce more than twice as many PM2.5s than all vehicles in most capital cities in winter. It's time we started to treat wood heater PM2.5 pollution in the same way as other health hazardous pollution and attempt to get rid of it for once and for all, so we can all enjoy clean air in our residential areas.

Further reading: a collection of scientific papers on which this article is based is available at The LEAD Group Office in Sydney. Also see the Air Quality Group's site: www.3sc.net/airqual/

Air Pollution Causes Eight Thousand Deaths Per Day

By CSIRO Atmospheric Research, Private Bag 1, Aspendale 3195 Australia. Tuesday, 24 August 1999

Air pollution kills eight thousand people every day worldwide, according to a recent international Commonwealth Science Council conference.

"The World Health Organization estimates that about 2.8 million people die each year due to indoor pollution (over 500,000 occur in China alone). And about 200,000 deaths are due to outdoor air pollution", says one of the conference organisers, Dr Peter Manins.

"Most of these deaths are caused by excessive levels of fine particles in the air, but smog is involved as well.

"There is an alarming number of deaths and illnesses due to the poor state of air quality in many countries in Asia and Africa. Indoor air pollution is particularly serious in many regions. The evidence is now accepted around the world," says Dr Manins.

Diesel vehicles and open fires produce most of the airborne particles that are dangerous to human health. The number of diesel vehicles is increasing much more rapidly than petrol vehicles.

The very large numbers of severe health effects and deaths due to particle pollution from indoor use of coal and biomass fuels (agricultural waste and wood) for cooking and heating, particularly in developing countries, are a real concern according to Dr Manins.

"However, simple steps such as ventilation to take the smoke outside can greatly reduce the problem," Dr Manins says.

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Lead in Wood smoke:

Larson & Koenig (Annual Review of Public Health, 1994) reported that lead (Pb) particles in wood smoke ranged from 0.1 to 3.0 mg per kg of wood burned. Burning 3 tonnes of wood will therefore result in between 0.3 and 9 g of Pb. Tests on automobiles in the US (a 1965 Mercury, 1969 and 1974 Fords, 1970 Buick and 1976 VW Beetle, published in Environmental Science and Technology, 1991) averaged 8.7 mg of lead/km. So, using one of these old cars, running on leaded premium petrol at 0.34 g/gal (0.9 g/l), or 0.22 g/gal (0.06 g/l) for the Mercury and Buick, you need to drive between 35 and 1040 km to emit the same amount of Pb as using a wood heater for the winter.