

# Chapter 2

## Particulate matter sources and effects

2.1 Everyone is affected by the quality of air that we breathe, and has an interest in ensuring the ongoing availability of safe, clean air. For the most part, Australians enjoy clean air which has been getting cleaner in recent decades. The NSW Environmental Protection Authority (EPA) reported that:

In terms of overall air quality in New South Wales, it has improved significantly since the 1980s. We have seen a steady decline in the order of 20 to 40 per cent in some of the key pollutants such as ammonia, carbon monoxide, lead and sulphur dioxide as well as the oxides of nitrogen and volatile organic compounds.<sup>1</sup>

2.2 It was clear throughout the inquiry, however, that air pollution is still a significant problem for certain parts of the Australian population. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) provided a definition of air pollution for the committee:

Air pollution refers to the presence in the atmosphere of chemicals, particulates, or biological materials that cause discomfort, disease, or death to humans, damage other living organisms such as food crops, or damage the natural environment or built environment. Examples of air pollutants include particulates, oxides of sulphur and nitrogen, carbon monoxide, volatile organic compounds, toxic metals (such as lead), ground-level ozone, and odours.<sup>2</sup>

2.3 Particulate matter (PM) refers to everything in the air that is not a gas; with the PM and air mixture referred to as aerosol. It includes both solid particles and vapours (liquid particles). Particulate matter is highly heterogeneous in size and composition. PM is often chemically active in the environment and in humans, can be transported long distances in the atmosphere, and can influence weather and climate.<sup>3</sup> The total mass of PM in the air is referred to as TSP (total suspended particles).<sup>4</sup> The particles of most concern for human health are those that can enter the lungs, namely particles less than 10µm (1µm = 1 thousandth of a millimetre) in diameter (PM<sub>10</sub>) and particles less than 2.5 µm in diameter (PM<sub>2.5</sub>).<sup>5</sup>

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- 1 Mr Buffier, Chief Executive Officer, New South Wales Environmental Protection Authority, *Committee Hansard*, 16 April 2013, p. 1.
  - 2 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 3.
  - 3 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 7.
  - 4 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 8.
  - 5 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, pp. 1–2.

## Sources

2.4 There are many sources of particulate matter included natural and anthropogenic sources. In Australia PM load naturally fluctuates due to airborne dust, sea salt, and smoke from bushfires. PM is categorised as primary or secondary depending on its source.

2.5 Primary particles originate from both anthropogenic and natural sources. Natural sources are derived from processes that occur naturally in the earth system, such as bubbles bursting on the sea surface which release sea salt aerosol into the atmosphere, wind-blown dust, and smoke from naturally lit bushfires. Anthropogenic sources result from human activity and include: dust associated with agriculture, mining, urban developments, and road traffic; smoke from deliberately lit bushfires, prescribed burning, and household wood heaters; emissions from vehicle exhaust, industrial processes, and commercial activities; and spray drift from aerial application of agricultural and horticultural chemicals.<sup>6</sup>

2.6 Secondary particles are formed by chemical reactions in the atmosphere that result in gases being converted to particles, which are also known as secondary aerosols. These conversions lead to the production of a large number of very small particles (nucleation) and the growth in size of existing particles (condensation).<sup>7</sup> These processes are represented graphically below:

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6 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, pp. 7–8.

7 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 8.

## ATMOSPHERIC AEROSOL

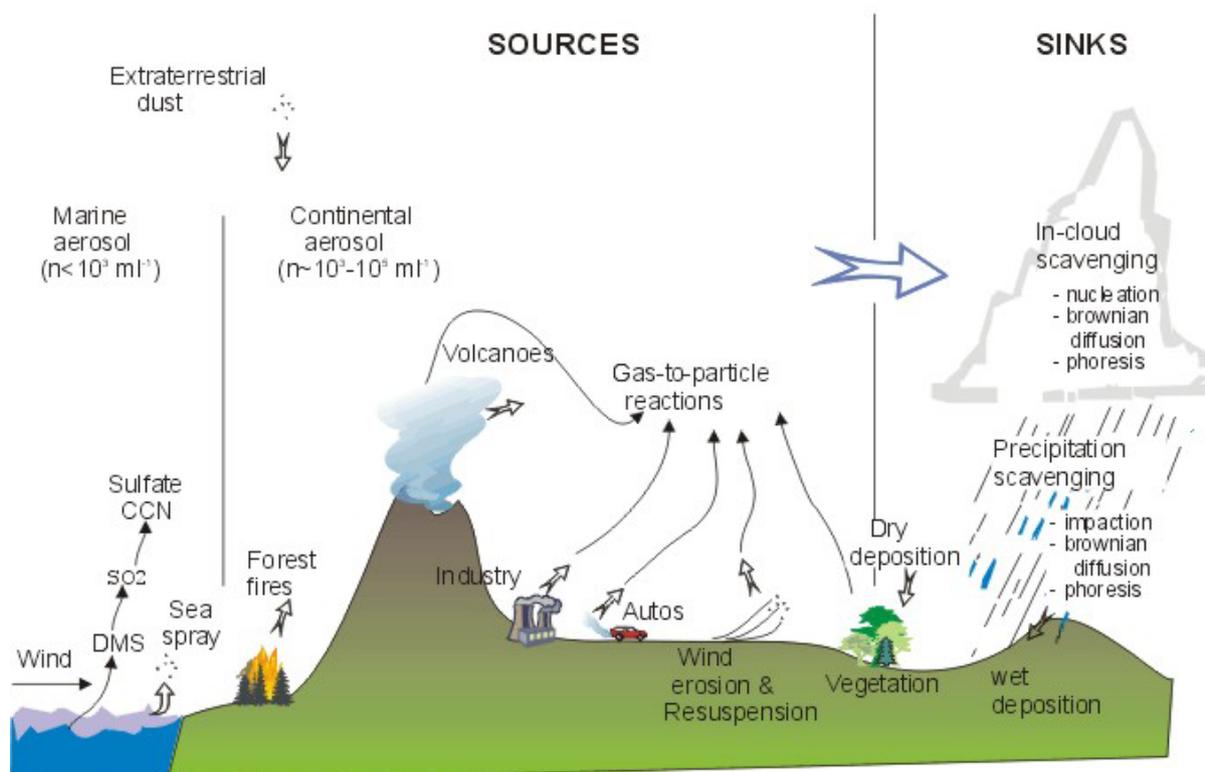


Figure 1 – Schematic of atmospheric aerosol sources<sup>8</sup>

2.7 It was put to the committee that the combination of natural and anthropogenic sources makes the controlling of emission of PM challenging.<sup>9</sup>

2.8 An example of the interplay between natural and anthropogenic sources in the production of PM is provided by the Sydney Particulate Study which demonstrated that local urban sources (motor vehicles, wood combustion, and industrial sources) may contribute less than fifty per cent of the fine particle mass in Sydney, with background sources (dust, smoke, sea salt, biogenic) comprising the remainder.<sup>10</sup>

2.9 The sources of different sizes of PM are as follows:

- $PM_{10-2.5}$  primarily is derived from suspension or re-suspension of dust, soil, and other material from roads, farming, mining, and dust storms but also includes sea salt, pollen, mould, and spores;
- $PM_{2.5}$  primarily is derived from direct emissions from combustion processes, such as petrol and diesel vehicles, wood burning, coal burning for power generation, and industrial activities such as smelters, cement plants, paper mills, and steel mills; and

8 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 7.

9 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 4.

10 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 4.

- PM<sub>0.1</sub> results from combustion related sources and atmospheric photochemical reactions.<sup>11</sup>

2.10 On-road motor vehicles and off-road engines such as generators, mining, earthmoving equipment and ships were cited to the committee as the main sources of anthropogenic particulate pollution in Australia.<sup>12</sup>

2.11 There are a number of indoor pollutants and emission sources that may be harmful to human health but are, in many cases, not regulated. Some of these are tabulated below:

<b>POLLUTANT</b>	<b>MAJOR EMISSION SOURCES</b>
Allergens	House dust, domestic animals, insects
Asbestos	Fire retardant materials, insulation
Carbon dioxide	Metabolic activity, combustion activities, motor vehicles in garages
Carbon monoxide	Fuel burning, boilers, stoves, gas or kerosene heaters, tobacco smoke
Formaldehyde	Particle board, insulation, furnishings
Micro-organisms	People, animals, plants, air conditioning systems
Nitrogen dioxide	Outdoor air, fuel burning, motor vehicles in garages
Organic substances	Adhesives, solvents, building materials, volatilization, combustion, paint, tobacco smoke
Ozone	Photochemical reactions
Particles	Re-suspension, tobacco smoke, combustion products
Polycyclic aromatic hydrocarbons	Fuel combustion, tobacco smoke
Pollens	Outdoor air, trees, grass, weeds, plants
Radon	Soil, building construction materials
Fungal spores	Soil, plants, foodstuffs, internal surfaces

11 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 8.

12 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 3.

Sulphur dioxide	Outdoor air, fuel combustion
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2.12 It was argued to the committee that there is a need to explore what standards or regulations may need to be put in place as building energy efficiency increases in order to balance efficiency gains against potential health costs, as energy efficiency gains often come at the cost of reduced ventilation.<sup>13</sup>

### Health impacts of poor air quality

2.13 There is a substantial body of evidence indicating that particulate matter has negative impacts on human health – regardless of the size of particulates.<sup>14</sup> A study published in the *Lancet* in 2012 found 'ambient particulate matter pollution' to be the ninth leading cause of global disease burden.<sup>15</sup> The National Health and Medical Research Council-funded Centre for Air Quality and Health Research and Evaluation (CAR), reported to the committee that:

People exposed to the short-term bursts or long-term higher levels of particulate pollution suffer a range of adverse effects, including:

- Increased risk of deaths, particularly due to heart and lung diseases;
- Increased risk of hospitalisation for heart and lung diseases; and
- Increased risk of asthma attacks.<sup>16</sup>

2.14 It was reported to the committee that the 'main properties of PM that determine its environmental and health risks are: concentration; size distribution; structure; and chemical composition.'<sup>17</sup> The effects on health vary substantially between geographic settings, partly as a result of variation in the chemical composition of the particulates, which is dependent on their local sources.<sup>18</sup>

2.15 The committee learnt that the size of the PM was the principal determinant of how deeply it is inhaled into the human respiratory system, with smaller particles able to penetrate further into the lungs.<sup>19</sup> As most particles with a diameter >10µm are generally filtered by the nose and throat, PM<sub>10</sub> is typically used as the threshold value

13 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p.15.

14 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 3.

15 Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. 'A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010.' *The Lancet*, 2012;380(9859):2224-60.

16 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 3.

17 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 3.

18 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 3.

19 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 4.

for studies on the effects of PM on human health.<sup>20</sup> The relative distribution of PM in the human respiratory system is represented in figure two.

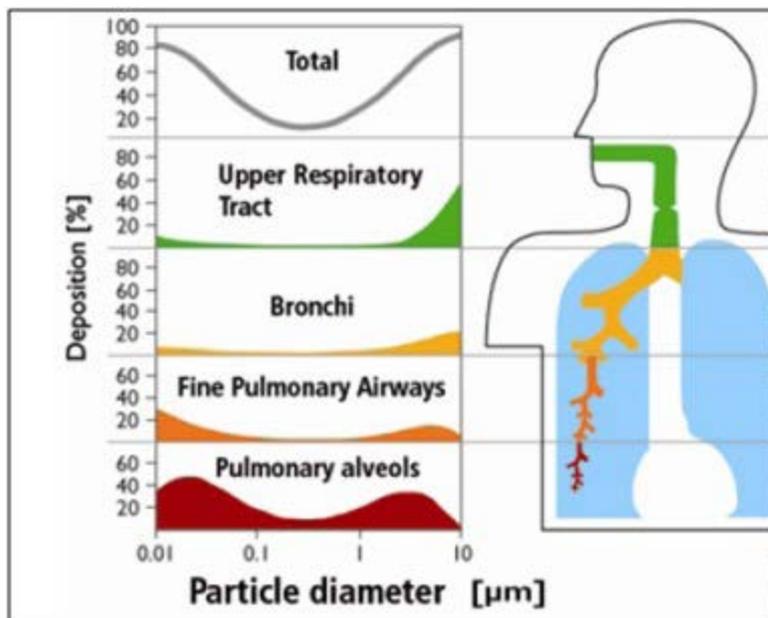


Figure 2 - Deposition of different sized particles in different segments of the respiratory system<sup>21</sup>

2.16 Furthermore, it was argued by the CSIRO that:

Epidemiological studies have concluded that there is a statistically significant relationship between fine particles and human health effects, such as decreased lung function, increased respiratory symptoms, increased chronic obstructive pulmonary disease, increased cardiovascular and cardiopulmonary disease, and increased mortality. Recent research has identified a strong link between PM<sub>2.5</sub> and life expectancy.<sup>22</sup>

2.17 The committee heard that there were particularly high health risks associated with PM<sub>2.5</sub>:

PM<sub>2.5</sub> is believed to be the most health-hazardous air pollutant, responsible for 10 to 20 times as many premature deaths as the next worst pollutant, ozone. Just as 'every cigarette is doing you damage', every gram of wood smoke or other particle emissions is also causing health problems. Wood smoke is more hazardous than cigarette smoke – in tumour initiation tests it was found to cause 12 to 30 times as many cancers as the same amount of cigarette smoke. The estimated health cost of a kg of PM<sub>2.5</sub> emissions in Sydney is more than \$235.<sup>23</sup>

20 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 8.

21 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 9.

22 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p.4.

23 Asthma Foundation NSW, *Submission 50*, p. 20.

2.18 There is also some evidence to suggest that ultrafine particles (UFPs) – particles less than 0.1µm in diameter – can be harmful to human health. It was reported by CAR that:

Epidemiological evidence about the adverse health effects attributable to exposure to UFPs, as distinct from the effects of other particles (measured as PM<sub>10</sub> and PM<sub>2.5</sub>) is limited at present. However, toxicological studies in animals and humans have shown diverse effects on cardiovascular, blood, respiratory and brain function. Further evidence is required to establish the relevance of these toxicological findings to population health and hence to gauge the importance of control measures specifically targeting UFP emissions.<sup>24</sup>

2.19 The committee heard that indoor air quality is also critical to human health, but has not been investigated as fully as the impacts of ambient air quality which is monitored and controlled to some extent.<sup>25</sup> A 2002 paper from the *Journal of Exposure Analysis and Environmental Epidemiology* found that people in Canada in the United States of America spent only between six and seven per cent of their time out of doors with the rest either in buildings or vehicles.<sup>26</sup>

### *Safe levels of exposure*

2.20 The committee heard, that at least for some pollutants, there is no safe level of exposure:

Of importance is that the new evidence not only supports the previous scientific conclusions but also indicates that the effect can occur at air pollution concentrations lower than those used to establish the existing WHO health guidelines, particularly into relation to PM 2.5 and PM 10. So far no limit of exposure where there is no impact has been identified.<sup>27</sup>

2.21 Similarly:

Available evidence suggests that, at least for particulates and for NO<sub>2</sub>, there is a linear dose response relationship over a large range of exposure levels. This means that, even at levels below the current targets, further health gains can be achieved by further reduction in pollutant levels.<sup>28</sup>

2.22 This position was supported by the Environment and Sustainable Development Directorate of the Australian Capital Territory (ACT) who noted 'there

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24 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 3.

25 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p.15.

26 Leech, JA; Nelson WC; Burnett RT; Aaron S; Raizenne ME, 'It's about time: a comparison of Canadian and American time-activity patterns', *Journal of Exposure Analysis and Environmental Epidemiology*, vol. 12 no. 6, November 2002, 431.

27 Professor Morawska, International Laboratory for Air Quality and Health, *Committee Hansard*, 11 June 2013, p. 2.

28 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 5.

is no safe threshold for particulate pollution at which health effects do not occur.<sup>29</sup> A number of submissions to the inquiry made similar points.<sup>30</sup>

### **Populations most at risk**

2.23 The health impacts of air quality are not shared equally by all people. Certain groups of people, and certain geographies, are at a greater potential risk than others. The populations who are at the greatest risk are those who are exposed to the largest quantity of harmful particulates, and those who are inherently more susceptible to exposure.

2.24 As noted above, the general Australian population enjoys comparatively good air quality. According to World Health Organisation (WHO) analysis, annual average PM<sub>2.5</sub> totals in 2010 gave Sydney a rating of seven, the Lower Hunter a rating of 8.2, New York 13, London 14, and Paris 23.<sup>31</sup> The committee notes, however, that these ratings are for relatively large urban areas. Within these areas there are populations exposed to higher levels of air pollution, and associated health risks. Populations most exposed to particulate matter are those people living in close proximity to transport corridors and industrial and agricultural pollution sources. The committee heard that:

The highly urbanised nature of Australia means that a high proportion of the population are co-located with major transport corridors and hence highly exposed to transport related emissions.<sup>32</sup>

2.25 While air pollution is often considered to be an urban problem, rural communities are also exposed to PM due to wind-blown dust smoke from controlled burning, bushfires, wood heaters, and PM from mining and other activities.<sup>33</sup> The CSIRO noted that 'regional towns co-located with heavy industry (e.g., Gladstone, Kalgoorlie, Mt Isa, Port Pirie);' are subject to higher risks from impacts of air quality.<sup>34</sup> It was further noted that 'Peri-urban populations (i.e. at the rural–urban interface)... may be vulnerable to spray drift from agricultural and horticultural sprays'.<sup>35</sup> The committee also received evidence that risk increases in areas where

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29 Environment and Sustainable Development Directorate of the ACT, *Submission 30*, p. 1.

30 See, Doctors for the Environment Australia, *Submission 4*, p. 3; Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 3; Asthma Foundation NSW, *Submission 50*, p. 20; Australian Network of Environmental Defender's Offices, *Submission 85*, p. 5; Dr Adrian Barnett, *Submission 92*, p. 1.

31 Mr Buffier, Chief Executive Officer, New South Wales Environmental Protection Authority, *Committee Hansard*, 16 April 2013, pp. 2–3; see also New South Wales Environmental Protection Authority, *Submission 80*, p. 19.

32 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 4.

33 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 4.

34 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p.12.

35 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p.12.

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there is poor dispersion due to a 'combination of meteorology, topography (e.g. valleys), and location factors (e.g. coastal regions with land-sea breeze circulations)'.<sup>36</sup>

2.26 It was reported to the committee that the segments of society who are most inherently susceptible to poor air quality are:

- Children and the elderly;
- Those with pre-existing heart and lung disease; and
- Socio-economically disadvantaged groups.<sup>37</sup>

2.27 The committee heard that exposure to air pollution can negatively impact unborn children:

One neglected area I want to highlight is the effect of pollution during pregnancy. There is now strong evidence that exposure to particulate matter during pregnancy reduces birth weight and shortens gestation time. This includes a recent international study of three million births worldwide and a study that I worked on of just under 1,000 mothers in Logan. There is also evidence of association between pollution exposure during pregnancy and stillbirth, and biological evidence of harm from studies finding greater DNA damage in the placentas of mothers with higher pollution exposure. This creates a potentially huge economic cost for Australia because we know that babies born early or underweight spend more time in hospital as children and have an increased risk of chronic disease in adulthood.<sup>38</sup>

2.28 The Australian Medical Association (AMA) also noted that workers in certain industries and occupations have a heightened risk of experiencing adverse health impacts due to poor air quality.<sup>39</sup>

***Committee comment***

2.29 There are a wide range of air quality issues that the committee has considered in the course of its inquiry. On the broadest of levels, the committee received evidence that global phenomena such as climate change have consequences for air quality. The committee heard from the CSIRO that:

There is an important nexus between Australia's air quality and a changing and increasingly variable climate because: a likely increase in frequency and severity of bushfires and droughts would increase the PM levels in urban and regional Australia; photochemical smog, which affects all Australian cities, is influenced by air temperature as well as urban vegetation and levels of ozone and increased air temperatures due to global warming are likely to exacerbate the incident and severity of photochemical

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36 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p.12.

37 Centre for Air Quality and Health Research and Evaluation, *Submission 29*, p. 4, Australian Medical Association, *Submission 114*, pp. 6–7.

38 Dr Adrian Barnett, Queensland University of Technology, *Committee Hansard*, 11 June 2013, p. 1.

39 Australian Medical Association, *Submission 114*, p. 8.

smog events in Australian cities; and the effects of air pollution will be in addition to other stressors that affect human health such as heat stress, with such combined effects very likely to adversely affect the morbidity and mortality of Australia's population.<sup>40</sup>

2.30 While the committee recognises the significant impact of broader influences on air quality such as climate change and urbanisation, the majority of evidence received during the course of this inquiry was concerned with more local and immediate impacts. The committee received detailed evidence around sources, health impacts, and risk factors in relation to three specific types of air pollution: coal, diesel, and wood smoke. After a discussion of standards and monitoring in Chapter 3, the remainder of this report discusses the evidence and makes recommendations in relation to each of these major sources of air pollution.

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40 Commonwealth Scientific and Industrial Research Organisation, *Submission 48*, p. 7.