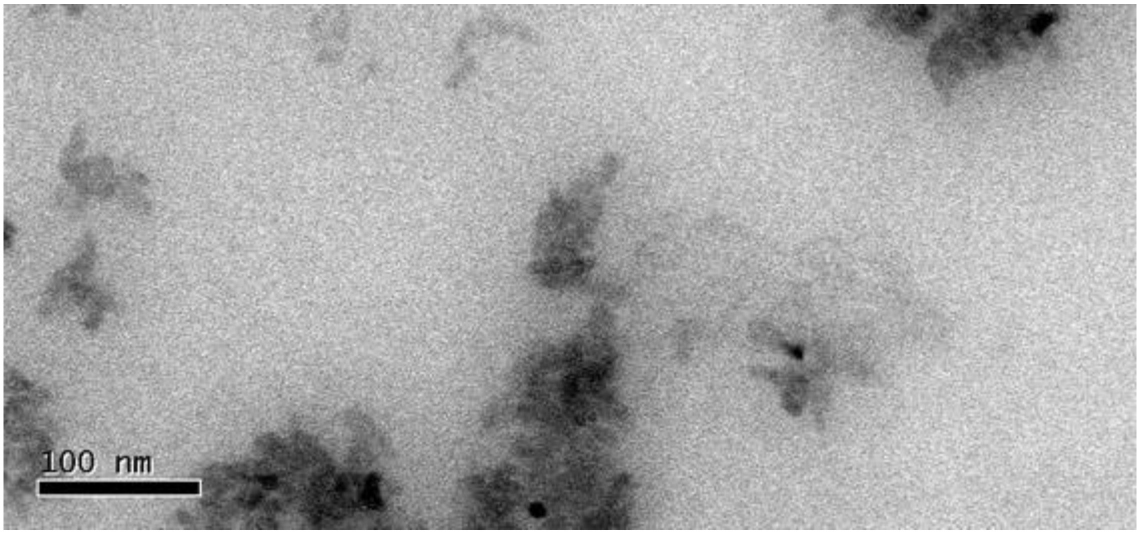
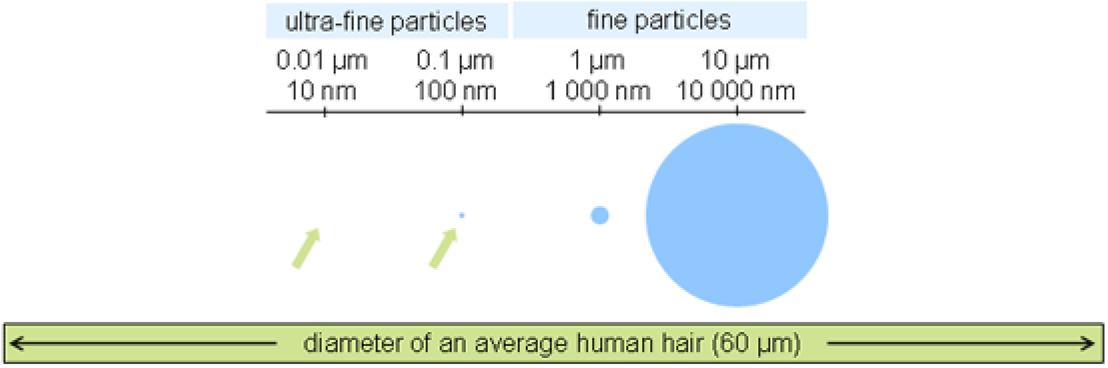


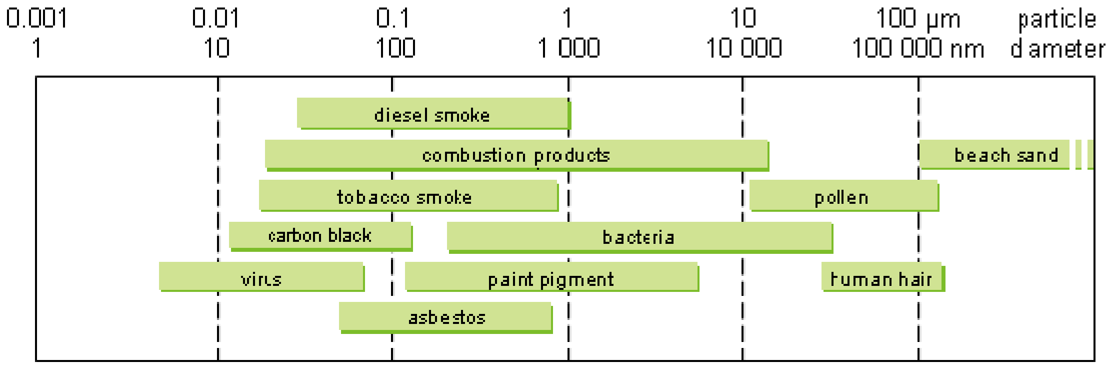
What are airborne ultra-fine and nano particles?

Although we can’t see them, the air we breathe is full of microscopic particles. These particles are health hazardous and are thus considered a specific type of air pollution. Often this type of air pollution is called fine dust. The size of these particles is in the order of several nanometers to several micrometers. Currently regulation focuses primarily on the measurement and reduction of fine particles. Fine particles are often identified by Particle Matter (PM) ratings. PM10 rating as an example represents the weight of particles that have a diameter smaller than 10 micrometer.



However, a very large fraction of particles in urban air (>90%) has minute particles of around 100 nanometers (nm) and smaller. These we call ultra-fine particles or nano-particles. The picture above clearly demonstrates the difference is dimensions of fine and ultra-fine particles. Ultra-fine particles range below the currently monitored levels. In other words, there is an important actually invisible factor in the air around people.

Airborne particles originate from many natural and man-made sources (e.g. sand dust, fires, diesel smoke, sea salt). The scheme below shows a number of particle types from well-known sources. Ultra-fine particles are normally only generated at very high temperatures, such as combustion processes. One can think of wood fires, industry, engines, cooking fumes, or cigarette smoke. Toner (carbon black) from copiers, laser printers and welding-fumes or nanomaterials are important sources as well.



The most important source of ultra-fine particles in urban air however is car traffic. Especially diesel exhaust consists of large amounts of ultra-fine particles. Such particles are generally formed by a basically insoluble core of carbon of 10-20 nm, often covered with chemicals like sulphates, metals and hydrocarbons. These extremely small particles tend to conglomerate in the air into particles of around 100 nm.

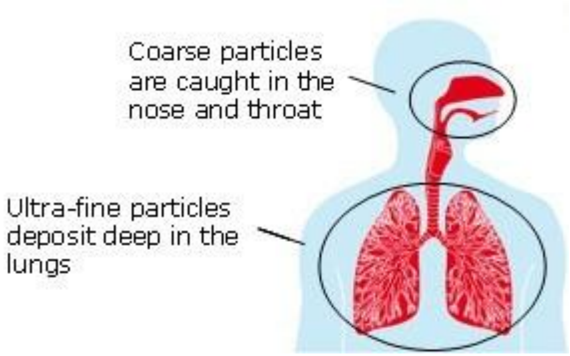
What are health effects of ultra-fine and nano particles?

In recent years, scientists have investigated the health effects of airborne particles and of ultra-fine particles in particular. They are finding convincing results indicating that airborne particles damage our health. These results are well described in literature, for example in the WHO Air Quality Guidelines

In short, statistical evidence has been found that acute negative health effects related with increased levels of airborne particles include:

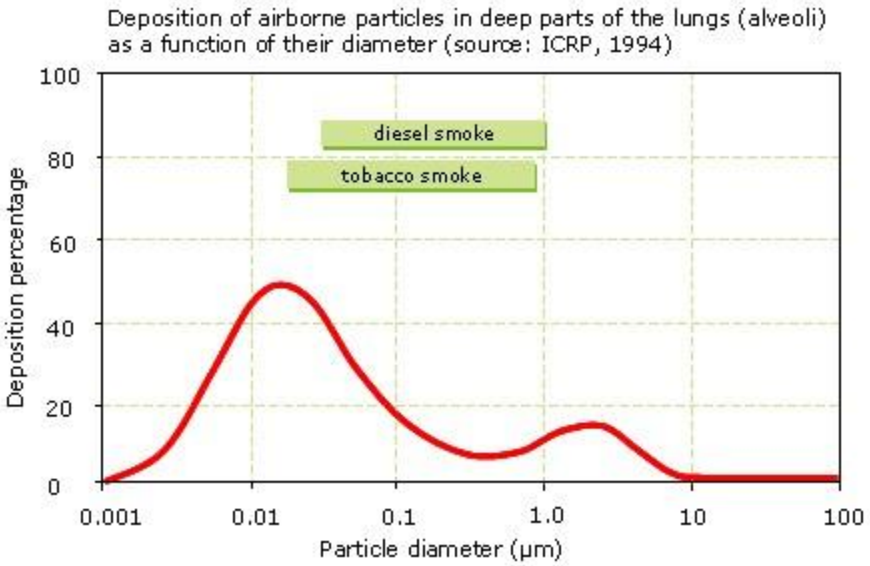
- Increased use of asthma medication
- Asthma attacks in patients having asthma
- COPD (chronic obstructive pulmonary disease) attacks
- Hospital admissions for cardiovascular diseases
- Deaths from heart attacks, strokes and respiratory problems

Beside these acute health effects on people with high susceptibility towards particles, scientists also expect a long-term effect on normal people: life expectancy decreases significantly as a result of high particle concentrations. Furthermore, a study describing the relation between the development of the lungs of children and the distance between their homes and a busy road may support this statement.[1]



Ultra-fine particles (in the range around one hundred nanometer) seem to play a special role and are potentially more health hazardous than coarse particles. For this reason it is still subject of ongoing scientific research. Some possible explanations have been suggested.

One is that, due to their aerodynamic properties, ultra fine particles penetrate and deposit deeper in the lungs than coarser particles. About 50% of the particles around 20 nm deposits deep in the lungs as is shown in the graph below. Larger particles are caught in the nose and throat.



Another explanation is that the concentration of ultra fine particles is generally much higher than the concentration of coarser particles. The lungs cannot deal with the high amounts of particles that deposit in the lung sacs, which lead to inflammation.

Related to this is the relatively high total surface area of ultra fine particles. The surface area of a given number or volume of particles is much higher for ultra-fine particles than for courser particles (see Concentrations). Scientists assume surface area is related to free radical activity and oxidative stress in the lungs. Oxidative stress is known to have inflammatory effects.

A fourth possible explanation is that the size of the particles is much smaller than the human cellular structures. They can enter the human body and end up in the blood stream causing heart and brain diseases.

Yet another aspect in the harmful effect of airborne particles is that (ultra-fine) particles like diesel exhaust are often covered with toxic chemicals like polycyclic aromatic hydrocarbons, which are known as carcinogenic.

[1] Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study, Gauderman, www.thelancet.com. Published online January 26, 2007.

Which ultra-fine particle concentrations can we expect?

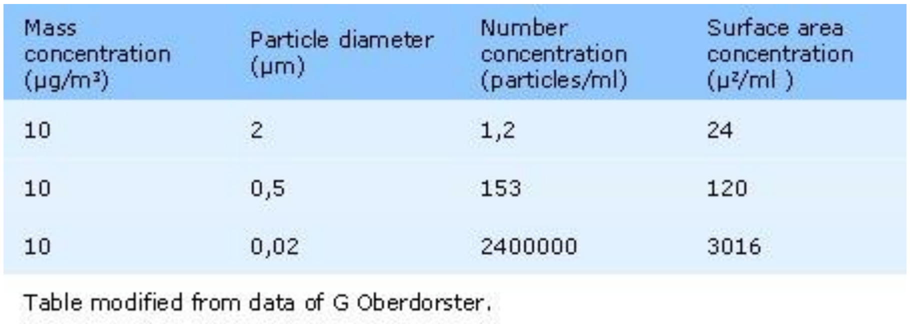
There is no standardization on ultra-fine particles at the moment. However, scientific discussions are ongoing on the formation of a standard. Nevertheless, it is possible to give some reference concentrations (Ultra-fine particles are measured in concentrations particles/cm^3)

Clean air in the alps	< 1.000
Clean office air	2.000 – 4.000
Outside Air in urban area	10.000 – 20.000
Polluted outside air (smog)	> 50.000
Cigarette smoke	> 50.000
Workplaces (like welding)	100.000 – 1.000.000

Note, it is expected that there is no threshold concentration below which there is no negative health effect. Air should be as clean as practically possible. The threshold concentration at which people feel immediate impact is around 50.000 particles/cm^3. Asthmatic people immediately feel the effect of smog.

Surface area, particle number, and size

Traditionally, the concentration of airborne particles is often measured as a mass concentration. Other measurement units such as number concentration or surface area concentration (total surface area of all particles in a volume of air) have a much more significant relation to the health effects. The table below shows the number and surface area concentration of a cloud of particles with a total airborne mass concentration of 10 $\mu g/m^3$ when it contains particles of different diameters and clearly shows the remarkable effect of the particle diameter. The number of particles in a certain volume of air increases dramatically along with the surface area per unit volume of air, as the particle size decreases into the region of ultra-fine particles.



Mass concentration ($\mu g/m^3$)	Particle diameter (μm)	Number concentration (particles/ml)	Surface area concentration (μ^2/ml)
10	2	1,2	24
10	0,5	153	120
10	0,02	2400000	3016

Table modified from data of G Oberdorster.

http://aerasense.com/index.php?pageID=5

What is PM$_{2.5}$? according to US EPA – Regulation of PM2.5 in USA

Particulate matter, or PM, is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that individually they can only be detected with an electron microscope. Many manmade and natural sources emit PM directly or emit other pollutants that react in the atmosphere to form PM. These solid and liquid particles come in a wide range of sizes. Particles less than 10 micrometers in diameter (PM$_{10}$) pose a health concern because they can be inhaled into and accumulate in the respiratory system. Particles less than 2.5 micrometers in diameter (PM$_{2.5}$) are referred to as "fine" particles and are believed to pose the greatest health risks. Because of their small size (approximately 1/30th the average width of a human hair), fine particles can lodge deeply into the lungs.

Where does PM$_{2.5}$ come from? Sources of fine particles include all types of combustion activities (motor vehicles, power plants, wood burning, etc.) and certain industrial processes. Particles with diameters between 2.5 and 10 micrometers are referred to as "coarse." Sources of coarse particles include crushing or grinding operations, and dust from paved or unpaved roads. Other particles may be formed in the air from the chemical change of gases. They are indirectly formed when gases from burning fuels react with sunlight and water vapor. These can result from fuel combustion in motor vehicles, at power plants, and in other industrial processes.

Who is most at risk? Roughly one out of every three people in the United States is at a higher risk of experiencing PM$_{2.5}$ related health effects. One group at high risk is active children because they often spend a lot of time playing outdoors and their bodies are still developing. In addition, oftentimes the elderly population are at risk. People of all ages who are active outdoors are at increased risk because, during physical activity, PM$_{2.5}$ penetrates deeper into the parts of the lungs that are more vulnerable to injury.

Background Particle pollution, also called particulate matter or PM, is a complex mixture of extremely small particles and liquid droplets in the air. When breathed in, these particles can reach the deepest regions of the lungs. Exposure to particle pollution is linked to a variety of significant health problems, ranging from aggravated asthma to premature death in people with heart and lung disease. Particle pollution also is the main cause of visibility impairment in the nation's cities and national parks.

To protect public health and welfare, EPA issues National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, particulate matter is one of these. EPA first issued standards for particulate matter in 1971; and revised the standards in 1987 and 1997. In September 2006, the Agency revised the 1997 standards.

The revised 2006 standards address two categories of particle pollution: *fine particles* ($PM_{2.5}$), which are 2.5 micrometers in diameter and smaller; and *inhalable coarse particles* (PM_{10}) which are smaller than 10 micrometers and larger than 2.5 micrometers.

The 2006 standards tighten the 24-hour fine particle standard from 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$, and retain the current annual fine particle standard at 15 $\mu g/m^3$. EPA has decided to retain the existing 24-hour PM_{10} standard of 150 $\mu g/m^3$. Due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution, the Agency has revoked the annual PM_{10} standard.

The Agency selected the levels for the final standards after reviewing thousands of peer-reviewed scientific studies about the effects of particle pollution on public health and welfare. External scientific advisors and the public examined EPA's science and policy review documents. The Agency also carefully considered public comments on the proposed standards. EPA held three public hearings and received over 120,000 written comments.

While EPA provisionally assessed new, peer-reviewed studies about particulate matter and health (including some studies received during the comment period), these studies were not the basis for the final decision. EPA will consider those studies during the next review of the PM standards. Learn more about the process of reviewing air quality standards.

What do the New Standards Mean for Your Area? In 2004, several areas in the United States were designated as not meeting the 1997 air quality standards for fine particulate matter ($PM_{2.5}$). See if your area was designated as not meeting the 1997 standards.

In 2006, EPA strengthened the air quality standards for particle pollution. The Agency expects designations based on 2007-2009 air quality data to take effect in 2010.

Maps Graph and Maps (10/25/06) (PDF, 10 pp, 1.2 MB)

Timeline

Milestone	**1997 $PM_{2.5}$ Primary NAAQS**	**2006 $PM_{2.5}$ Primary NAAQS**
Promulgation of Standard	July 1997	Sep. 2006
Effective Date of Standard	Sep. 1997	Dec. 18, 2006
State Recommendations to EPA	Feb. 2004 (based on 2001-2003 monitoring data)	Dec. 18, 2007 (based on 2004-2006 monitoring data)
Final Designations Signature	Dec. 2004	October 8, 2009
Effective Date of Designations	April 2005	30 days after publication in the Federal Register
SIPs Due	April 2008	3 years after effective date of designations
Attainment Date	April 2010 (based on 2007-2009 monitoring data)	No later than 5 years after effective date of designations
Attainment Date with Extension	Up to April 2015	No later than 10 years from effective date of designations

http://www.epa.gov/oar/particlepollution/naaqsrev2006.html

PM2.5 regulation according to the European Commission

Humans can be adversely affected by exposure to air pollutants in ambient air. In response, the European Union has developed an extensive body of legislation which establishes health based standards and objectives for a number of pollutants in air. These standards and objectives are summarised in the table below. These apply over differing periods of time because the observed health impacts associated with the various pollutants occur over different exposure times.

Pollutant	*Concentration*	*Averaging period*	*Legal nature*	*Permitted exceedences each year*
Fine articles (PM2.5)	25 µg/m3***	1 year	Target value entered into force 1.1.2010 Limit value enters into force 1.1.2015	n/a

Sulphur dioxide (SO2)	350 µg/m3	1 hour	Limit value entered into force 1.1.2005	24
	125 µg/m3	24 hours	Limit value entered into force 1.1.2005	3
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	Limit value entered into force 1.1.2010	18
	40 µg/m3	1 year	Limit value entered into force 1.1.2010*	n/a
PM10	50 µg/m3	24 hours	Limit value entered into force 1.1.2005**	35
	40 µg/m3	1 year	Limit value entered into force 1.1.2005**	n/a
Lead (Pb)	0.5 µg/m3	1 year	Limit value entered into force 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m3 limit value applied from 1.1.2005 to 31.12.2009)	n/a
Carbon monoxide (CO)	10 mg/m3	Maximum daily 8 hour mean	Limit value entered into force 1.1.2005	n/a
Benzene	5 µg/m3	1 year	Limit value entered into force 1.1.2010**	n/a
Ozone	120 µg/m3	Maximum daily 8 hour mean	Target value entered into force 1.1.2010	25 days averaged over 3 years
Arsenic (As)	6 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Cadmium (Cd)	5 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Nickel (Ni)	20 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Polycyclic Aromatic Hydrocarbons	1 ng/m3 (expressed as concentration of Benzo(a)pyrene)	1 year	Target value enters into force 31.12.2012	n/a

**Under the new Directive the member State can apply for an extension of up to five years (i.e. maximum up to 2015) in a specific zone. Request is subject to assessment by the Commission. . In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (* 48 µg/m3 for annual NO2 limit value).

***Under the new Directive the Member State was able to apply for an extension until three years after the date of entry into force of the new Directive (i.e. May 2011) in a specific zone. Request was subject to assessment by the Commission. In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (35 days at 75*µg/m3 for daily PM10 limit value, 48 µg/m3 for annual Pm10 limit value).

****Standard introduced by the new Directive.*

Under EU law a limit value is legally binding from the date it enters into force subject to any exceedances permitted by the legislation. A target value is to be attained as far as possible by the attainment date and so is less strict than a limit value.

The new Directive is introducing additional PM2.5 objectives targeting the **exposure** of the population to fine particles. These objectives are set at the national level and are based on the average exposure indicator (AEI).

AEI is determined as a 3-year running annual mean PM2.5 concentration averaged over the selected monitoring stations in agglomerations and larger urban areas, set in urban background locations to best assess the PM2.5 exposure to the general population.

Title	***Metric***	***Averaging period***	***Legal nature***	***Permitted exceedences each year***
PM2.5 Exposure concentration obligation	20 µg/m3 (AEI)	Based on 3 year average	Legally binding in 2015 (years 2013,2014,2015)	n/a
PM2.5 Exposure reduction target	Percentage reduction* + all measures to reach 18 µg/m3 (AEI)	Based on 3 year average	Reduction to be attained where possible in 2020, determined on the basis of the value of exposure indicator in 2010	n/a

** Depending on the value of AEI in 2010, a percentage reduction requirement (0,10,15, or 20%) is set in the Directive. If AEI in 2010 is assessed to be over 22 µg/m3, all appropriate measures need to be taken to achieve 18 µg/m3 by 2020.*

Principles

European legislation on air quality is built on certain principles. The first of these is that the Member States divide their territory into a number of zones and agglomerations. In these zones and agglomerations, the Member States should undertake assessments of air pollution levels using measurements and modelling and other empirical techniques. Where levels are elevated, the Member States should prepare an air quality plan or programme to ensure compliance with the limit value before the date when the limit value formally enters into force. In addition, information on air quality should be disseminated to the public. See more under Implementation.

http://ec.europa.eu/environment/air/quality/standards.htm

Australia - Atmosphere Theme Report

Australia State of the Environment Report 2001 (Theme Report)
Lead Author: Dr Peter Manins, Environmental Consulting and Research Unit, CSIRO Atmospheric Research, Authors
Published by CSIRO on behalf of the Department of the Environment and Heritage, 2001
ISBN 0 643 06746 9

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Urban Air Quality (continued)

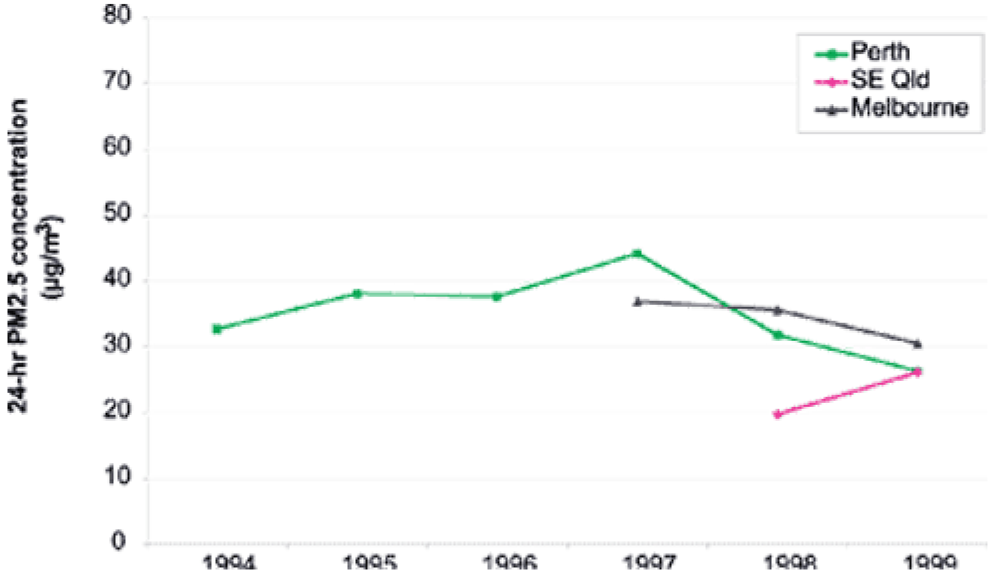
Indicators of the condition of air quality (continued)

PM2.5 in urban areas

Some studies from other countries have indicated that more deaths are attributable to the concentration of particulate matter of diameter below 2.5 m (PM2.5) than to the concentration of PM10. However, particles with sizes between 2.5 and 10 m may be more important in relation to asthma and respiratory illnesses (Denison 2000). There are few regular PM2.5 measurements undertaken in Australia, and no air quality standard has been set for PM2.5.

Figure 105 gives the maximum PM2.5 values measured for Melbourne, Brisbane and Perth, whereas Figure 106 apportions the sources for the Perth readings during each of the seasons 1994 to 1995.

Figure 105: Maximum 24 hour PM2.5 concentration for selected Australian cities.



Source: State environmental authorities

The PM2.5 to PM10 ratio varies with season (Table 20) and this is true in all Australian cities (Table 21). In every case the proportion of PM2.5 particles is higher in winter than in summer. Figure 106 shows typical sources of PM2.5-sized particles in Perth. The variation of PM2.5 in Perth since 1994 (Figure 107) indicates that the composition of the PM2.5 particles can change with season and with year. Much of the time it is smoke, from industrial or residential combustion, that is the dominant source but in certain years bushfires will add their contribution as well. During certain seasons other processes dominate. Occasionally this may be soil-based particles. Secondary production, which consists of chemical processes that convert gases into particles, can also produce a significant contribution.

Table 20: Analysis of 24-hour PM10 and 24-hour PM2.5 data for Melbourne from 1988 to 1996

	Whole study period				**Cool season (April-Oct.)**				**Warm season (Nov.-Mar.)**			
	Mean	**s.d.**	**Min.**	**Max.**	**Mean**	**s.d.**	**Min.**	**Max.**	**Mean**	**s.d.**	**Min.**	**Max.**
PM10	18.97	6.99	11.31	79.59	18.53	7.43	11.31	79.59	19.6	.24	12.55	76.81
PM2.5	9.42	3.65	6.15	42.58	9.85	4.00	6.18	42.58	8.79	2.97	6.15	35.33

Source: EPAV (2000b: Table B4a).

Table 21: Ratio of PM2.5 to PM10 based on episodic measurements

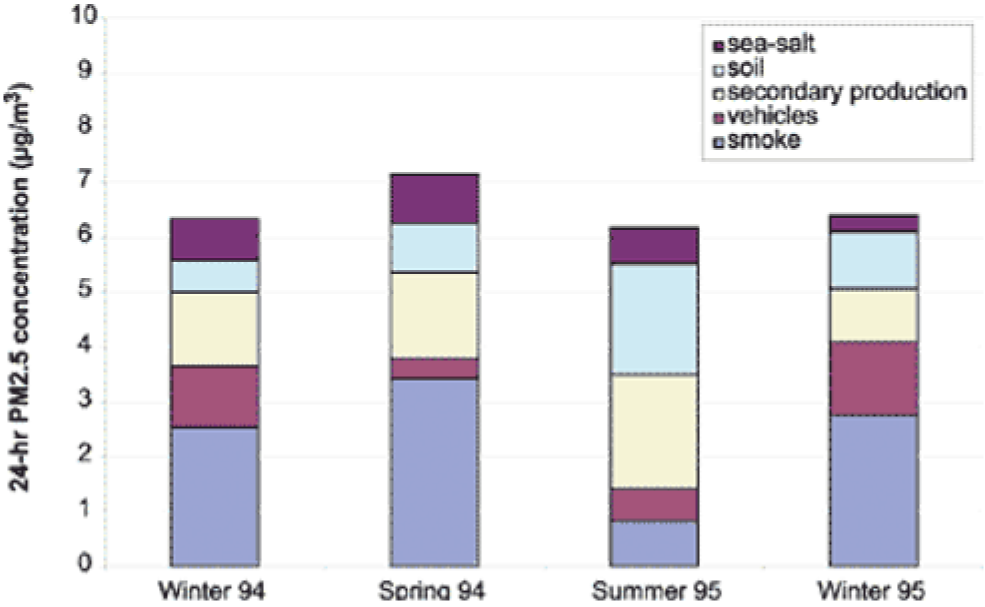
City	**Winter ratio**	**Summer ratio**

Brisbane	0.44	0.26
Melbourne[A]	0.53	0.44
Melbourne	0.60	0.40
Sydney	0.58-0.80	0.41

[A] See Table 20.

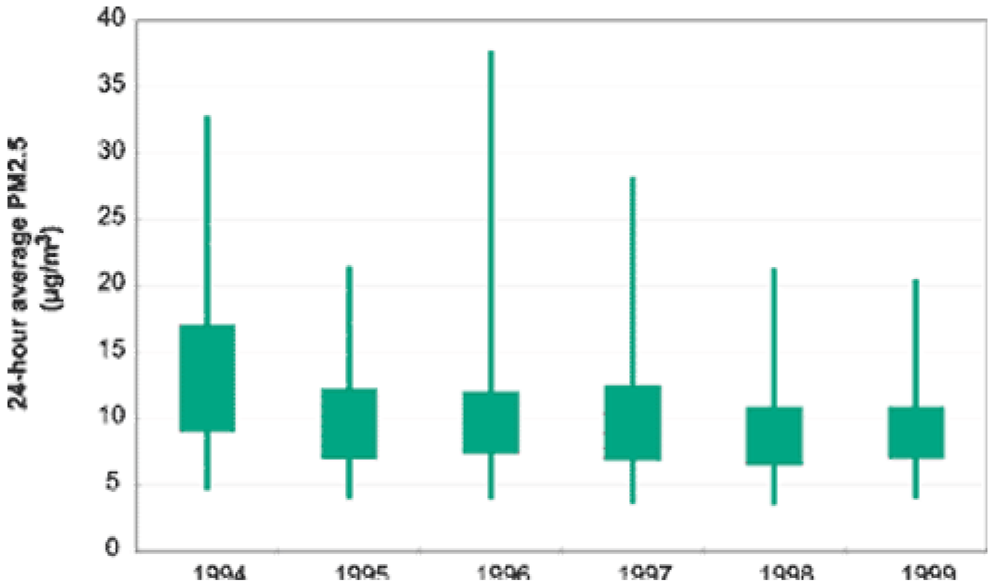
Source: NEPC (1998).

Figure 106: Source contributions to PM2.5 concentrations in the Perth Metropolitan Region between winter 1994 and winter 1995 recorded during the Perth Haze Study.



Source: DEP (2000)

Figure 107: Annual maximum, 90th and 50th percentiles (median) and 10th percentile of maximum 24 hour PM2.5 concentrations from Perth (Caversham).



Source: Data from Department of Environmental Protection, WA

Implications

Australia does not have a PM2.5 standard, although the issue is being considered by NEPC. On the basis of the above results, the NEPM 24-hour PM10 standard of 50 g/m^3 limits the atmospheric PM2.5 concentrations to between 20 and 40 g/m^3 depending on the city and the season. This means that the NEPM provides an upper limit to the PM2.5 concentration that is more stringent than the United States EPA 24-hour PM2.5 standard of 65 g/m^3 set in 1997. The United States also set an annual PM2.5 concentration of 15 g/m^3. This indicates that long-term standards for particulate matter are needed.

http://www.environment.gov.au/soe/2001/publications/theme-reports/atmosphere/atmosphere04-4h.html

So what about Hong Kong 's dismal PM2.5 and ultrafines' levels ?

PM2.5 regulation according to the HK Government EPD

DOES NOT EXIST !

ClearTheAir
爭氣行動

‘Hong Kong Fragrant Harbour
Asia World City’