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The CAFE programme and the thematic strategy on air pollution

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EU emission standards for light and heavy road vehicles

No. 16, May 2004:
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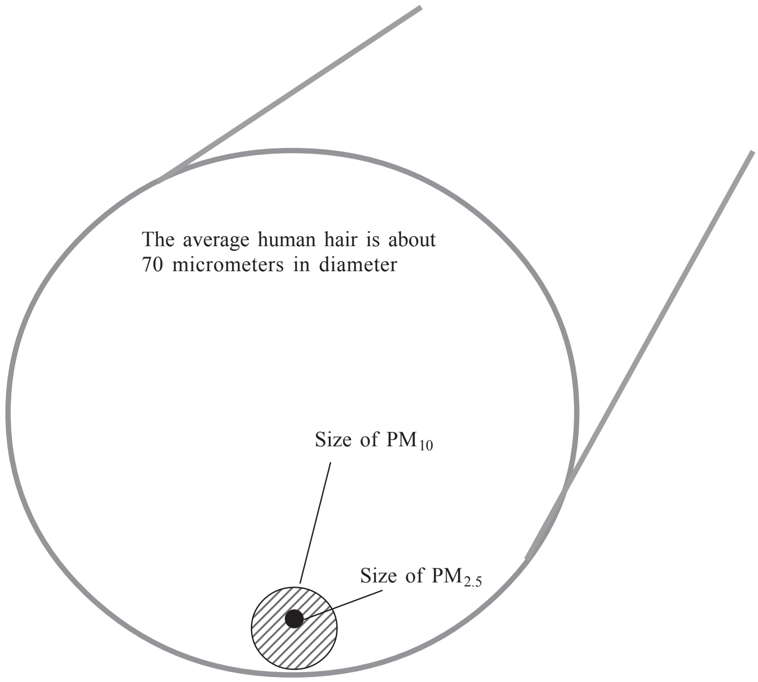


Small but dangerous

Recent research indicates that fine particles ($PM_{2.5}$) in the air in the year 2000 caused an average shortening of statistical life expectancy of more than eight months in the EU, equivalent to 3.6 million life years lost annually. This means that these particles have the most serious effects on people's health of all air pollutants.

Effects on human health

A large number of studies carried out in both the US and in Europe have shown that when the concentration of small particles in air rises, even from low levels, there is a rise in mortality from respiratory, cardiac and circulatory diseases, and more people seek hospital care for bronchitis and asthma. WHO (2005a) summarizes the state of knowledge as follows:

❑ Particles (PM) in general increases the risk of respiratory death in infants younger than one year, affects the rate of lung function development, aggravates asthma and causes other respiratory symptoms such as coughs and bronchitis in children.

❑ Fine particles ($PM_{2.5}$) seriously affect health, increasing deaths from cardiovascular and respiratory diseases and lung cancer. Increased $PM_{2.5}$ concentrations increase the risk of emergency hospital admissions for cardiovascular and respiratory causes.

❑ Coarse particles (PM_{10}) affects respiratory morbidity, as indicated by hospital admissions for respiratory illness.

People are not all affected equally by air pollutants – certain sections of the population are much more sensitive than average. These include children, the elderly and those with underlying disease, such as respiratory disorders.

Short-term exposure

WHO (2005a) states that short-term changes in PM_{10} at all levels lead to short-term changes in acute health effects. Effects re-

Table 1. Estimated health damage due to $PM_{2.5}$ in the EU 2000 and through implementation of current legislation (CLE) 2020. Source: EC 2005c.

Health effect	Units (1000s)	2000	2020 CLE
Mortality - long-term exposure	Life years lost	3,619	2,467
Mortality - long-term exposure	Premature deaths	348	272
Infant mortality	Cases	0.68	0.35
Chronic bronchitis	Cases	164	128
Respiratory hospital admissions	Cases	62	42
Cardiac hospital admissions	Cases	38	26
Restricted activity	Days	347,700	222,000
Respiratory medication use, children	Days	4,200	2,000
Respiratory medication use, adults	Days	27,700	20,900
Lower respiratory symptoms (LRS), children	Days	192,800	88,900
LRS, adults with chronic disease	Days	285,300	207,600

lated to short-term exposure include inflammatory reactions in the lungs, respiratory symptoms such as cough and bronchitis, adverse effects on the cardiovascular system and increases in medication use, hospital admissions and mortality.

Although long-term exposure gives rise to the most serious health effects (see below) the acute effects that arise from short-term exposure to high concentrations are important, since they affect a large proportion of the population, for example in the form of restricted activity days (see table 1). WHO stresses that, based on known health effects, both short-term (daily) and long-term (annual), guidelines are needed for fine as well as coarse particles.

Long-term exposure

Because long-term exposure to PM results in a substantial reduction in life expectancy, the long-term effects clearly have greater significance to public health than the short-term effects (WHO 2005a).

The effects of long-term exposure include increases in lower respiratory tract symptoms and chronic obstructive pulmonary disease, reductions in lung function in children and adults, and reduction in life expectancy, due mainly to cardiopulmonary mortality and probably to lung cancer. These effects are demonstrable even at levels well below the limit values.

$PM_{2.5}$ shows the strongest association with mortality: An increase in long-term concentration of $PM_{2.5}$ by 10 $\mu g/m^3$ increases the risk of deaths from all causes by 6 per cent.

These estimates are based on exposure comparisons between cities, and assume that all residents of a city have the same average exposure levels. But recent research in California has shown that assessments of exposure that are based only on community average concentrations may lead to an underestimation of the health risks by a factor two or three (EC 2005d).

Significance of size and origin

It is the very smallest particles that are believed to be the most harmful, because when they are inhaled they can penetrate deep into the lungs. The focus of debate is now turning to $PM_{2.5}$. However, many researchers point out that coarse particles ($PM_{2.5}$–PM_{10}) also have considerable health effects and their levels also need to be reduced.

The shape and chemical composition of the particles as well as their size are thought to influence their harmfulness, as do the substances that adhere to their surfaces.

At present it is not possible to distinguish between the health effects of particles with different origins, so for the time being all particles in the same size range are regarded as equally harmful. Toxicology studies indicate, however, that so-called primary particles from combustion have a higher toxic potential than secondary particles (see box 2). These primary particles are often rich in metals and organic compounds, and also have a relatively high surface area (WHO 2004a).

How many are affected?

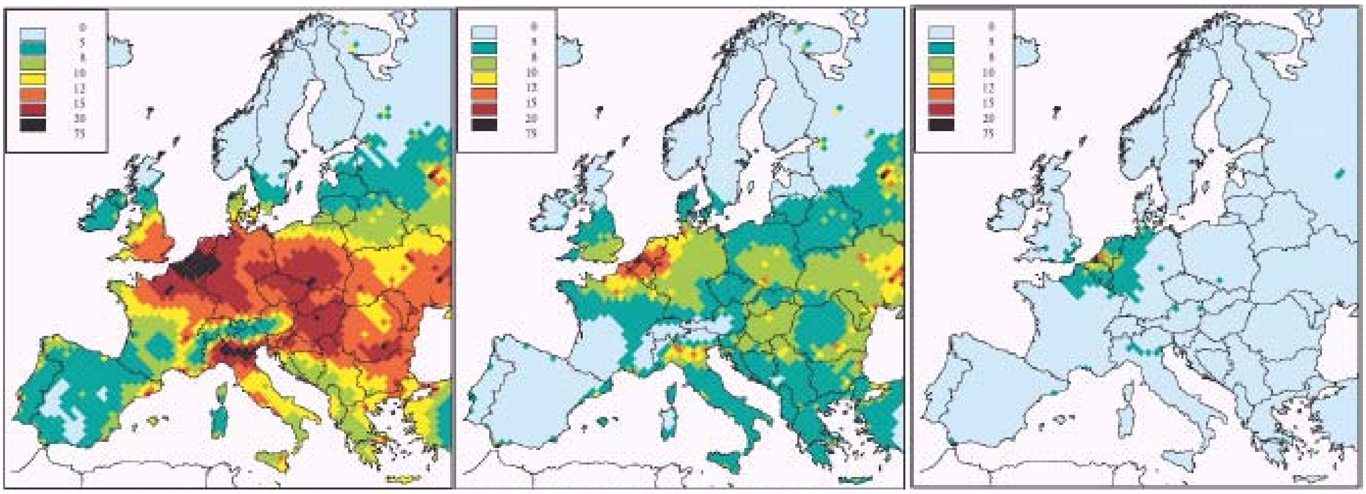
Knowledge of the concentrations in the air and the links that exist between exposure and response makes it possible calculate the effects. Although these calculations do involve some uncertainties they still give a clear indication of the scope of the problem.

Effects in Europe 2000

In the EU thematic strategy on air pollution (EC 2005a) the health effects of levels of fine particles ($PM_{2.5}$) in the air in the year 2000 are estimated to lead to an average shortening of statistical life expectancy of more than eight months in the EU, equivalent to 3.6 million life years lost annually.

This effect is comparable to the loss of life expectancy due to road accidents in

Figure 1. Loss in statistical life expectancy that can be attributed to anthropogenic contributions to $PM_{2.5}$ (months). For the emission levels in the year 2000 (left), and for two projected emission levels for 2020: CLE (centre) and MTFR (right).



the EU, even though it does not include secondary organic aerosols and only refers to impact on the population over 30 years of age, thus underestimating the total impact. Figures for each country are given in table 2.

Geographically, the greatest damage to health occurs in the Benelux area, in northern Italy, and in parts of Poland and Hungary. In these areas, the average loss in life expectancy may be more than one year. See Figure 1.

In addition to premature deaths, particles cause a range of other effects on people's health, including increased need for respiratory medication in adults and children and almost 350 million days of restricted activity in 2000, see table 1.

Effects in Europe 2020

Under the current legislation scenario the average loss of life expectancy in the EU caused by $PM_{2.5}$ is expected to drop from 8 months in 2000 to 5.5 months in 2020. The number of life years lost will fall from 3.6 to 2.5 million, see table 1.

Bigger improvements are possible if further measures are taken to reduce levels. The effects on life years lost and premature deaths of implementing the thematic strategy and technically feasible reductions are shown in table 2.

Cleaner air brings huge benefits

Improvements in health generate the largest quantified monetary benefits when air pollution is reduced. The European Commission (EC 2005c) shows that the benefit of reducing the average background concentration of $PM_{2.5}$ by 20–25 per cent between 2010 and 2020 is estimated to be between 37 and 119 billion euro per annum in 2020. These figures are between five and 24 times higher than the estimated costs, which range between 5 and 8 billion euro per annum.

Guidelines and standards

The World Health Organization, WHO, has until recently been unwilling to set any air quality guidelines for particles, since it is considered unlikely that a level will be found that does not have harmful effects. Instead, it has given a dose-response relationship, that can be used to calculate for example how many people would be affected by a given level of particles in the air.

In the revised WHO air quality guidelines that were adopted in autumn 2005 (WHO 2005c) it is stated that the link between exposure and effects can still be used, depending on local circumstances, to establish limit values. But numerical values are also given to provide guidance on the concentrations at which increasing, and specified mortality responses due to PM are expected based on current scientific insights, see table 3.

A working group under the CAFE programme reported in a position paper (CAFE 2004) that for health reasons the EU should aim for a reduction in annual mean concentrations of $PM_{2.5}$ to levels of around 10 µg/m^3 or lower. In the short term, by 2010, the group recommended that limit values in the range 12–20 µg/m^3 should be considered.

EU limit values

Limit values for PM_{10} were adopted in 1999. The directive came into effect in 2001, and the PM_{10} limit values became legally binding in the EU in January 2005, see table 3.

In September 2005 the Commission presented a proposal for a new directive (EC 2005b) that would mean retaining the current PM_{10} standard and adding a new standard for $PM_{2.5}$ – as so called concentration cap of 25 µg/m^3 as annual mean – to be met by 2010.

As a rule of thumb, levels of $PM_{2.5}$ are around 60–70 per cent of PM_{10} levels, so the proposed concentration cap for $PM_{2.5}$ does not represent any strengthening of requirements in relation to the PM_{10} standard that is already in force. On the

Table 2. Estimated health effects (premature deaths) due to exposure to $PM_{2.5}$ in EU25 in 2000 and in 2020 for three scenarios: Current legislation (CLE), Thematic Strategy (TS) and Maximum technically feasible reductions (MTFR).

PM: Premature deaths.

		2020 scenarios		
Country	**2000**	**CLE**	**TS**	**MTFR**
Austria	5500	4590	3660	3230
Belgium	12880	10030	8010	7280
Cyprus	230	270	260	260
Czech Rep.	9070	6450	4680	4190
Denmark	3270	2730	2250	1960
Estonia	630	410	360	320
Finland	1270	1250	1200	1070
France	42090	34740	27010	23700
Germany	75040	62590	46610	42330
Greece	7230	6910	6410	6140
Hungary	12870	8410	6000	5460
Ireland	1170	960	760	650
Italy	50690	37890	30580	27840
Latvia	1330	910	810	730
Lithuania	2190	1680	1450	1310
Luxembourg	320	290	200	180
Malta	192	206	190	182
Netherlands	15440	13970	10550	9510
Poland	32850	24890	19440	17890
Portugal	5040	3540	2830	2460
Slovakia	4250	3390	2470	2210
Slovenia	1580	1280	1010	890
Spain	19940	14190	11830	10880
Sweden	3280	2680	2380	1990
UK	39470	27370	19910	17570
Sum EU25	347822	271626	210860	190232

Table 3. Guidelines, target values and limit values.

	Max. 24-hour mean value (µg/m^3)	**Annual mean value** (µg/m^3)
PM10		
WHO guideline (WHO 2005c)	50 (99th percentile*)	20
EU limit value, from 2005 (Directive 1999/30/EC)	50 (96th percentile*)	40
Preliminary EU limit value 2010 (B)	*50 (98th percentile*)*	*20*
Guide value, Sweden, from 2010	35 (90th percentile*)	20
Guide value proposed by IMM (C)	30	15
PM2.5		
WHO guideline (WHO 2005c)	25 (99th percentile*)	10
EU concentration cap from 2010 (D)		25
US limit value from 2010	65 (E)	15
Limit value, California		12
Guide value, Sweden, from 2010	20 (90th percentile*)	12
Limit value proposed by CAFE working group (F)		12-20

* The percentile is a statistical measure that indicates how many times (in this case days) a limit value may be exceeded. 90th percentile = 37 exceedances per year. 96th percentile = 35 exceedances per year. 98th percentile = 7 exceedances per year. 99th percentile = 4 exceedances per year.

(A) European Union 1999, Directive 1999/30/EC.

(B) Interim values in present directive (1999/30/EC). In the proposal for the new directive (EC 2005b) the Commission want to eliminate these, however.

(C) IMM = National Institute of Environmental Medicine, Sweden, 2000.

(D) EC 2005b.

(E) Should be reduced to 35 µg/m^3 according to proposal by EPA in December 2005.

(F) CAFE 2004.

other hand the proposal allows a number of concessions to the current regulations, including more time for countries to meet the limit values and the opportunity to discount pollutant contributions from natural sources for compliance purposes (see box 1 for details).

To complement the new concentration cap it is proposed that member states should reduce average human exposure to urban background levels of $PM_{2.5}$ over the period 2010–2020. A general, non-binding 20-per-cent reduction is proposed.

The United States

In 1997 the USA set an annual limit value of 15 µg/m^3 for $PM_{2.5}$ which is to be met by 2010. The state of California has had a limit value of 12 µg/m^3 since 2003.

In a review of the federal limit value that was carried out in 2005 a Staff Paper from the Environment Protection Agency proposes that in light of the latest scientific information the limit value should be reduced, and levels as low as 12 µg/m^3 are being discussed (US EPA 2005).

Emissions of primary particles

Emissions of primary particles are considered to have fallen in recent decades, but the true extent is still inadequately known. According to the EU thematic strategy on air pollution, emissions of primary particles ($PM_{2.5}$) in 2000 totalled 1,744,000 tonnes in the EU25. The emissions by country is shown in table 4.

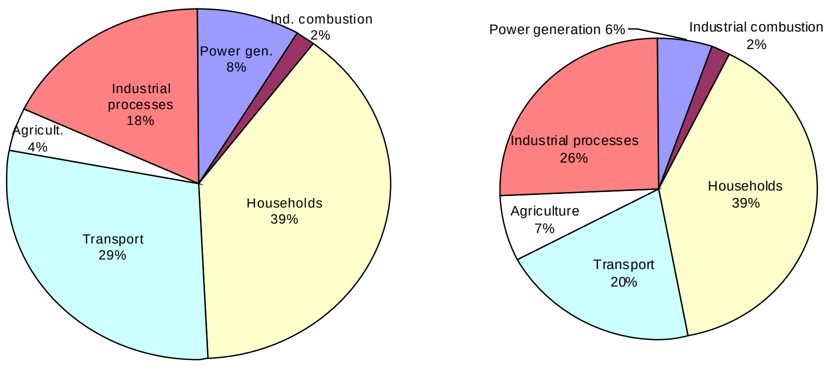
According to the baseline scenario (current legislation) that is used in the thematic strategy, emissions of $PM_{2.5}$ would fall by 45 per cent between 2000 and 2020 (to 969,000 tonnes), mainly as a result of stricter emission standards for cars and heavy vehicles. See table 4.

Emissions from international shipping in European waters are expected to rise over the same period from 210,000 to 330,000 tonnes.

It is possible to achieve larger reductions in emissions than predicted under the baseline scenario if additional measures are taken. If the thematic strategy is implemented, emissions of primary $PM_{2.5}$ from land-based sources in the EU would fall to 712,000 tonnes in 2020. The maximum technically feasible reduction is calculated as 606,000 tonnes by 2020 (again, see table 4).

Note that the figures above refer solely to emissions of primary particles. A significant proportion of the particles that are found in the atmosphere are, however, secondary particles formed from other pollutants, particularly nitrogen oxides, sulphur dioxide and ammonia. See Box 2.

Figure 2. Emissions of $PM_{2.5}$ per sector in EU25, year 2000 (left) and 2020 baseline scenario (right). Source: EC 2005c.



Distribution by sector

At EU level the household and transport sectors account for the largest emissions of primary particles ($PM_{2.5}$), see figure 2. The household sector is dominated by emissions from domestic wood stoves while transport is dominated by diesel engines.

Abatement options

Special attention should be given to those particles that, in laboratory trials, show the highest toxicity and often occur in hotspots. These include particles from combustion processes, and particularly exhaust fumes from diesel engines. A large, but unregulated source, is domestic wood stoves. In urban areas, up to 10 per cent of the population may be living in such "hot spots". WHO concludes that the public health burden of such exposure is significant (WHO 2004b).

It is important that abatement programmes do not focus solely on meeting the relevant limit values for PM_{10}, as this could mean that too great an emphasis is placed on the largest particles. These admittedly represent the largest fraction by weight, but are not likely to have the biggest effect on health.

It is also important to avoid focusing solely on local hotspots where limit values are exceeded, such as areas with heavy road traffic. It is at least as desirable to effect a reduction in the background levels, since it is long-term exposure that accounts for the majority of the most serious health effects.

A significant proportion of the regional background level consists of secondary particles (see box 2). Reducing the level of these particles requires measures in those sectors of society that produce large emissions of sulphur dioxide, nitrogen oxides and ammonia.

The Commission is currently preparing the revision of the directive on national emission ceilings (NEC), which sets binding requirements for maxium total emissions of sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia, for each member state. A proposal for a revised directive that will require more far-reaching reductions in the air pollutants that act as precursors to secondary particles, is foreseen by mid-2007. The proposal may include national emission ceilings also for primary particles.

References

CAFE 2004. Second Position Paper on Particulate Matter. CAFE Working Group on Particulate Matter. 20 December 2004.

EC 2005a. Thematic Strategy on Air Pollution. COM(2005) 446.

EC 2005b. Proposed Directive on Ambient Air Quality and Cleaner Air for Europe. COM(2005) 447. Can be downloaded at http://europa.eu.int/comm/environment/air/cafe

EC 2005c: Commission staff working paper: Impact assessment of the thematic strategy on air pollution and the directive on "Ambient air quality and cleaner air for Europe". SEC(2005) 1133.

EC 2005d. Science for Environment Policy. DG Environment News Alert. 5 December 2005.

IMM 2000. Particles in ambient air – a health risk assessment. Pershagen, G. (Ed.). Scandinavian Journal of Work, Environment & Health. Vol. 26, suppl. 1, 2000.

US EPA 2005. Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. QAQPS Staff Paper. EPA-452/R-5-005. www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html

WHO 2000. Air Quality Guidelines for Europe. Second Edition. WHO Regional Publications, European Series, No. 91.

WHO 2004a. Health Aspects of Air Pollution. Results from the WHO Project "Systematic Review of Health Aspects of Air Pollution in Europe", June 2004.

WHO 2004b. Health Aspects of Air Pollution – answers to follow-up questions from CAFE, Report on a WHO working group meeting, Bonn, Germany 15-16 January 2004. Available at www.euro.who.int/document/E82790.pdf.

WHO 2005a. Particulate matter air pollution: how it harms health. Fact sheet EURO/04/05. Berlin, Copenhagen, Rome, 14 April 2005.

WHO 2005b. Press Release EURO/08/05. Berlin, Copenhagen, Rome, 14 April 2005.

WHO 2005c. WHO air quality guidelines global update 2005. Report on a Working Group meeting, Bonn, Germany 18-20 October 2005. Available at www.euro.who.int/Document/E87950.pdf

Further information

Particulates and health: The above reports from WHO give a good summary of the current state of knowledge. Available along with other relevant material from WHO Europe, www.euro.who.int (select "Health topics" and then "Air").

The CAFE programme and the thematic strategy on air pollution: Summarized in a fact sheet from the secretariat, available at www.acidrain.org. See also the Commission's website, http://europa.eu.int/comm/environment/air/cafe/. Here you can find the strategy itself, an impact assessment and the CAFE position paper mentioned above (CAFE 2004).

NGO positions: European environmental NGOs have prepared position papers for both the thematic strategy on air pollution and the proposed directive on ambient air quality and cleaner air for Europe (COM(2005) 447). Available at http://www.acidrain.org/pages/policy/sub6_10.asp

What can be done at local level: "A Breath of Fresh Air" (2002) is a fact sheet from the European Environmental Bureau (EEB) explaining EU legislation and possible local action to improve air quality. Available at www.eeb.org.

Box 1.
Weakening of agreed EU standards

The Commission's proposal for a new air quality directive (EC 2005a) means the removal of indicative standards for PM_{10} that were meant to come into effect in 2010 under the current directive. These indicative limit values would have meant a halving of the highest permissible annual mean value in comparison with 2005 (from 40 to 20 µg/m^3) and a reduction in the number of days of permissible exceedances of the daily limit value from 35 to 7 per annum. (See table 3.)

The Commission's proposal would make it possible for member states to exceed already agreed standards, including those for PM_{10}, for up to five years. Such a postponement would also include the proposed new $PM_{2.5}$ concentration cap. According to the proposal, if a country can show that it has taken all reasonable measures to implement the legislation but is nevertheless unable to comply with air quality standards in certain areas, it is proposed to allow it to request an extension to the compliance deadline by up to five years in the affected zones provided that certain criteria are met and plans are put in place to move towards compliance.

In its proposal the Commission also wants to make it possible to discount pollutant contributions from natural sources for compliance purposes. This means that where pollution arises from natural sources, such as wind-blown Saharan sand or sea spray, these will not count towards exceedances of limit values. However, no research has been done to show that particles from natural sources should be any less harmful, so the ability to discount such sources will effectively mean that greater health risks are accepted for the population in certain areas.

Table 4. Emissions of primary particles ($PM_{2.5}$) in 2000 and in 2020 for three scenarios: Current legislation (CLE), Thematic Strategy (TS) and Maximum technically feasible reductions (MTFR).

		2020 scenarios		
Country	2000	CLE	TS	MTFR
Austria	37	27	22	20
Belgium	43	24	17	16
Cyprus	2	2	2	1
Czech Rep.	66	18	13	12
Denmark	22	13	12	10
Estonia	22	6	5	2
Finland	36	27	26	16
France	290	167	114	101
Germany	171	111	90	83
Greece	49	41	31	23
Hungary	60	22	9	8
Ireland	14	9	8	6
Italy	209	100	75	69
Latvia	7	4	3	2
Lithuania	17	12	9	5
Luxembourg	3	2	2	2
Malta	1	0	0	0
Netherlands	36	26	22	20
Poland	215	102	62	53
Portugal	46	37	24	21
Slovakia	18	14	7	6
Slovenia	15	6	3	3
Spain	169	91	64	56
Sweden	67	40	38	23
UK	129	68	54	48
SumEU25	1744	969	712	606

Box 2. What are particles?

Particulate matter (PM) is an air pollutant consisting of a mixture of particles that can be solid, liquid or both, are suspended in the air and represent a complex mixture of organic and inorganic substances. These particles vary in size, composition and origin.

Their properties are summarized according to their aerodynamic diameter, called particle size. The measurements used at present are the weights of two particular fractions:

- ❑ PM_{10}, particles with an aerodynamic diameter smaller than 10 µm[1], which may reach the upper part of the airways and lung.
- ❑ $PM_{2.5}$, with an aerodynamic diameter smaller than 2.5 µm. These are regarded as more dangerous because they penetrate more deeply into the lungs and may reach the alveolar region.

WHO (2004a) divides particles into three groups:
coarse, diameter 2.5-10.0 µm;
fine, 0.1-2.5 µm; and
ultrafine, less than 0.1 µm.

The fine and ultrafine fractions are more strongly associated with anthropogenic activities than the coarse fraction, which may contain for example wind-blown dust.

Difference between weight and number

Most measurements, and all current air quality standards for particles, refer to the weight of particles in different size ranges, such as PM_{10} and $PM_{2.5}$. Both are measured in units of µg/m³. The ultrafine particles ($PM_{0.1}$) represent only a fraction of measured PM_{10}-levels, but may make a considerable contribution to health effects.

Apart from the fact that there are many more small particles for a given unit of weight[2] they also cause more damage, since they can penetrate further into the airways and have a much larger surface area per unit weight. The number of particles should therefore provide a better measure of their harmfulness, but is more difficult to measure.

Primary and secondary

Particles are classed as either primary or secondary:

Primary particles are those that are formed during combustion, but may also consist of dust, small soot flakes, pollen, etc. Major sources of anthropogenic emissions are combustion processes (often small-scale appliances) and internal combustion engines (primarily diesel engines).

Secondary particles consist mainly of sulphate and nitrate salts that are formed in the air from sulphur dioxide and nitrogen oxides. Ammonia and volatile organic compounds (VOCs) are also of interest. Any source that emits these substances therefore contributes to their formation. Most fine particles in air are of secondary origin.

Long-range transport

The size of the particles determines the time they spend in the atmosphere. While sedimentation and precipitation remove PM_{10} from the atmosphere within a few hours of emission, $PM_{2.5}$ may remain there for days or even a few weeks.

Consequently, $PM_{2.5}$ can be transported over long distances. In most places only a small proportion of the background concentration is traceable to local emissions, and a large percentage, particularly of the finest fractions, consists of particles that were emitted in other locations or formed as secondary particles in the atmosphere. In urban environments, along major roads for example, the local contribution can be considerable, however.

Current levels

Particles occur naturally in air, in the form of wind-blown dust, sea salt and desert sand, for example. The natural background level varies with the local geography as well as climatic conditions. As a mean, the natural input to PM_{10} in Europe varies from 3 to 8 µg/m³ in most EU regions, with the highest values recorded in the southern part of the union (CAFE 2004).

In Europe it is PM_{10} concentrations that are measured most widely. The limit values that have been in effect in the EU since 2005 are exceeded by a large margin in many cities (primarily the daily limit value). Measurement of $PM_{2.5}$ levels has begun in a growing number of locations. In cases where data is only available for PM_{10} it can be taken as a rule of thumb that $PM_{2.5}$ levels are around 60–70 per cent of PM_{10} levels.

In rural areas, secondary inorganic particles, especially aerosols of sulphates and nitrates, account for the largest contribution of both PM_{10} and $PM_{2.5}$, about 35–55 per cent. Second in mass is elemental and organic carbon (primary PM from combustion processes), accounting for about 15–35 per cent of PM_{10} and 17–40 per cent of $PM_{2.5}$ (CAFE 2004).

Particularly high concentrations of particles can occur close to major emission sources (such as roads and small-scale combustion installations), but also during periods of stable weather, when the air is not mixed. At roadside stations, local traffic usually accounts for the major contribution (including exhaust and abrasion products), with 40 to 55 per cent of the annual PM_{10} levels and 45–60 per cent of $PM_{2.5}$ (CAFE 2004).

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[1] Actually particles of such a size that 50 per cent pass through a given sampling filter. µm = micron = one thousandth of a millimetre. 10 µm = one hundredth of a millimetre.

[2] A particle measuring 10 microns in diameter is equivalent in weight to a thousand particles with a diameter of 1 micron or a million particles with a diameter of 0.1 micron, assuming spherical shape and equal density.