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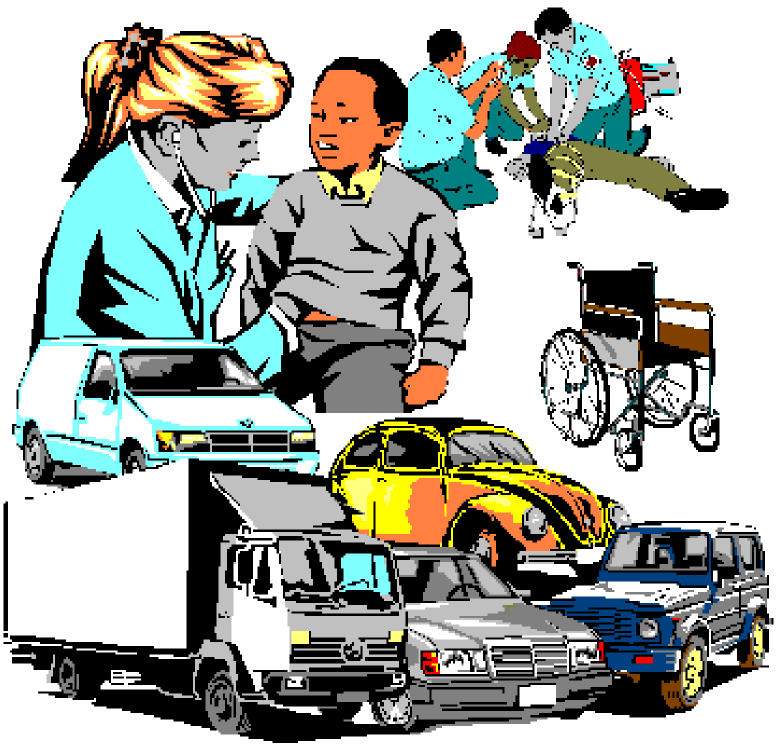

Traffic and Health

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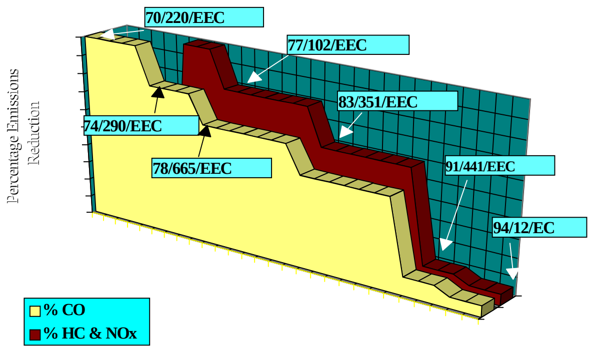
1. Introduction to Traffic and Health

During the last two decades in Europe it has been obvious for all to see that traffic levels have substantially increased in all urban areas. The number of cars on the road has more than doubled from 61 million in 1970 to 159 million in 1995. There has also been a massive increase in freight being transported by road leading to a rise of 236% in heavy goods vehicles during the same period (7.6 million to 18 million). This increase in vehicles added to an increase in kilometers driven by individual vehicles, has led to a substantial rise in transport related air pollution in urban areas, even though there has been substantial reductions in emissions from individual new vehicles (see Graphs 1 and 2)

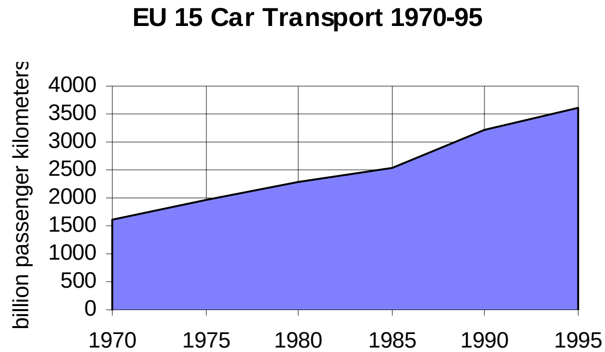
Traditionally, it was the domestic burning of coal and industrial pollution which were the dominate sources of high concentrations of urban air pollution. However, comprehensive measures have been taken, which have substantially reduced their contribution to overall levels. Unfortunately during the same period the marked increase in traffic has meant as levels of sulphur dioxide and black soot have been reduced, concentrations of less visible but potentially more harmful pollutants have been increasing. Recent scientific studies investigating the effect of transport related air pollution on health have found strong links between present day concentrations of air pollution and adverse health effects including the worsening of respiratory symptoms, exacerbating asthma, decrease in lung function, increased hospital admissions for respiratory and heart problems as well as an increase in premature mortality. Traffic is also the number one cause of noise disturbance which not only causes annoyance but also can lead to sleeping problems, increased blood pressure and higher levels of stress. Not always considered an environmental problem but always considered a health consequence of traffic is the levels of injury and death caused by road traffic accidents; in the EU alone it leads to 45 000 deaths a year.

In 1996 the European Community adopted the Framework Directive on Ambient Air Quality Assessment and Management. This directive provides the framework for the setting of air quality standards and the creation of a comprehensive monitoring network for the twelve targeted pollutants. Individual daughter directives will set the limit values for each pollutant and exact details of how each should be monitored; the first daughter directives covering lead, nitrogen dioxide, particulate matter and sulphur dioxide should be adopted by the end of 1997 with a directive on ozone following shortly afterwards. This legislation will provide environmental groups with a powerful tool for the improvement of air quality. This publication aims to put into context the role of traffic in reducing air quality, the negative effects that this reduced air quality is having on our health and the way in which these new daughter directives can be used to put pressure on authorities to improve air quality.

Graph I - EC Emissions Legislation



Graph 2



2. Sources of Air Pollution

In the European Union, motor vehicles in general and cars in particular are the main source of high levels of air pollution concentrations in urban areas. Transport accounts for 63% of nitrogen dioxides (NO_2), 47% of non-methane volatile organic chemicals (NMVOCs) which includes benzene, 10-25% of particulate emissions (PM) and 6.5% of sulphur dioxide (SO_2) at the regional level in Europe. In urban areas, where 70% of the population live, the contribution of traffic is often very much higher. Taking particulate matter as an example, the European Environment Agency (EEA) recognises that although traffic only accounts for 10-25% of European emissions its contribution to ground level urban concentrations is considerably higher. In a study carried out by the European Commission into air quality in seven major European cities, traffic was estimated to account for 66% of PM with a maximum contribution of 96% in London as well as contributing to 68.5% of NOx and up to 22% of SO_2. In addition, the EEA estimates that cars account for at least 90% of urban benzene levels.

Not only does traffic account for a higher percentage of air pollution in urban areas than at regional level, but also it pollutes at street level or more precisely at breathing level. Unlike most industrial sites which now have large chimney stacks to disperse pollution, traffic pollutes literally right under our noses, so that our exposure to this source of pollution is higher than to other sources. Moreover, we are also exposed to pollution hot spots, areas where air pollution is particularly high, which adds to our overall daily exposure. In areas such as busy roads and street canyons (streets with high buildings on either side) air pollution can be as much as 2 to 4 times higher than at background sites. In underground car parks and in tunnels, levels can be as much as 40 times higher and benzene levels near petrol stations can be 15 times higher than at background. One of the most worrying hot spots is the car itself. In car levels for PM, NO_2, CO and VOCS are between two and three times higher than at roadside. This means that a cyclist who on average breathes 2.5 times as much air as a driver is still exposed to lower levels of certain air pollutants.

Many will argue that our exposure to hot spots is transient and does not account for much of our exposure. However, a recent study in Paris (see Table 1) shows that it can still account for important periods of time especially for commuters. Moreover, as traffic jams get longer, our exposure to hot spots can only become more severe. One cautionary note should be made about exposure. Much of our normal day, approximately 80% is spent indoors, meaning that our exposure to pollution is dominated by indoor levels. However, indoor concentrations have been found to be strongly related to ambient (outdoor) levels. For example ambient PM pollution accounts for 65-75% of indoor concentrations. Such findings therefore suggest that notwithstanding the time spent indoors, ambient concentrations are still a useful indicator of a populations exposure, to the major air pollutants.

Table 1 - Exposure of citizens to atmospheric pollution in Paris*

Site	Daily exposure	CO mg/m^3	NO_2 $\mu g/m^3$	Pb $\mu g/m^3$	Ozone $\mu g/m^3$	Benzene $\mu g/m^3$	SO_2 $\mu g/m^3$
parking lots	<0.5 h	20-70	100-500	200-400	-	100-300	100-300
road tunnels	a few minutes	20-100	100-200	200-400	-	100-400	50-100
cyclists, motorcyclists	0.5-1 h	-	-	-	-	-	-
car drivers	1-4 h	6-13	-	-	-	30-80	-
bus passengers	0.5-2 h	3-6	-	-	-	15-35	-
metro passengers	0.5-3 h	1-3	40-100	100-200	0-20	5-15	-
pedestrians	1-3 h	2-6 (1h)	60-100	50-100	-	10-30	30-100
people who live or work next to roads	8-24 h	3-5 (24h)	60-100	50-100	0-50	15-25	20-80
primary school students	6-8 h	0.5-5 (8h day)	20-60	20-60	-	4-25	-
people who do not live next to roads	12-24 h	0.5-1 (24h)	50-70	10-30	40-80 summer 13h-20h	4-7	10-30

*adapted from ‘La pollution atmosphérique d’origine automobile et la santé publique’ 1996[i].

3. Air Pollution Levels

Air Pollution levels across the European Union remain poor, according to reports by the European Topic Centre on Air Quality, the World Health Organisation (WHO) and the EEA. It is estimated that all Europeans living in urban areas (70% of the population) are exposed to levels which exceed the internationally recognised WHO air quality guidelines for the protection of health, for at least one pollutant. Although northern Europe is less polluted then western and southern Europe, even in the cleanest cities, people are exposed to levels which can have adverse effects on health.

Two important types of air pollution, in terms of health, are winter smog characterised by high levels of PM, SO_2 and NO_2 and summer smog which occurs when levels of ozone and other photochemical pollutants rise (see Box 2). The European Topic Centre estimates that 70% of European cities experience at least one and often several episodes of winter smog per year. In their annual report on ozone, they conclude that in recent years all EU countries have experienced ozone levels above the EU threshold for the protection of health. It is southern and western European countries that suffer the worst problems from ozone pollution.

In addition to its association with winter smog, PM has been targeted by the WHO and the EEA as an important public health concern. Its levels across Europe are unacceptably high if health is to be properly protected. Scientific evidence suggests that there is no level at which PM is safe and therefore the WHO has not set a guideline value. However, the UK expert panel on air quality decided on a limit value of 50 ug/m^3 as a 24-hour average value for PM10. Practically all European cities which monitor PM10 exceed this value (see Table 2).

The EEA in its most recent report concludes that although levels of SO_2 and NO_2 are declining, levels in many areas of the EU still pose a threat to public health. The EU guide value for SO_2 is exceeded substantially throughout Europe, except in Northern towns. The guide value for NO_2 is exceeded in all parts of Europe and in some cities the EU limit value is exceeded by 75%. For benzene a lack of monitoring in Europe makes it difficult to analyse the situation. However, for towns that monitor, background levels are within the range 1.6-11 ug/m^3 with streetside levels peaking at 47 ug/m^3 as a yearly average level. The WHO sets a limit value of 1 ug/m^3 and various EU governments set values between 3-16 ug/m^3 as yearly values.

Estimates suggest that 20% of the EU population is exposed to noise levels which are unacceptable, with a further 45% living in so-called 'grey areas' where noise pollution cause serious annoyance during the daytime. As far as traffic accidents are concerned, although it accounts for only 1-3% of all deaths, accidents cause 12-19% of all deaths in people between the ages of 15-44.

Table 2 - Estimated health impacts of ambient air pollution in Europe

Indicator of health deficiency	Proportion of the health deficiency attributed pollution	Estimated number of cases (annual)
Cough and eye irritation in children	0.4 - 0.6%	2.6 - 4 million
Lower respiratory illness in children causing a medical visit	7 - 10%	4 - 6 million
Ambulatory visits due to respiratory disease	0.3 - 0.5%	17 - 29 thousand
Decrease of pulmonary function by more than 5%	19%	14 million
Incidence of chronic obstructive pulmonary disease	3 - 7%	18 - 42 thousand
Hospital admissions due to respiratory disease	0.2 - 0.4%	4 -8 thousand

WHO European Centre for Environment and Health. Concern for Europe’s tomorrow, 1995

Box 1 - Air Quality

Air quality is characterised by the use of air quality indicators, usually given as the concentration of selected compounds over a given averaging period. For example, the average amount of SO_2 in the air over an 8 hour period could be given as: **150 ug/m^3 (micrograms per cubic meter of air) as an 8-hour average.** To relate these indicators to their health and environmental effects, limit values and guide values are created.

Limit values are legally binding definitions of the permissible concentration of a pollutant over a given period. In the past EU limit values have been a compromise between the protection which is needed and the economic cost of reducing pollution to these levels. Guide values are recommended levels which usually aim to substantially protect health and the environment. In this publication World Health Organisation Air Quality Guidelines (WHO AQGs) are frequently mentioned. These values, based on current knowledge, are the internationally recognised standards for the protection of health.

Box 2 - SMOG

The term smog, a combination of the words smoke and fog, has come to represent periods, of up to several days, when air pollution concentrations rise to such an extent that it becomes a visible blanket over a city. Both summer and winter smog occur during periods of stable, clear weather when the normal dispersal of pollution by relatively clean air does not occur. Summer smog is always accompanied by hot sunny weather, since it is the sun acting on the precursor pollutants (mainly NOx and VOCs) which creates ozone. Winter smog usually occurs when you have a weather inversion - a layer of cold air above a city - which traps warmer polluted air underneath. During smog episodes, air pollution concentrations can reach 10 times the normal ambient concentrations causing serious problems for health.

4. Health

Air pollution is causing serious adverse health effects at concentration levels commonly occurring in European urban areas. The initial evidence linking health problems to air pollution came from North America and centered on the effects of PM and ozone. Certain governments and industries felt that this evidence was not valid for Europe. However, during the last few years a substantial body of European research has been carried out which clearly demonstrates that it is. Notable among this research is the APHEA study which, using a common approach, examined the relationship between increases in air pollution and short-term health effects in 15 European cities.

Box 3 - HOW AIR POLLUTION GETS AT YOU

Pollutants can enter the body by being breathed in (inhaled), eaten (ingested) or through skin absorption. Inhalation is the primary route of exposure to the classical air pollutants, which travel deep into the lung where air exchange takes place, causing damage to cells. For example ozone, which is a powerful oxidising agent, damages cells on the lung wall causing liquid to flow into the lungs. For certain pollutants the lung has mechanisms for removing pollutants from the air. For example nasal hairs and mucous membranes remove particles above 10µm (a human hair is 70µm) stopping them reaching the lungs. It is particles below 2µm which are the most effective at reaching the deepest parts of the lung, which is why more and more researchers believe small traffic-related particles are the most important factor for causing adverse health effects. By contrast the body has no mechanism for removing ozone from the air it breathes, which explains why those who take physical exercise outdoors during when ozone is heavy suffer higher levels of health effects.

Box 4 - Health Effects Research

To determine the effects of air pollution on health, researchers use animal tests, clinical studies and epidemiology.

Animal tests: Due to the similarity of small airway disease in animals by exposing them to air pollution, it is possible to track the progression and reversibility of injury. Such tests are particularly useful for determining the exact biological process that causes the observed health effect.

Clinical Studies: Human volunteers are exposed in the laboratory setting to controlled levels of pollution, providing relevant information on human health effects associated with brief exposure to specific doses of pollutants.

Epidemiological Studies: Performed in the real world rather in than in the laboratory, investigators attempt to measure the pollutant exposure of a carefully defined group of people and determine whether exposure is associated with ill health. A strength of epidemiological studies is that they analyse actual health effects in human populations at ambient pollution concentrations.

Source: Drawn from Natural Resources Defense Council, Breath Taking-Premature Mortality due to Particulate Air Pollution in 239 American Cities, May 1996.

4.1. Risk and Vulnerability

Air pollution does not pose the same risk to everyone in a community. Individual susceptibility varies and a significant minority of the population is at particular risk. The young, the elderly, those already suffering from pre-existing illness, pregnant women and their foetuses are part of this high risk group. When premature mortality from short-term increases in air pollution is considered, it is the elderly and those suffering from cardiovascular and respiratory diseases who are victims. The young suffer higher levels of respiratory illness due to air pollution and asthmatics commonly experience adverse effects at lower levels of air pollution than the general public.

In comparison to other public health problems such as smoking and poor diet, air pollution is considered less of a public health concern. However, WHO have investigated the likely consequence of the elevated levels of PM for the whole of Europe. They estimated that PM accounts for 4-6 million lower respiratory illnesses among children and 6-10 thousand extra deaths per year. This evaluation is based on limited pollution data, and if the pollution situation is the same for areas where data does not exist than the figures **quadruple.** In addition, these figures are only for one pollutant and only consider short-term effects. When WHO related the data, from American studies into the long-term effects of PM, to the Dutch air pollution situation, it was estimated that current PM levels were reducing the life expectancy of the average Dutch citizen by 1.1 years. Such risk estimates point to the real public health problem that air pollution poses.

Box 5 - Asthma and Allergies

The prevalence of asthma and allergic disease in western Europe increased twofold during the 1980s and has continued to increase steadily since. Although some research implicates traffic as a possible cause, the consensus of scientific opinion is that the increase is due to an unknown factor of western lifestyle since in eastern European countries where air pollution is higher there has not been a similar increase.

If traffic pollution has not been linked to higher levels of asthma and allergic disease, there is little doubt that it increases the symptoms among sufferers. PM, ozone and SO_2 have been shown to increase the level of hospital admissions and medicine use among asthmatics. In addition, ozone increases the sensitivity of hay fever sufferers to pollen.

4.2 Particulate Matter

The term particulate matter (PM) covers a wide range of substances in the air from wind blown dust or sand to smaller particles which are produced from the combustion of coal, oil, gasoline and diesel fuels in transportation, manufacturing and power generation. The particle mix not only includes visible soot, but also less visible finer particles comprised of carbon particles, and aerosols formed when gases such as sulphur dioxide, nitrogen dioxide and volatile organic compounds react in the air to create particles. These different particles vary considerably in size. Those emitted directly into the atmosphere (e.g. carbon soot, fly ash, dust and dirt) tend to vary between 1 µm (microns) and 100 µm; a human hair is 70 µm. Secondary particles (those formed from gaseous precursors) tend to vary between 0.1 µm and 1 µm. In urban areas of the EU it is traffic which is the dominant source of the smaller particles with diesel cars and trucks emitting significantly more PM per vehicle than gasoline powered vehicles.

Particle size is very important when examining the health effects of PM. The human body uses nasal hairs and mucous membranes to effectively stop particles above 10 µm getting into the lungs. Particles of less than 5 µm can get into the bronchial tubes but it is particles below 2 µm which are the best at reaching the deepest parts of the lung, the alveoli, where air exchange takes place. Smaller particles also remain in the atmosphere for longer and due to their chemical background are often acid in nature. Therefore, although no conclusive toxicological evidence exists to demonstrate how PM causes health effects, more and more researchers believe that the smaller, traffic related particles, are the critical factor for health. Such an evaluation makes it critical that not only is PM10 measured throughout Europe but this should also be reinforced with PM2.5 measuring, especially in urban areas.

Aerosols are formed when gases such as sulphur dioxide combine with other chemicals in the air producing tiny particles suspended in a gas.

Box 6 - Measuring PM

Up to the present day PM has been measured in various ways. The new European directive on air quality should put in place a common approach for the whole of Europe. But for the moment the main monitoring systems for PM are:

Black smoke - air is passed through a filter for a fixed period of time and then the darkness of the filter is measured. This can lead to underestimation of levels.

TSP (Total Suspended Particles) - air is drawn through a high volume sampler and the total amount of PM is measured by weight. All PM enters including those from non-combustion processes.

PM10 and PM 2.5 - this is the same process as for TSP but only the amount of PM below 10 µm or 2.5 µm is allowed through the filter. These are the best methods being the most relevant for health.

Health Effects of PM

As PM increases so does mortality for cardiovascular and respiratory causes as well as total mortality. Levels of hospital admission for respiratory illness such as bronchitis and asthma increase and there are higher numbers of respiratory symptoms such as cough, soar throat and sinusitis. The effects of PM on health have led WHO and the EEA to put it forward as a significant public health issue and the UK Expert Panel on Air Quality to conclude that levels should be reduced as far as possible.

In Europe and the US a significant body of research has examined the short-term effect of variations in PM concentrations on mortality. Although the studies have taken place in areas with different climatic conditions, in different seasons and in different parts of the world, there is a remarkable consistency in the results. In an analysis of the data by Dockery & Pope, two leading researchers in the field, it was concluded that for every 10 $\mu g/m^3$ increase in PM10 there is a corresponding increase of 1% in mortality (see Table 3). The recent APHEA study in Europe has found similar results estimating a 0.6% increase in mortality. The WHO, the UK Expert Panel on Air Quality and the US Environmental Protection Agency have all reviewed the data and concluded that present day levels of PM cause premature mortality.

Researchers suggest that mortality due to PM is a case of causing those already suffering from cardiovascular or respiratory problems to die prematurely rather than causing death among the healthy. However, they are unsure whether it is shortening lives by days, weeks or months; the length of time is an important factor in deciding on the public health problem that mortality due to PM poses. However, notwithstanding this debate two other factors make this issue important in terms of public health.

Firstly, new evidence suggests that levels of PM is causing increases in infant mortality. A study of 4 million infants born between 1989 and 1991, found that mortality rates were 10% higher among infants in areas with high levels compared to an area with lower levels of PM. Secondly, although short-term effects on mortality seem only to affect the most vulnerable in society, US studies show that the long-term exposure can increase the likelihood of disease and reduce life span by 1-2 years among the whole population. In the US Six Cities study, the effect of living in increasingly more polluted cities was investigated. The study was remarkable not only because it followed 8 800 adult subjects for 14-16 years but because it also took into account confounding factors such as smoking, diet and occupational exposure. The results of the study showed that as air pollution rose, life expectancy fell (Table 4). Following the Six Cities Study, the American Cancer Society published the results of a similar study where 1.2 million adults from 50 US states were followed. This second study found very similar results to the Six Cities study, thus supporting the view that long-term exposure to PM poses a serious public health problem.

Table 3 - Estimates Of The Effects Of Daily Mean Particulate Pollution On Health (Dockery et Pope 1994)

Health Indicator	Percentage change per 10 µg/m^3 increase in PM_{10}
Increases in Daily Mortality	
Total deaths	**1.0**
Respiratory deaths	**3.4**
Cardiovascular deaths	**1.4**
Respiratory admissions	**0.8**
Emergency department visits	**1.0**
Exacerbation of asthma	
Asthmatic attacks	**3.0**
Bronchodilator use	**2.9**
Hospital admissions	**1.9**
Increase in reporting of respiratory symptoms	
Lower respiratory	**3.0**
Upper respiratory	**0.7**
Cough	**1.2**
Decrease in lung function	
Forced expired flow	**0.15**
Peak expiratory flow	**0.08**

Table 4 - Association between Air Pollution and Mortality - Dockery et al.

	Town
Least Polluted	Portage
	Topeka
	Watertown
	Harriman
	St. Louis
Most Polluted	Steubenville

Beyond mortality, many studies show that PM causes a range of adverse health effects which can be as serious in a public health perspective (see Table 5). Studies from across Europe have shown that hospital admissions for chronic obstructive pulmonary disease (COPD) and asthma are increased. Other European and US studies show that respiratory symptoms in children increases as well as levels of respiratory disease. In Switzerland, an association was found between PM levels, even below 100 µg/m^3, and increases in upper respiratory symptoms such as coughing, colds, sore throat and earache among children. Research also shows that lung function can be impaired and asthmatics are forced to increase the use of medicine. The results from the APHEA study supports these earlier findings.

Table 5 - Theoretical effect of a 3 day episode of PM pollution on a population of 1 million inhabitants*

Health Indicator	Number of subjects effected per million exposed		
	50 µg/m^3 PM_{10}	100 µg/m^3 PM_{10}	200 µg/m^3 PM_{10}
Mortality	4	8	16
Hospital Admissions for respiratory causes	6	12	24
Bronchodilator usage among asthmatics	1400	2 800	5 600
Symptom exacerbation among asthmatics	1000	2 000	4 000

Although PM is considered the most worrying pollutant in terms of health, it has relatively few environmental effects. It does cause, in combination with acid rain, damage to historic buildings but does not severely effect the natural environment.

Winter Smog

During still, dry, winter weather, levels of various pollutants and in particular PM, SO_2 and NO_2 rise well above their background levels. Such episodes can last up to several days and can lead to increases in air pollution related health effects. For example in 1991 in London, NO_2 levels increased fourfold and PM levels were markedly increased. The consequences on health included an increase in daily mortality and the number of admissions to hospitals.

As for PM, winter smog episodes are associated with a range of health effects (Table 6). including increases in daily mortality, hospital admissions, respiratory illness and more absenteeism from work. Recent evidence from the UK has also linked levels of winter smog to increases in the number of heart attacks. It was estimated that 6 000 heart attacks a year were linked to winter air pollution, which translates to 3 000 deaths since half of all attacks are fatal. However, since levels of several pollutants rise simultaneously it is difficult to determine which pollutants are at fault. US experience has placed the blame almost solely on PM, however in Europe strong evidence exists to suggest that SO_2 and to a lesser degree NO_2 are partly responsible for the observed health effects.

The results from the APHEA study suggest that SO_2 does have an independent effect on health from PM. The study reported that for every 100 µg/m^3 increase in SO_2 there was a 6% increase in mortality. Studies in Athens, Lyon, Marseille and Barcelona also found that total mortality was associated with SO_2 levels. These studies and others also found increases in hospital admissions and reductions in lung function to be associated with SO_2. Near factories which produce SO_2, complaints of eye and nose irritation are often reported.

Table 6 - Health Outcomes Associated with Controlled Exposure to Ozone

	Ozone concentration (µg/m^3)

Health Outcome	1h Ozone	8h Ozone
Decrease in FEV (most sensitive 10% of healthy children and young adults)		
5%	250	120
10%	350	160
20%	500	240
Inflammatory changes (healthy young adults)		
2 fold increase	400	180
4 fold increase	600	250
8 fold increase	800	320

WHO 1994

The relationship between ambient levels of NO_2 and health is less clear. Increased short-term exposure to NO_2 has been shown to increase upper respiratory symptoms such as cough and congestion, especially among children. . The problem, with most studies into NO_2 is that the potential confounding role of other pollutants is high. The observed effects may for example be caused by PM or SO_2 rather than NO_2. However, in an area where a trinitrotoluene plant caused NO_2 to dominant pollution levels and where low levels of other pollutants existed, an association between bronchitis among children and variations in NO_2 levels was observed. Furthermore, laboratory experiments have also shown that asthmatics are particularly sensitive to NO_2. Certain studies show a 10% increase in airway resistance for asthmatics at levels of 560 $\mu g/m^3$, a level which can occur during peaks of pollution in European cities. Evidence also exists to suggest that it increases the sensitivity of people who are allergic to pollen

Research into the long-term effects of NO_2 on health are more conclusive. Many studies have examined the effect of having a gas cooker in the home on respiratory symptoms in children, since gas cookers increase indoor exposure to NO_2 by an average of 30 $\mu g/m^3$. In an analysis of all the studies a 20% increase in lower respiratory problems such as persistent cough and wheezing was associated with exposure. Although not found in all studies, long-term exposure to ambient NO_2 levels has also been linked to increases in respiratory disease among children. The effect of long-term exposure on adults is however less certain. Several studies have examined people with higher exposure because they either work near roads (e.g. traffic police) or live near major roads. Although some of the studies point to higher levels of respiratory symptoms, others do not and the possibility of confounding with other traffic pollutants is high. However, even though studies into the health effects of NO_2 exposure are less conclusive than for PM, SO_2 and ozone, it should still be seen as a one of the worst traffic related pollutants because of its many environmental effects, because it is the major precursor pollutant to ground level ozone and because several studies have linked it to adverse health effects.

In terms of the environment in combination with SO_2 it is the principle cause of acid rain, which has had a devastating effect on the forests of northern Europe. It is also a cause of the eutrophication of soil, lakes, rivers and coastal waters (Eutrophication is the process where high levels of nutrients lead to too much plant and algae growth starving the area of oxygen and thus leading to damage to the ecosystem). In terms of the built environment, the acid aerosol created by NO_2 causes significant damage to stone and metal structures, with the associated costs of repair.

4.3 Ozone

Ozone (O_3) is a gas which occurs both in the troposphere (at ground level) and in the stratosphere (at high altitudes). It is a well known environmental problem that in the stratosphere there has been a reduction in the amounts of ozone. At this level ozone shields the earth from some of the harmful effects of UV radiation. Conversely at ground level, because it is an extremely powerful oxidising agent, ozone is a serious pollutant that effects health and the environment. In fact, it destroys organic matter so effectively that it can be used to disinfect water. Along with other strong oxidants, it forms what is called photochemical or summer smog. It is estimated that background levels of ozone have doubled in the last century though short-term trends are hard to identify since changes in climatic conditions (i.e. hot sunny weather) have a greater effect on peak levels than small changes in the emissions of precursor pollutants.

At ground level ozone is a secondary pollutant because it is not emitted directly into atmosphere but is produced in a complicated chemical reaction initiated by sunlight. Intense sunshine in combination with the precursor pollutants - oxides of nitrogen (NOx) and volatile organic chemicals VOCs - react to form ozone. The dominant source of the precursor pollutants is human activity. Traffic is the main source of NOx, whilst VOCs are produced by traffic, industry and evaporative emissions due to solvent use as well as the distribution and handling of petrol. As ozone is highly reactive, indoor levels are much lower than outdoor levels since it reacts with windows and indoor surfaces. Therefore, unlike many other pollutants exposure occurs almost entirely outdoors.

Health Effects of Ozone

Ozone has received a great deal of scientific attention over the past 30 years, which has led to a large body of evidence being gathered on its health effects. Recent studies including APHEA have shown that levels commonly occurring in European cities can cause increases in mortality, hospital admissions for asthma and other respiratory problems, reductions in lung function and symptoms such as wheezing, coughing and chest tightness in healthy adults and children who are exercising.

The ability of ozone to decrease the lungs ability to function is one of its most investigated health effects. At concentrations as low as 200 $\mu g/m^3$ over a 6 hour period, a level which occurs during summer smog episodes, exposure to ozone can cause the inflammation of airways, coughing and pain during deep breathing. Although lung function reverts to normal 24 hours after exposure, little is known about the possible effects of repeated exposure to such concentrations. Animal tests have shown that long-term exposure can lead to higher rates of cancer but opinion is divided on whether it might have a similar effect on humans.

Certain groups of people are particularly vulnerable to ozone and start to show adverse effects at lower concentrations, even as low as 120 $\mu g/m^3$ as a one-hour average value, which is two-thirds of the EU threshold value for ozone. People who take part in outdoor physical activity, those with pre-existing respiratory problems, children and those who are particularly sensitive to ozone are all considered vulnerable.

- **Active Individuals -** Exposure to ozone, is much more related to activity levels than for a pollutant such as PM. Unlike for PM, the body has no mechanism for stopping ozone reaching the lowest part of the lung and therefore the amount you breath is the amount you receive. Those taking part in outdoor activities are therefore more vulnerable because their increased breathing rates (e.g. a cyclist breaths two and half times as much air as a resting person), significantly increases their dose. A study of amateur cyclists in the Netherlands, reported a decrease in lung function at levels below 120 µg/m^3 as a one hour value (a level which persists for much of the summer months in almost all EU countries).

- **Age** - Studies both in the laboratory and in summer camps have shown that those below the age of 25 show a greater responsiveness to ozone than older age groups. This age group is also more likely to be active outdoors in the summer months. Children are at particular risk because they spent a greater amount of time out of doors during the summer than adults, there is a higher prevalence of asthma among children and because they inhale more air in proportion to their body weight.
- **Responders -** Among the whole population 10% of people are considered particularly sensitive to ozone. This group called responders has been shown to experience lung function problems at levels twice as low as for the general population. It does not seem that this group is made up of individuals with pre-existing illness but of individuals who for an unknown reason are much more affected by ozone exposure.
- **Asthmatics -** Although in laboratory studies, asthmatics and those with pre-existing respiratory illness have shown similar loss of lung function as healthy individuals, they do experience more airway resistance and the symptoms are longer lasting. In addition, because asthmatics start from an already reduced lung capacity, any reduction is more likely to cause a clinical effect than the equivalent reduction for a non-asthmatic.

Research into hospital admissions and medicine use among asthmatics supports the view that equivalent reductions in lung function cause greater clinical effects. Studies in North America and Europe have shown that as ozone levels increase so do hospital admissions for asthmatics. The ERPURS study, carried out between 1987and 1992 in Paris and the surrounding area, demonstrated a link between increases in ozone and home visits to asthmatics by family doctors. Moreover the WHO based on he epidemiological evidence has concluded that a level of 200 µg/m^3 as a one hour value will cause a 25% increase in symptom exacerbation among asthmatics (Table 7).

Although in the past little evidence linked increases in ozone concentrations with increased mortality, the APHEA study did find such a link. Their data points to a 4% increase in mortality for a 100 µg/m^3 increase. In the ERPURS study total mortality was also associated with increased ozone.

Table 7 Health Effects Associated with Changes in Ambient Concentrations of Ozone (based on epidemiological studies)

	Ozone concentration ($\mu g/m^3$)	
Health Outcome	**1h Ozone**	**8h ozone**
Symptom exacerbation among healthy adults or asthmatics - normal activity		
25% increase	200	100
50% increase	400	200
100 % increase	800	300
Hospital admissions for respiratory conditions		
5% increase	30	25
10%increase	60	50
20% increase	120	100

Although legislation to curb ozone is these days driven by health concerns, the original legislation in the US was created to protect against crop damage. Many studies have demonstrated that at levels far below those which effect health, irreversible damage is occurring to plants. Damage also occurs to forests and to materials. Certain types of rubbers and plastic are particularly prone to ozone damage. Exposure to ozone leads to fading and embrittlement of paints, cracking of rubbers and fading of dyes in textiles or reduction of textile strength.

4.4 Air Pollution and Cancer

Research into the carcinogenic effect of vehicle emission has targeted both the effects of individual pollutants as well as the general chemical soup which is emitted into the air by different vehicle types. Several of the pollutants have been classified by the WHO's International Centre for Cancer Research as probably carcinogenic and benzene has been classified as definitely carcinogenic.

To be classified as carcinogenic, a pollutant must be shown in animal and human studies to cause an increase in the likelihood of cancer; for benzene this is the case. Most of the human studies have followed people who work in environments where benzene levels are 1000 times higher than in the ambient air. The results of the studies show that exposure to such levels does increase the risk of developing certain types of cancer notably leukemia.

Based on these workplace studies, the WHO has proposed a limit value for the ambient air. They suggest that a lifetimes exposure to 1 $\mu g/m^3$ as an annual average would cause 4 extra cases of leukemia in a population of 1 million people. This is based on the workplace studies and presumes that there is no concentration at which benzene no longer causes an increase in cancer. Converting these risk factors to acceptable standards, the UK Expert Panel on Air Quality Standards proposed a target value of 3.5 $\mu g/m^3$ (1 ppb) and Germany proposes a target value of 2.5 $\mu g/m^3$ as annual averages.

The pollutants which are considered to probably cause an increase in cancer include, 1,3 butadiene, benzo(a)pyrene and diesel particles as a class. Of these it is the last which occurs at a substantial level in the ambient air. Tests on animals have shown increases in cancer and the results on humans who work in areas where their exposure to diesel particles is high, have shown some positive correlations between exposure and cancer. The results have been considered conclusive enough to suggest that diesel particles are probably carcinogenic.

The Six Cities study also examined whether, those living in polluted towns suffered higher levels of lung cancer. The results were that both non-smokers and smokers had a 37% higher chance of developing lung cancer when the most polluted town was compared to the least polluted. However, smokers in general had an 840% higher chance of developing cancer in comparison to non-smokers. The issue of smoking behaviour also effects benzene since for non-smokers, the ambient air is a significant source of exposure, however for smokers, it is cigarettes which dominant their exposure.

4.5 Noise Pollution

In the European Union it is estimated that 20% of the population are exposed to noise levels above 65 dB(A), a level at which serious disturbance occurs. It is also estimated that 50% of the population live in areas where levels are between 55 dB(A) and 65 dB(A), so-called grey areas, where noise pollution can cause annoyance. Road traffic and aviation noise are both important contributors to overall noise levels and with increased traffic predicted in both these areas, it is expected that more and more people will suffer from the effects of noise pollution.

The major problem traditionally associated with noise pollution is disturbance. Sometimes and often due to noise pollution at work, it has been associated with loss of hearing. However, research now shows that noise pollution has a wide array of health effects which can damage the mental and physical well being of the concerned population.

Noise pollution can cause a nuisance. It can make watching television, listening to music, talking to friends difficult. People may choose to stay indoors or shut windows to reduce noise levels. More importantly it makes it difficult to concentrate, especially among the young who show lower concentrations levels when ambient noise levels are high.

Noise affects sleep. Living next to a busy street can cause background noise levels to be sufficient to reduce the quality of sleep. At levels experienced by at least 20% of the Europeans, both deep sleep - which acts to aid physical recovery - and dream sleep - which is important for mental recovery - are reduced. Importantly noise experienced during the day is ‘remembered’ by the body and even if night time noise is low, sleep can still be affected. In addition, even when we think we have adapted to noise, examinations of sleep patterns shows that we have not adapted.

Noise has also been shown to increase stress levels. A certain amount of evidence points to the fact that those who live in very noisy areas - such as near airports - suffer higher levels of mental disorders. Noise is not considered the sole cause but is thought to make things worse for people who are already in stressful situations. Another marker of stress is high blood pressure. Certain studies have also suggested that living or working in a noisy environment can lead to higher blood pressure. However, more research is needed to confirm this observation.

4.6 Traffic Accidents

Although not traditionally seen as an environmental problem of traffic, the choice of using cars as our primary means of transport does create an environment with substantial levels of accidents. In the EU there are six times as many deaths per passenger kilometer by road transport than by rail. Road transport accounts for 96% of all transport related deaths, amounting to 48,000 deaths per year. Although this is only 1-3% of deaths in each Member State, it accounts for 12-19% of all deaths among those aged from 15-44. The age structure of victims is a very important characteristic, since road traffic accidents deprive us of active and productive individuals, who on average, if not killed in a road traffic accident would have lived another 40 years.

Accidents continue to be an important health consequence of road traffic. Although the total number of deaths on the road has declined by an average of 1% per annum during the last 15 years, total accidents have not seen such a decline. In 1995 there were 3.3 million injuries due to road transport accidents. The yearly cost, (merely in terms of the current additional expenditure on national health services, administration and damage reparation[1]) is estimated by the European Commission at 15 billion ECU. Moreover the costs of these accidents persist long after the "health" problems caused have been resolved and the victims leave hospital. Many accidents leave people with severe and permanent disabilities, particularly mobility impairments.

Moreover, Much could be done to improve this situation, and at the same time improve air pollution. Speed restrictions, better public transport and the proper separation of pedestrian, bicycle and road traffic would decrease accidents as well as reducing air pollution and energy consumption, these being only a few of the win-win measures which could be introduced[2].

5. The European Framework Directive on Air Quality Assessment and Management

Due in part to the failure of earlier directives on air quality standards to adequately tackle air pollution and due in part to the European Union's desire to protect its citizens from the effects of poor air quality, the European Framework Directive on Air Quality Assessment and Management was adopted in September 1996. The general aim of the directive is to define the basic principles of a common strategy to:

A) Define and establish objectives for ambient air quality in the Community designed to avoid, prevent or reduce harmful effects on human health and the environment as a whole.

As the Framework Directive only creates the general principles for setting air quality standards, the Commission in addition must set specific limit values and threshold values for individual pollutants. It must base these on the protection of health, taking into account the most recent scientific evidence, and the protection of the environment both natural and built. The Commission has already put forward

[1] In addition there is also the expenditure currently required (to varying degrees in all European countries) to remove the barriers that exist preventing the full integration of those with disabilities into society, although such costs are required independent of the additional numbers of disabled caused by traffic accidents.

[2] See the T&E series of publications "Greening Urban Transport" - T&E 94/2, 94/6, 94/6A, 94/7, 94/8, 94/9, 94/10, 94/11, 94/12

proposals to cover lead, nitrogen dioxide, particulate matter and sulphur dioxide. Proposals for the rest of the pollutants should be adopted following the timetable in Table 8.

For those pollutants for which the European Commission has already proposed limit and threshold values, they have followed fairly closely the principles of protecting health and the environment. In fact, they are in line with the WHOs air quality standards.

B) Assess the ambient air quality in Member States on the basis of common methods and criteria.

In the European Union there has never before been a comprehensive system based on common methods and criteria for the measurement of ambient air quality. The obligation to create such a system is therefore one of the most important elements of the directive. In the past by not monitoring many Member States have hidden air pollution problems, in the future this directive should make that impossible and thus give clean air campaigners the information they need to improve air quality.

Table 8 - Timetable for Adoption of the Daughter Directives

Pollutant	Expected Date of Daughter Directive
Lead	June 1997
Oxides of Nitrogen	June 1997
Particulate Matter	June 1997
Sulphur dioxide	June 1997
Benzene	no later than 31 Dec. 1997
Carbon monoxide	no later than 31 Dec. 1997
Ozone	no later than March 1998
Arsenic	no later than 31 Dec. 1999
Cadmium	no later than 31 Dec. 1999
Nickel	no later than 31 Dec. 1999
Mercury	no later than 31 Dec. 1999
Poly-aromatic Hydrocarbons	no later than 31 Dec. 1999

Preliminary Assessment

In order to fulfill the specific obligations that the daughter directives create, Member States must make a preliminary assessment of air quality. This assessment should be carried out before the period by which the daughter directives should be transposed into national legislation elapses. Normally Member States are given 1-2 years after adoption at European level to transpose a directive. Therefore for the first wave of pollutants one could presume that by the end of 1999 (see Box 7), these preliminary assessments should have occurred. The areas where assessment should occur include agglomerations above 250 000 inhabitants as well as all other areas of the Member State.

Full Assessment

At the end of the period by which the daughter directives should be transposed into national legislation, all Member States will be obliged to monitor pollutant concentrations in:

- agglomerations above 250 000 people;
- zones where levels are between the limit values and the levels of tolerance[3];
- zones where the limit values are exceeded.

Unlike previous legislation the daughter directives will also set down the exact principles for monitoring each pollutant, including:

- the location of the sampling points;
- the minimum number of sampling points;
- the measuring and sampling techniques.

The fact that, for the first time, exact details of how monitoring should occur, is extremely important. For example for a pollutant such as PM it is extremely important to monitor not only at background but also at streetside where levels must be higher. Hopefully, once implemented, clean air campaigners will have an important information base for determining not only how clean their area is but also where the major pollution hotspots can be found.

[3] Levels of tolerance - to take into account the actual levels of a given pollutant when setting limit values and the time needed to implement measures for improving air quality, the Council may also set a temporary margin of tolerance for the limit value.

C) Obtain adequate information on ambient air quality and ensure that it is made available to the public.

Another of the positive elements of this directive is that accepts the need to inform the public about air quality. Two approaches are taken, firstly by obliging Member States to provide information to citizens and secondly by demanding that Member States provide information to the Commission which under the directive they are themselves obliged to make public.

Box 7 - The Legislative Time Frame

Adoption of proposal by the European Commission for a daughter directive covering the first four pollutants. Autumn 1997

First reading of the proposal by the European Parliament. Spring 1998
Common Position by the Council Of Ministers. Autumn 1998
Second reading by the European Parliament. Spring 1999
Directive adopted by the European Community. Autumn 1999

Most directives give Member States 1 to 2 years to adopt the legislation. If this is the case for the daughter directives than they should come fully into force across the EU between Autumn 2000 and Autumn 2001.

Member States

As of 21 March 1988, Member States will be obliged to designate at the appropriate levels the competent authorities and bodies responsible for implementation of the directive. At this point they will also have to make the information available to the public. For clean air campaigners this is very important, since once a body has been designated as responsible, it is they who should be the contact point for information and who should be lobbied to ensure that they comply with all the obligations under the directive.

It is also the intention of the European Commission, through the daughter directives, to oblige Member States to provide a source of information on daily pollution levels. This may be through teletext systems, the internet or telephone helplines. However, for the moment no legislation has been adopted at the European level.

European Commission

A year after the individual daughter directives should have been transposed into national legislation, Member States are obliged to start providing the European Commission with an annual list of agglomerations and zones where: the limit values plus the margin of tolerance are exceeded; the levels are between the limit value and the margin of tolerance; the levels are below the limit value. Once they start to receive this information the Commission will publish annually the list of these agglomerations and zones. In addition, every three years thereafter, the Commission will publish a report of the information received. Both these publications will be immense use to campaigners, since they will provide in the first instance information about the air quality in relation to the limit values for the whole of Europe and in the second instance analysis of the information, hopefully including trends in air pollution.

D) Maintain ambient air quality where it is good and improve it in other areas.

The aim of monitoring, assessing and providing information is in the end to provide European citizens with air quality that does not cause adverse effects to them or to their environment. It is therefore an essential element of the directive that Member States should be obliged to improve air where it is below standard and maintain it where it is already cleaner than the limit values proposed**.**

Although the dates by which the limit values in the daughter directives become law, will not be before at least 2005, the Framework Directive does create obligations on the Member States to act before this point. In fact once the date for transposition into national law has passed for each pollutant, Member States must draw up action plans for zones where for at least one pollutant, the limit value and the margin of tolerance are exceeded. These action plans must be made available to the public and must include certain specific information (see annex I).

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[i] SOCIÉTÉ FRANÇAISE DE SANTÉ PUBLIQUE. Bilan de 15 ans de recherche international, Collection Santé et société N° 4, mai 1996.