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AN UPDATE ON

AIR POLLUTION AND ACID RAIN

Introduction

Air pollution has caused some of the biggest environmental problems on earth - climate change, acid rain and human health problems such as asthma.

The most up-to-date scientific research suggests that emissions of CO_2, and other greenhouse gases as a result of human activity, will raise global average temperatures by 1.4 to 5.8ºC by the end of the 21^{st} century. This will affect weather patterns, water resources, ecosystems and there is likely to be a greater incidence of extreme climate events such as droughts. Scientists have detected many early signals of global warming; glaciers that have not retreated since the last ice age 12,000 years ago are now doing so, and the 10 hottest years on record have been in the past 14 years. Pollutants such as NO_X and SO_2 cause acid rain and deplete ecosystem biodiversity.

Emissions history

Emissions of chemicals that can cause acid rain *(Table 1)* fell by nearly 50% in the UK between 1990 and 2002 *(Fig. 1)*. The largest fall was in the electricity, gas and water sector which decreased by 70% to 1.0 million tonnes; this large fall reflects the decline in the use of coal for power generation in favour of natural gas.

In 1990, the major power producers used coal equivalent to 48.9 million tonnes of oil compared to 0.01 million tonnes of gas. However, by 1999 the major power producers had increased the use of natural gas to 24.2 million tonnes of natural gas; natural gas has a lower sulphur content than coal and therefore releases lower levels of sulphur dioxide when burnt *(Fig. 1)*. In addition, emissions from the manufacturing sector fell by 47%, domestic sector emissions fell by 43% and in the agricultural sector fell by 19%.

Fig. 1 Reduction in NO_X/SO_2 emissions from 1970 to 2002.

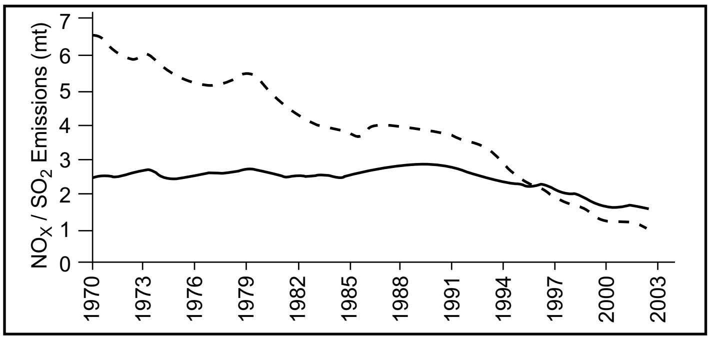
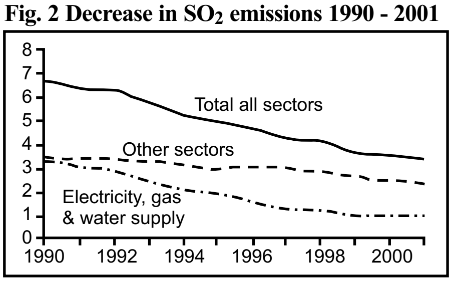


Table 1 Sources and variations in emissions of several chemical air pollutants.

POLLUTANT	SOURCE AND FLUCTUATIONS IN EMISSIONS
Ammonia	Ammonia emissions are dominated by agricultural sources, with emissions from livestock and their wastes (75% of the UK's total emission) and have risen as domestication increases. These emissions derive mainly from the decomposition of urea in animal wastes and uric acid in poultry wastes. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques. The other agricultural sources included are emissions from fertiliser use, crops and decomposition of agricultural vegetation.
Cadmium (Cd)	Emissions of cadmium have declined by 83% since 1970. The main sources of cadmium are non-ferrous metal production, and iron and steel manufacture. The decline in emissions is a result of the general fall in coal combustion and the decline in fuel oil combustion in power generation. The large reduction in waste emissions is due to improved controls on large incinerators from 1997 onwards and their conversion to power generating plant.
Carbon Dioxide (CO_2)	When the Kyoto Protocol was drawn up in 1997, the CO_2 level had already reached 368 ppm but in by 2004 had hit 378 ppm. Each year the global population releases 7 billion tonnes of carbon into the atmosphere. The Intergovernmental Panel on Climate Change projects that, if unchecked, carbon dioxide concentrations in the atmosphere will have risen to between 650 and 970 ppm by 2100. This rise is largely due to the burning of coal and therefore is one of the main pollutants targeted by the Kyoto pact. The CO_2 will remain in the atmosphere for more than a century - therefore the more quickly the world can make cuts, the better.
Lead (Pb)	Since 1970 lead emissions have declined by 98%. The largest source is lead from lead additives in petrol and the lead content of leaded petrol was reduced from around 0.34 g/l to 0.143 g/l in 1986. Since 1987 sales of unleaded petrol have increased particularly as a result of the increased use of cars fitted with catalytic converters. Leaded petrol was phased out from general sale at the end of 1999, and consequently a there has been a decline in the road transport sector. Lead emissions have also declined as a result of the decreasing use of coal. The large reduction in waste emissions is due to improved controls on MSW incinerators from 1997 onwards and their conversion to power generating plant.
Sulphur dioxide (SO_2)	Since 1970 there has been a substantial overall reduction of more than 84% in SO_2 emissions; there was a steady decline between 1970 and 2002 with the exception of small peaks in 1973 and 1979 (corresponding to the harsh winters in those years). The two main contributors are solid fuel and petroleum products. A decline in fuel oil use and the reduction in the sulphur content of oil used in domestic / commercial heating has led to emissions being reduced by 80% (since 1970) and 94% respectively. The only sector to show a rise in SO_2 emissions between 1990 and 2001 was the transport sector *(Fig. 2)*, which had a seven fold increase to 0.7 million tonnes. This reflects a substantial rise in air transportation by UK airlines; the distance flown by UK airlines doubled between 1990 and 2001, to 1048 million kilometres. A greater demand for aviation fuel has lead to a rise in emissions.
Nitrogen dioxide (NO_2)	The major source (43%) of NO_X emissions in the UK is road transport. Since 1970, overall NO_X emissions have decreased by 37%, although this decrease has not been constant. Up to 1984, the NO_X emissions were steady with small peaks in 1973 and 1979 due to the cold winters in those years. From 1984, emissions rose markedly as a result of the growth in road traffic, reaching a peak in 1989.
Arsenic (As)	Since 1989, total NO_X emissions have declined by 43% as a result of a 45% decrease from road transport, due to the introduction of catalytic converters and stricter regulations and a 51% reduction from power stations. Arsenic emissions have declined by 82% since 1970, as a result from the decline in coal use, in favour of natural gas use. The large reduction in waste emissions is due to improved controls on MSW incinerators from 1997 onwards and their conversion to power generating plants.

Fig. 2 Decrease in SO_2 emissions 1990 - 2001



UK Government monitoring and the impact on human health

The UK government has initiated a "Headline Air Quality Indicator" and this ensures that pollution levels will be monitored across the country. It measures the average number of days per site on which pollution levels were above National Air Quality Standards (the standards represent defined levels which avoid significant risks to health). As levels increase above the standard, the likelihood of effect on health increases. For example, levels of ozone in the 'high' band may cause cough and discomfort on deep breathing during exercise in some people.

From 1990 there has been a steady improvement in air quality within urban areas; air pollution was recorded as moderate or higher on 22 days on average per site in 2004, compared with 50 days in 2003, 20 days in 2002 and 59 days in 1993. In general, there has been a long term decline in the number of air pollution days, largely because of a reduction in particles and sulphur dioxide, but fluctuations from one year to the next can occur because of differences in weather conditions. More ozone is produced in hot, sunny weather, as was the case during 2003.

Both the UK government and the European Union have set emission limits to protect human health *(Table 2)*.

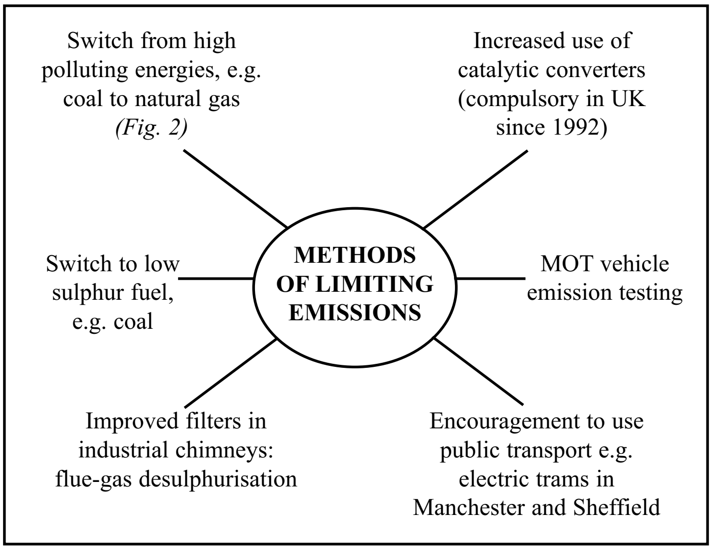
Table 2 UK and European Union hourly emission limits with respect to the protection of human health.

Pollutant	DEFRA low level pollution hourly limits (parts per billion)	EU hourly limits (parts per billion)
Nitrogen Dioxide	150	105 *
Sulphur Dioxide	400	132
Ozone	90	90

** maximum of 18 exceedences per year*

Controlling emissions

The main way to address the problem of acid rain and air pollution is to **limit** emissions of pollutants:



International solutions

Total deposition of sulphur on the UK during 1998 was around 0.33 million tonnes compared to 1.19 million tonnes emitted in 1999. This highlights that the UK emits more sulphur pollution than is deposited in the UK. A significant proportion of sulphur and nitrogen pollutants are exported to other countries, mainly Germany, France, Norway, Sweden, the Netherlands and Russia. The prevailing wind from the southwest is the main factor affecting where UK pollutants are deposited.

Acid rain is therefore an international **transboundary** problem (i.e. crosses international borders) that therefore requires international co-operation and initiatives to reduce emissions *(see Table 4 on page 3)*.

Kyoto Protocol

The 1997 Kyoto Protocol requires industrialised countries to reduce their greenhouse gas emissions by around 5% of their 1990 levels, between 2008 and 2012. Comparatively rich nations have agreed to the principle that as they have been largely responsible for the historic growth of global warming, they should take a leading role in reducing its effects. To come into force internationally, the Kyoto pact had to be approved by at least 55 states contributing at least 55% of the industrialised world's 1990 greenhouse gas emissions. In September 2004, the Russian Federation finally signed and the pact came into force on the 16th February 2005. This means that 30 industrialised countries will be legally bound to meet quantitative emission targets. The UK, for example, is to cut emissions by 12% and Japan by 6%. China and other big developing countries are not due to accept reductions in Kyoto's second round until 2012.

The main problem has been that large air polluters such as the USA and Australia (who emit more that 1/3 of all pollutants) rejected the pact because they feared that it would damage their economy and it had a flaw in that the agreement did not bind developing countries. To make things worse, the US has increased emissions of greenhouse gases by 13.4% since 1990. Independent analyses of the annual cost to the world of complying with Kyoto put it at between $150 billion and $350 billion a year (the global development aid budget is $50 billion annually). For many countries such as New Zealand, achieving the Kyoto targets will be a major challenge that will require new policies and new approaches.

Trading emissions

Many countries across the globe will be able to trade "excess" carbon; this is the amount that they have saved through efficiency measures e.g. national legislation to halt emissions, and any "stores" they have in their forests. The EU trading scheme began in January 2005; under the scheme, companies are issued with pieces of paper that grant them permission to emit a certain quantity of CO_2 into the atmosphere in a particular year. Companies that don't have enough permissions to cover their emissions will have to buy them in from someone who does. This is the main way in which governments will meet the Kyoto targets.

Although China is not bound by the Kyoto protocol (because it was classified as a developing country in 1997), China is taking advantage of the emissions trading to subsidise its economy. At Anding, in China, methane and leachate is collected from a landfill site and burned (to evaporate it) and then can be added as a solid sludge onto the landfill without finding its way to the underground water table. This earns China the equivalent of 800,000 tonnes of CO_2 savings each year, which can be sold to Western governments (likely The Netherlands) needing to cut emissions, for a price starting at US$1 a tonne. Beijing gets a cleaner garbage dump at a price subsidised by the buyer in the Netherlands.

Several other projects are in the process of approval for carbon trading in china, including a methane capture system in a big Shanxi coal mine, a wind farm in Inner Mongolia and a hydro-electric dam. Similar carbon-trading swaps have long been in preparation across many other developing countries that, like China, were not required to commit to emission reductions in the first round of the Kyoto process. Some are truly inventive, such as a cattle feed developed by an Australian scientist to reduce the methane-rich belches of India's holy cows and other ruminants!

Carbon tax

New Zealand has plans for a new carbon tax which will help the country meet targets under the Kyoto Protocol. Industries which emit carbon dioxide will have to pay a tax of up to $12 a tonne of carbon dioxide emissions from 2007. The result will raise petrol prices by 12% and gas /electricity prices by 8%. The tax revenue obtained would be used to offset other taxes and into climate change projects. New Zealand has a large supply of carbon sink credits generated by its forests (estimated at 55 million tonnes of CO_2 equivalent) and would sell these credits for up to $750 million to other countries that are unable to meet their Kyoto standards. Ireland has a strategy to cut carbon by 9 million tonnes per year, but has abandoned the idea of a carbon tax; the proposed tax faced strong consumer and business objections. Instead, it will offer energy efficient alternatives and buy carbon credits.

Climate change levy

The UK has set itself a domestic objective to reduce **carbon dioxide** emissions by 20% (on 1990 levels) by 2010, and by 60 % by 2050. The UK government therefore launched the **Climate Change Levy** in April 2001. It is based on the principal of a **tax** per unit of energy *(Table 3)* and the aim is to reduce the UK's CO_2 emissions of at least 2.5 million tonnes of carbon a year by 2010 (in line with the Kyoto Protocol) and to encourage energy recycling. The Levy applies to industrial and commercial energy use, not households or transport; industries' taxes are offset by reductions in employers' national insurance contributions. Eighty percent discounts are available for energy intensive companies that agree to meet emission targets set by DEFRA. Exemptions from the levy include electricity generated from renewable energy. The levy raised approximately £1 billion in its first year.

Table 3: Climate change Levy tax rates

	Pence per kWh	$ per tonne C
Gas	0.15	45
Coal	0.15	24
Electricity	0.43	46
LPG (gas)	0.07	n/a

Low Emission Zone for London

London's air quality is the worst in the UK and Europe, and has a considerable effect on the health of local residents. The primary source of these pollutants in London is road traffic. Government emission targets are not likely to be met unless drastic air quality proposals are considered and implemented. It is proposed to introduce a **Low Emission Zone** to central London. Such zones, already in use in Sweden and currently under consideration for parts of the UK, aim to cut pollution by preventing high-polluting vehicles (e.g. those without catalytic converters) from entering certain areas. The creation of these zones therefore encourages vehicle owners to use cleaner (often newer) vehicles and to make use of clean vehicle technologies, thus improving the local air quality.

Summary

The increase in air pollution and acid rain due to human activity has been recognised since the 1920's. The turning point for air pollution control in the UK particularly came to a head when the "Great Smog" of 5th - 9th December 1952 led to an estimated 4,000 deaths in London; the Clean Air Act came into force in 1956 and resulted in industries cleaning up their emissions from chimneys. The 1970's and 1980's saw the severest problems in acidification of lakes and rising health problems such as asthma.

International agreements such as the Kyoto Protocol are a step toward reducing the problems of acid rain and global warming. However, future problems will come from the growth of coal plants in the U.S. and the even faster growth in China and India; these will add billions of tons of carbon to the atmosphere, overwhelming any possible gain from the Kyoto treaty. In addition, no-one is building new nuclear plants (advantage of few emissions), supplies of oil and gas are tightening, and prices have shot up (natural gas costs now three times the 1990 price). Now, the US electricity companies are going back to burning coal. To have half a chance of curbing global warming to within safe levels, scientists estimate that the world's greenhouse gas emissions need to fall dramatically to between 30% and 50% of 1990 levels by 2050 - therefore more agreements are needed.

Useful websites

Air quality archive: http://www.airquality.co.uk/archive/index.php
DEFRA: www.defra.gov.uk/environment
UK Statistics: www.statistics.gov.uk

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This Factsheet was researched by Jo Browne.
Curriculum Press, Bank House, 105 King Street, Wellington, TF1 1NU. Tel. 01952 271318.

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Table 4: results of international agreements to cut air emissions in Europe

INTERNATIONAL AGREEMENT	AIMS	RESULTS
1979 (1983 modification) UN Convention on Long Range Transboundary Air Pollutants	15 European countries, along with Canada, signed and agreed to cut their 1980 sulphur emissions by 30% by 1993	Most members adopted this in 1985. All that signed achieved the 30% reduction and some even more e.g. Belgium and Netherlands (50%), and France (60%). Emissions of SO_2 are estimated to have fallen by 25-30% between 1980 and 1990. However, with an increase in vehicle traffic NO_2 emissions were reduced slowly.
1988 Directive on Large Combustion Plants (88/609/EEC)	Emission limits for dust, SO_2 and NO_2 from new combustion plants were set. It also committed the UK to reducing emissions of SO_2 (60%) and NO_2 (30%) from the 1990 levels by 2003 from existing large combustion plants.	One of the most important agreements to control acid rain. In 1998, UK large combustion plant NO_X emissions were 61% in 2001 LCP emissions were 76% below the baseline – a success!
1994 Second Protocol for sulphur	Most western countries agreed to reduce sulphur emissions by between 70 and 80% by 2000 (against 1980 levels) whilst eastern European countries had a lower target of 40-50%.	The UK just about met this target with a 65% decrease; largely a result of vehicle catalytic converters.
1993, 1999 Directives on Sulphur Content in liquid fuels (93/12/EEC and 99/32/EC)	The maximum permitted concentration of sulphur in diesel was 0.05% and in gas oils 0.2% (0.1% in 1999) by 2008. Additionally, updates of the Directive means that Sulphur had to be reduced to 0.005% from 2005.	Introduction of freely available low sulphur fuel has assisted this.
1998 Directive on emissions of air pollutants from cars & heavy vehicles (98/69/EC)	New emission standards (NO_X and SO_X) for cars; to be introduced in 2 steps from 2000 and 2005.	All new cars since 2000 must meet these levels
1999 Gothenburg Protocol on acidification, eutrophication and Ground-level Ozone	Emission ceilings for 2010 were set for 4 pollutants; sulphur, NO_X, Volatile Organic Compounds (VOC's), ozone and ammonia. Aims to cut Europe's sulphur emissions by 63%, NO_X by 41%, VOC emissions by 40% and ammonia by 17% (from 1990 levels). It also sets tight limits on specific emission sources e.g. power stations and cars. UK to reduce sulphur emissions by 85% and nitrogen emissions by 49%.	Ongoing but in the UK, SO_2 emissions have now been reduced to approximately 1 million tonnes (73% reduction) whilst the NO_X emissions are approximately 1.5 million tonnes and already show a 45% reduction.
1999 UNECE Convention on Long Range Transboundary Air Pollution Control	27 countries signed to cut emissions of SO_2, NO_X, volatile organic compounds and NH_3 (ammonia) by setting country-by-country emission ceilings to be achieved by year 2010.	Ongoing