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AIR POLLUTION:

ITS IMPACT ON HEALTH AND POSSIBLE SOLUTIONS

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Pollutants get into us by several routes. Only three have substantial public health importance; the lung, the gut (food and water) and to a lesser extent the skin. Historically both lung and gut were major routes of pollution, particularly in rapidly industrialising countries. Improved water quality means this is a much less common source of pollution now in richer countries. Air pollution however remains a significant problem everywhere and is the subject of this lecture.

People often think of air pollution as a modern phenomenon but it has always been with us. Pollution can be from either indoor or outdoor sources with indoor cooking and heating historically a major cause of pollution and still a significant one in many countries. Industrialisation, including in particular the heavy use of coal following the Industrial Revolution substantially increased the risk of outside air pollution. London's pre-eminence as a global city came at a cost in air pollution, although it was a boon for art, creating atmospheric conditions ideal for impressionist paintings and providing smog that poets and writers of crime novels made use of.

Attempts to address air pollution are not new. For example King Edward I banned the use of sea-coal in London in 1272, and John Evelyn's *Fumigatum* of 1661 recommended polluting industries like lime burning were removed from London. Some of the scientific discussions around this were highlighted in the *Ballad of Gresham College* of 1663.

The biggest spur to UK action in recent times was the great smog of 1952. The combination of atmospheric conditions, cold leading to greater use of coal and the background levels of pollution in London led to a smog in which at least 4,000 people died (maybe up to 12,000) and 100,000 were made unwell over three days. This led to the Clean Air Act of 1956, despite some reluctance from the government of the day.

Not all air pollution is human created and in some parts of the world human made pollution is a minority. Volcanoes, dust storms, forest fires and lightning are examples of highly air polluting natural events. The UK has no active volcanoes but the last major eruption of Laki (1783) in Iceland killed around 23,000 people in the UK probably mainly from sulphur dioxide. In most industrialised countries however most pollution is from human activity. It is on human created outside air pollution that this lecture will concentrate. A key theme is that air pollution is not a single problem; it is a series of problems with different health effects and technical solutions.

Air pollution of any sort has effects on the lung, but many pollutants have wider effects. There are great many potential air pollutants and this lecture will concentrate on a few of the most important ones for the UK as a typical industrial country. In particular it will consider lead, sulphur dioxide, nitrogen oxides, ammonia and

particulate matter. Headlines in newspapers tend to concentrate on deaths from air pollution but these are the tip of a very large pyramid of ill-health which it produces.

One of the things which makes dealing with air pollution in policy difficult is that it is subject to strong advocacy positions, in both directions. This reflects the fact that there are genuine trade-offs between optimising economic and health outcomes. The least wealthy countries, and the least wealthy in a society can bear the brunt of both the economic impacts of curbing pollution which can be a constraint to growth, and the health effects of bad air pollution. But especially the health effects.

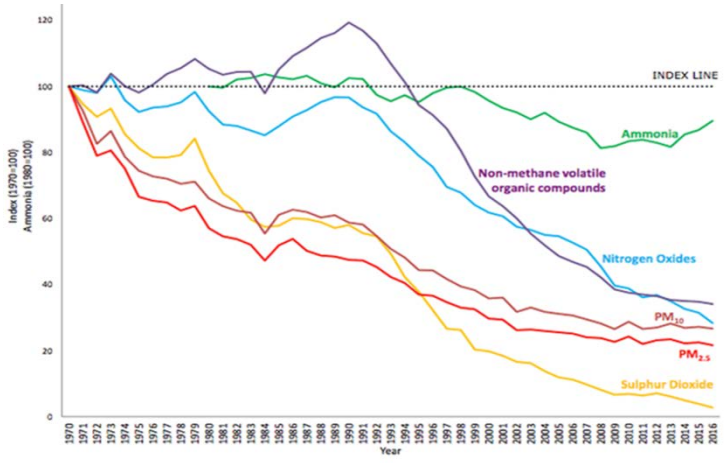
Throughout this lecture series we have come back to the question about what is the role of the individual and what is the role of the state in improving public health. In the case of outside air pollution the individual can only have a very modest impact and the state on behalf of society has to act if action is needed and wanted. Unlike in some other areas of public health there is a broad support for the role of the state in reducing air pollution among commentators in the press, although not for every measure, and a fairly broad political consensus on its importance.

To get some idea of the scale of the air pollution challenge, the World Health Organisation global estimates are that one in every nine deaths in the world is due to pollution. Around 3 million deaths are attributable solely to outside air pollution with a heavy predominance of heart disease, stroke and lung cancer. Globally, although the data are best in wealthier countries, the health burden of pollution is heaviest in poorer and industrialising countries.

Attributing specific numbers of deaths and disease to air pollution has some serious technical challenges. The degree of certainty about the health effects varies by pollutant and disease. There is very clear evidence for disease following on from lead, particulate matter (PM) and sulphur dioxide (SO_2). There is reasonable evidence for harm but less certain evidence on the size of the harm from nitrogen oxides, ozone and indirectly ammonia. It is easier to associate sudden medical events including deaths, asthma, stroke and heart attack with pollution than for more insidious conditions including dementia and cancer. It is also easier to quantify the health effects of pollution from sudden, highly polluting events than long-term lower-level exposure.

Mortality is certainly not the only serious outcome. For example there is reasonable evidence that children born to mothers exposed to air pollution have lower birthweight, and there is good evidence for association between lead and adverse brain development in foetuses and children. There is also good evidence an association between lung development and air pollutants in children, and as air pollution reduces lung function in children improves. We can obsess too much about the exact numbers of deaths and illnesses. Waiting for more data is often the right thing to do, but for many pollutants including lead, particulates, sulphur dioxide, nitrogen oxides in particular the evidence of significant harm is easily good enough now to be confident that reducing them is beneficial to health in large numbers of people, and especially the vulnerable. There is an important technical question as to what extent it is a peak (threshold) effect, or a cumulative lifetime risk.

Lead in petrol is an instructive extreme example. Lead has been known to be toxic at high levels for two millennia. Tetraethyl lead (TEL) was developed by General Motors by Thomas Midgley in the 1920s. It was one of several potential engineering solutions to increase compression in engines. There were clear warnings of toxicity from the very start of the programme including from one of the great pioneers of occupational medicine, Alice Hamilton. However for three decades research into this was dominated (monopolised) by the industry. By the 1960s there was reasonable evidence that lead from petrol had a substantial effect on the brains of foetuses and children, reducing IQ and with possible links to crime. Although the industry had argued that lead from petrol made little difference to the background lead in the environment, once restrictions began the average American child's blood level plummeted. The UK also began phasing down use of lead with a ban on four-star (leaded) petrol finally coming in 1998. Officially the world is now petrol leadfree.



Although the popular narrative is that pollution is steadily getting worse in the UK in fact the data do not support this. Anyone interested in public health will want to reduce all the main air pollutants substantially from where they are now, but we should not ignore the fact that there have been very significant reductions for many of them over the last few decades. The data on the left are the latest from DEFRA/ONS on the change in some major air pollutants in the UK over time.

The next pollutant to be considered is sulphur dioxide (SO_2). There are several health effects from this, and in particular very rapid effects triggering asthma attacks in some people. It also has wider respiratory effects and is associated with preterm birth and excess mortality. It additionally contributes indirectly to particulate matter which will be considered later. For sulphur dioxide the great majority of the burden is from industry, with domestic supply a small additional component. High sulphur fuels have contributed a small amount to the total mass but importantly they produce sulphur dioxide in the places where people walk, love, cycle and drive. The biggest producer of sulphur dioxide is industry, and by far the most important contributor to this is burning coal. Simply, if we burn less coal to produce power we will produce less sulphur dioxide. There are lower sulphur coals and the lowest sulphur coal reduces sulphur dioxide by up to 85% but it is also more expensive. There are various methods to reduce sulphur dioxide from waste gas in particular using limestone in a variety of methods. There has also been a recent move towards low sulphur fuels in transport and significant improvements in the production of self dioxide industrial processes and ore processing. The combined effect of these has been a very substantial reduction in sulphur dioxide. In the UK this reduction has been around 96% since 1970 mainly by reducing coal in towns and by changing the fuel mix. There are however areas of the world where there remains very heavy sulphur dioxide pollution in particular over parts of China and elsewhere in Asia, largely mirroring where coal is burnt. Most of the effects will be felt locally but sulphur dioxide can also travel some distance on the tradewinds. It has environmental effects (through acid rain) in addition to its health effects.

In contrast to sulphur dioxide, ammonia which is associated with the agricultural industry has dropped very slowly. In the UK the majority of it is due to soil fertilisers, cattle and poultry. At high concentrations ammonia is very irritant and can trigger asthma but other than those occupationally exposed there is no current evidence of substantial effects of prolonged low-level exposure. It does however contribute to particulate matter formation, and since particulates are some of the most dangerous air pollutants this may be very important in some settings. From a public health perspective, reducing ammonia as a by-product should be a significant priority for the agricultural industry.

Whilst ammonia is almost entirely derived from agriculture so is highest in rural areas, although the effects can be felt more widely, nitrogen oxides are very heavily concentrated in urban areas in large part due to transport. They have direct effects, and more indirect effects through contributing to generating particulates. Overall nitrogen oxides have been dropping substantially over some years, but this rate of decline was reduced by a strong push towards diesel engines. The really high concentrations of nitrogen oxides are around busy roads. Pollution is only important for health if it is in a place where people come into contact with it; the streets of major cities are one place they do.

Steadily tighter environmental standards for vehicles have led to a gradual reduction in nitrogen oxides in both heavy vehicles and commercial vehicles. A legitimate concern about some of the standards is that they do not

represent realistic driving conditions, and that is before some vehicle manufacturers deliberately cheated the system. The rate of nitrogen oxides reducing has therefore be much slower than had been anticipated. There are however engineering solutions which do very substantially reduce nitrogen oxides with conventional petrol and diesel engines. As a gradual switch to electric, and some hydrogen vehicles occur transport should contribute negligibly towards NOx in the medium future. Clearly the best forms of transport is active transport such as cycling or walking; these contribute effectively nothing to nitrogen oxides and are very good for cardiovascular health.

Probably the most important group of outdoor air pollutants are the particulate matters. These come in various sizes but two in particular have been studied extensively in terms of their impact on health. PM10 is the larger. Much of this gets trapped in the airways of the lung. PM2.5 is much smaller and gets the very bottom of the lung causing local inflammation and possibly crosses it into the blood. PM2.5 in particular is now strongly associated in multiple studies with mortality, stroke, heart disease, cancer and possibly cognitive decline and dementia. Reducing it is therefore a major priority.

In the country as a whole particulate matter comes from multiple sources, and up to 50% of it can be transnational. Some of the natural causes a particular matter is never going to go including dust from Saharan storms, sea spray and from vegetation. The very high levels however which affect the largest number of people are in cities and these are strongly associated with transport in particular. Wood-smoke is also a significant contributor. As with nitrogen oxides engineering can very substantially reduce exhaust emissions of these even in conventional engines. Electric engines reduce them still further. It is important to remember that transport can however increase particulate matters by other means including brakes, tyres, and the motion of wheels stirring up dust that has settled (resuspension). There are also significant particulates in the underground. Whilst eliminating particulate matter completely is not realistic, reducing it very substantially undoubtedly is and this would have a major impact on health.

Not all the solutions to pollution involve engineering. For example plants, and in particular trees, can have a significant impact on reducing pollution by absorbing it.

Throughout this lecture series we have considered the ladder of state intervention, in descending order of severity: ban, tax heavily, regulate, 'nudge' tax or intervention, mass voluntary programme, engage with industry, inform, leave up to individuals. Realistically most of the things that can be done for pollution are towards the top end of this ladder.

Whilst air pollution is a still significant but falling risk in wealthier countries, in many rapidly industrialising and middle-income countries it a large and growing menace. Pollution levels in Beijing are roughly 5x those in London, and those in Delhi roughly 10x. These risks need to be managed down. There are some genuine economic trade-offs, but the health effects are likely to be very important. Air pollution is an urgent international problem, and needs to be tackled.