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ACID RAIN

by

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The expression "acid rain" has in recent years aroused the interest of the media, and we have articles in the press and programmes on television purporting to explain the subject. Many members of the public, in Europe and America, believe that this is a new and a dangerous phenomenon. They believe that it is caused by industry, particularly the electrical industry, emitting large amounts of sulphur into the atmosphere, with the result that the rain is made acid and that this affects trees and fresh waters, so that fish are eliminated from them. They believe that the problem could easily be solved by the control of the pollution from electric power stations, and that this control is not exercised because of the greed or the lack of concern of the operators. Now unfortunately, this is a gross oversimplification of the situation. There is indeed a problem, but its causes are complex, and we do not always know how best to try to solve it.

Many of those working in this field think we should stop talking about "acid rain". We should really be considering the effects of several types of air pollution which may often act as gases and not through the effects of precipitation. I shall in this paper deal with all the ways in which the emissions from the burning of fossil fuels may affect the environment.

The production of heat and of energy has always produced pollution. We had smoke (particulates) and toxic gases (of which sulphur dioxide was the main culprit). Damage in urban areas has been known for hundreds of years. Plants were killed or damaged, mainly by the sulphur dioxide, which also rotted buildings and corroded metals. Human health was affected, probably by a combination of smoke and sulphur dioxide. It was the polluted air which did the damage, though the rain was also dirty - and more that a hundred years ago R.A. Smith, the first British alkali inspector (that is, the first government official appointed to control air pollution) published a book in 1872 on acid rain. In this instance he really meant acid rain, for he collected it in various localities and measured its acidity.

In Britian, and in most Western countries, this gross pollution has been controlled or at least reduced. Smoke is seldom emitted in large amounts, and the famous London "pea-soup" fogs are a thing of the past. The improvement is largely caused by the reduction in the use of raw coal. The use of natural gas, cleaned and de-sulphurised before distribution has reduced sulphur dioxide output. Oil, much of which is low in sulphur, has helped. And electric energy, even when produced from coal, has been generated at a distance so that most of the urban consumers escape its worst environmental effects. Also nuclear power, our cleanest form of energy, is increasingly important in safeguarding the environment.

The decrease in the emission of smoke is considerable, but a great deal of sulphur dioxide is still produced. In Britian this reached a maximum of some six million tons a year in 1970. The output has since then been substantially reduced to four million tons. This decrease is important, as will be seen when we look at the possible harmful effects of the gas.

One important solution to our urban pollution problem has been to discharge an increasing proportion of the polluted flue gases from industry at high levels from tall chimneys. This has produced a spectacular fall in the ground level concentraion of sulphur dioxide in urban areas. This has allowed sensitive plants to be grown where fifty years ago they could not survive. A less welcome effect has been that the fungal disease of roses, black spot, has returned to city parks. Roses themselves are rather resistant to pollution, and so they benefited from this pollution of the air.

The effect of the tall chimneys is that the sulphur dioxide and other toxic gases are quickly mixed with the air and so diluted down to levels which are much less phytotoxic. We are finding indications that this dilution, though important, may not be sufficient to prevent all damage to crops and other plants in a region near to the source of emission, but this is a strictly local problem, restricted to a hundred or perhaps two humdred miles. So the direct effects of gaseous pollution usually occur within the country which produces this pollution; it may not give rise to international problems.

There is no doubt that the policy of discharge through high chimneys is beneficial to those living near to the source, but it is often complained that this is the cause of damage in more distant localities. Fortunately there is little truth in this allegation. It is true that the sulphur which would have damaged the vegetation near the source is not absorbed there, as would have happened with lower chimneys. This is important to those who would have suffered, but the amount of sulphur dioxide that would have been removed is very small - even with low chimneys most is in the mass of air above the ground, and so does not come into contact with the vegetation. The process of mixing is such that, within 50 or 100 miles there is very little difference within the air mass whether the initial discharge was from high or low chimneys, and if this finds its way into the rain the results are litte different. High chimneys are a local boon which does little harm to distant regions.

At one time we thought that this policy of "dilute and disperse" had completely solved the problem. As already mentioned, we now know that the dilution may be sufficient to prevent acute phytotoxicity, but that chronic effects may occur, caused not only by sulphur dioxide, but by other gases including oxides of nitrogen and ozone. We are finding that these gases, either alone or in combinations, may be more damaging than we previously imagined. But nevertheless, this is still a local problem. The gases are quite quickly diluted to harmless levels. Unfortunately, this is not the end of the matter. We now know that these very dilute gases, harmless in that form, may be transformed slowly into other chemicals which may be more easily washed out of the air by the rain, and which may then damage fresh waters, and possibly crops, trees and the soil, many hundreds of miles from their source. This damage is usually attributed to "acid rain". In fact, of course, almost all rain, clean or polluted, is acid. Very clean rain may have a pH of 5.6, being in equilibrium with the carbon dioxide in the air. Even where pollution is minimal, a pH of 5 or lower is not uncommon.

I have already mentioned that very acid rain, caused by emissions from fuel burning and factories, has been recognized in Britain for more than a hundred years. However, this is not what is worrying the Scandinavians, who complain of the effects of pollution produced in Britain and borne by the wind to their shores. It is not the cause of disagreement between the United States and Canada. I believe that it may be useful, and may help to reduce confusion, if we distinguish between what I will call primary acid rain and secondary acid rain.

Primary acid rain is caused by the washout from the atmosphere by falling rain of substances as they are emitted in urban and industrial areas. It may contain many different chemicals, for instance hydrochloric acid. It may be very acid - levels of pH 3 have been recorded. However, there is little evidence that this primary acid rain does much harm to plants or to buildings. It is the gases which do this.

It should be noted that rain may, at different times, contain very different amounts of pollutants. A shower after a long dry period will be particularly contaminated. The first rain to fall will generally contain more pollution than that which falls at the end of a rainstorm. This means that plants may be washed clean by this later, purer, water. Primary acid rain may affect soils and fresh water in some cases, as all the pollution is bulked in these situations. It should again be noted that primary acid rain is essentially a local phenomenon. As we move away from the source of the emission, the rain generally becomes less and less acid.

Secondary acid rain is something quite different. It is produced when the oxides of sulphur and nitrogen have been transformed in the air to sulphuric and nitric acid, and when these are removed, by rainout and washout. The transformation to acid, particularly of sulphur, is a slow process, and generally takes several days in which the pollution may have travelled many hundreds of miles. Were there no transformation to acid, there would be no acid rain problem. The gases are much too dilute to do direct harm to the environment.

A great deal of research is going on regarding this production of acid. We know that the reaction is affected by temperature, sunlight and the presence of other substances such as oxidants and hydrocarbons in the atmosphere. If we could control this transformation, perhaps by controlling some of the other substances which take part, then there would be little point in removing the sulphur dioxide from the gases emitted by power stations.

Secondary acid rain may be important because it contains the acid from such large volumes of air. The rain brings down onto the ground the acid in a column of air reaching up to many thousands of feet. Also in a mountainous area, rain generated over a wide area may come down heavily in a much smaller area.

Secondary acid rain is much too dilute to have any direct phytotoxic effects, even on very sensitive species of plants like lichens. In fact, we find a rich flora of leafy lichens in most areas where acid rain damage has been reported. This includes the Black Forest in Germany, Southern Norway and various localities in Scotland. This also shows that in these places, gaseous sulphur dioxide levels are very low and are not the cause of the damage.

I believe that my division of primary from secondary acid rain is useful, and helps to explain what happens, but it is probably unduly simple. In many areas we will find a mixture of primary and secondary rain, and one may grade into the other. The important point is to realize that what happens hundreds of miles downwind is quite different from what happens mear the source. My conception also explains why some workers have said that acid deposition is proportional to output, and others find no such close correlation. Near a pollution source, where dry deposition and primary acid rain are involved, deposition is likely to parallel emission, while at a great distance, where the rate of transformation of the pollutants may be a major factor, it is not surprising that no close correlation can be detected.

So far I have given the impression that sulphur dioxide is the main cause of acid rain. Fifty years ago the main phytotoxic pollutant arising from the use of fossil fuels was, in fact, sulphur doixide. Today, motor vehicles and high-temperature boilers produce a growing quantity of oxides of nitrogen, which contribute to the production of oxidants, including ozone, and in cities like Los Angeles, to P.A.N. Ultimately oxides of nitrogen are the precursors of nitric acid. In what I have called secondary acid rain, only about two-thirds of the acid is sulphuric, the remainder being nitric. There seems to be a tendency for the nitric fraction to increase. The concern of the media with sulphur as though it was the only cuase of acid rain, is misleading.

Dry deposition of sulphur dioxide and other substances, at high doses, damages the plants as already described, and different species show very different susceptibilities. However, dry deposition also contributes to the transfer of acids to the soil. There is some dry deposition on bare soil itself, but more to vegetation, and the greater the surface of the plants the larger the amount deposited. Thus trees pick up considerable quantities. These deposits may be washed off by the rain - a process known as "throughfall". Even where concentrations of gas are so low as to have no recognizable effects on the vegetation, the throughfall may contain as much of the pollutants as the rain itself.

Secondary acid rain certainly has no direct harmful effect on plants, as it is so dilute. However, it may contribute to acidity of fresh water, and may affect plants via the soil, where it is deposited year after year and the effect may thus be cumulative.

In my opinion there is little doubt that acid precipitation, the acidity being caused by gaseous emissions from burning fossil fuels, has contributed to an increase in acidity in many lakes and rivers in Scandinavia, Scotland and North America. These changes have been most serious where the rocks are granitic with low calcium levels in the soils and poor buffering capacity in the fresh water. There has, so far, been little evidence of damage in well buffered waters in areas with sedimentary rock rich in calcium.

However, the situation is far from simple, and much more research will be needed before the exact relationship between output of pollutants and damage to fish and aquatic life is understood.

Thus I have mentioned that the output of sulphur dioxide between 1970 and 1982 fell by a third in Britain. Britain is the major contributor to what may loosely be called Norway's acid rain. This decrease in sulphur output has not been mirrored in any improvement in Norwegian lakes or fisheries. This gives support to the view that there is some other limiting factor, possibly the level of some catalyst which governs the rate of transformation of sulphur dioxide to sulphuric acid.

In countries with a very cold winter, snow poses a particular problem. All the rain, and the pollution it contains, may be stored as snow for six months. When it thaws the acidic materials come out in the first fraction of the melt, which may thus be very concentrated. If the ground is still frozen, this water will run over the surface straight into the streams, and have a drastic, if temporary, effect. At other times, the rain has to pass through the soil before it reaches the stream, and may be modified as it does so.

This whole question of the increasing acidity in streams and lakes is not as simple as is often imagined. There are lakes which are naturally very acidic.

Acidification has often occurred in the past quite independently of man-induced air pollution. Afforestation, the clearing of forest, the burning of vegetation, all have effects which complicate the issue. Acidification, if it is caused by pollution, may be related to the output of sulphur, but other substances such as nitrogen also play a part. When we examine a series of lakes, though the most acid generally are devoid of fish and the least acid support good populations, we find many anomalies. Fish survive where they might be expected to have disappeared, and lakes whose water at least as far as pH would appear suitable may be fishless. Often it appears that it is not only the acidity, but the levels of metals like aluminium, which may be toxic, which are the controlling factors. Nevertheless, it is generally agreed that if we could control more effectively the output throughout the world of air pollution it would be generally beneficial to fresh waters and to their fisheries.

The situation has sometimes been ameliorated, particularly in Sweden, by adding lime to neutralize the acidity. For lakes and slow-running streams this has been an effective, if a temporary, solution but it is generally considered only as a technique to use until a permanent solution can be found to the problem.

Acid rain is also thought to be endangering the forests in many countries. Here it is not the level of the gases in the air which is important, or the rain itself which is harming the trees, but the effect on the soil, and thus on the roots. In soils with a good buffering capacity, that is, generally those drived from sedimentary rock containing plenty of calcium, no harmful effect has been observed, and calculations suggest that none is likely for a very long time. In acidic soils, with poor buffering, the situation may be different. Here the end result may be the release of a toxic level of aluminium, which may poison the roots.

It is not easy to obtain a clear picture of exactly what is happening to the trees in different countries. At one time we thought that there was serious damage to the forests of Scandinavia; now most scientists from Norway and Sweden deny that this has happened, though some consider that in the future damage is possible. A more serious situation is thought to exist in Germany. Accounts in the press have suggested that the Black Forest has been devastated. I visited this area in June this year, and was glad to find that, to the ordinary visitor, the forest appeared as beautiful and healthy as ever. However, there was indeed serious but local damage to firs and spruce, mainly at high altitudes where the trees were under stress. The damage in other parts of Germany would appear to be more serious, but I found few German scientists who thought that "acid rain" was the only, or even the main cause. In general they seemed to blame a variety of perhaps-interrelated causes, including drought, cold, fungal disease, ozone and, possibly, the effect of acidity on the soil. This does not mean that there is not a serious problem, but until we are sure of the cause it may be unwise to take what may be the wrong measures to try to cure it.

Of one thing we can be reasonably certain. The damage to trees in the Black Forest is not caused by the output of sulphur dioxide from industry in that area. We know this because of the rich growth of lichens, which would be the first plants to be eliminated by sulphur dioxide. This means that the drastic efforts of the German government to reduce sulphur output from their industry may be, globally, very altruistic, but it will do nothing to solve the problem of the trees in the Black Forest.

Many people have suggested that too little is being done to solve these problems. They suggest that better pollution control is always worthwhile, whatever the cost. However, the answer is not quite so simple. We just do not know what are the most important causes of damage, where they occur. If we reduced sulphur output by fifty per cent, something possible but costly, it might have little effect, and might discourage the introduction of other more effective, controls. It may be more effective to concentrate on dealing with the output of oxides of nitrogen, whose effects are often overlooked.

Finally, we must realize that pollution control may have its own harmful effects on the environment. To reduce sulphur output we could use fluidised bed furnaces, or other techniques which include lime as the substance which prevents the sulphur dioxide from reaching the atmosphere. This would mean a great increase in quarrying for limestone, often in Britain in National Parks, something conservationists (who are the most vocal about the sulphur emissions) would resolutely oppose. Then there would be a very great increase in the output of carbon dioxide, something which might have its own serious environmental effects, as has been pointed out by another speaker. There would also be a great deal of very toxic slurry to get rid of, and where would we find sites for this in view of the objections which would be raised, again by the very people most concerned with the problem of acid rain? With all these difficulties, it only sensible to try to identify the real nature of the problem so that all our efforts to control it will be effective.

This also brings us back to the whole energy question. Clearly the most effective way to minimize environmental damage is to be more economical, and reduce our use of all types of fossil fuel which produce so many different pollutants. We should make the greastest possible use of renewable and non-polluting sources of energy like water power, solar energy and the wind...not forgetting the bitter opposition by conservationists to the hydro-electric schemes in Tasmania, that solar collectors to supply industry would have to cover vast areas of the countryside with a great effect on the environment, and that huge windmills would be noisy and intrusive. This is why those who wish to preserve the environment must come down in the end to advocating the careful use of much more nuclear power, as being the cleanest and least intrusive form of energy at present available to mankind.