ACID RAIN

Quest explores how it became a catalyst for global cooperation in tackling environmental issues

In the 1970s and '80s, one of the environmental issues dominating news headlines internationally was 'acid rain', although scientists in Europe and North America had been researching the problem since the 1950s. In fact, the first documented use of the term was by the British chemist Robert Angus Smith in his book *Air and Rain: The Beginnings of a Chemical Climatology*, published in 1872.

"It has often been observed that the stones and bricks of buildings, especially under projecting parts, crumble more readily in large towns, where much coal is burnt, than elsewhere," he wrote. "I was led to attribute this effect to the slow, but constant, action of the acid rain."

He suggested that the acidity was caused by sulphuric acid resulting from intensive coal use in towns, as well as by nitric acids associated with the burning of biomass such as wood and peat in rural areas.

Fast forward to 1960, when Eville Gorham in Canada reported that air pollution from a smelter was causing acidification of nearby ponds. Three years later, Gene Likens and his team in the United States found that rain at the Hubbard Brook Experimental Forest was very acidic, although they were uncertain of the cause. It was only after a Swedish scientist, Svante Odén, published an article in his country's leading newspaper in October 1967 that the issue started receiving attention.

Dr Odén had been monitoring the chemistry of surface waters in Scandinavia, and had found that lakes were becoming more acidic. He attributed this to acid precipitation caused by air pollution emanating from the United Kingdom and central Europe – the International Meteorological Institute in Stockholm, Sweden, had taken over the coordinating role of the European Air Chemistry Network in 1956, so he had the data to back up his claims. He reported that lake acidification was the probable cause of declining fish catches and mass mortality events reported by fisheries officers and anglers, and suggested that soils would be affected too if they lost their neutralising ability, with negative impacts on crop production and forest growth.

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Acid rain dissolves the calcite in marble and limestone, causing damage to buildings and statues.

What is acid rain?

Acid rain is caused primarily by emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) associated with the burning of fossil fuels. The SO_2 and NO_x react with water, oxygen and other chemicals in the atmosphere to form acids such as sulphuric acid (H_2SO_4) and nitric acid (HNO_3), which fall to the ground in rain or other forms of wet (snow, fog or hail) or dry (particles or gases) deposition. For this reason, acid rain is more typically referred to as acid deposition nowadays.

While normal, unpolluted rain has a pH of about 5.6 because atmospheric carbon dioxide (CO_2) reacts with water to form carbonic acid (H_2CO_3), acid rain usually has a pH of 4–5. And since the pH scale is logarithmic, acid rain with a pH of 4.6 is ten times more acidic than normal rain.

The main sources of emissions linked to acid deposition are coal-fired power stations, metal smelters processing sulphide ores, other industry, vehicle exhausts, domestic coal- and wood-burning, and agricultural biomass-burning, but natural sources such as volcanoes, lightning and forest fires also contribute. Polluted air can be transported by wind over long distances and across national borders, making acid deposition a transboundary problem.

The publication of this rather alarming article in the same month as the release of two books by prominent Swedes on environmental degradation and overexploitation of natural resources triggered widespread public and political interest in the country. By the end of that year, Sweden had proposed that a conference be convened by the United Nations General Assembly to facilitate coordinated action on "the extremely complex problems related to the human environment".

The United Nations Conference on the Human Environment was duly held in Stockholm in June 1972. One of the first

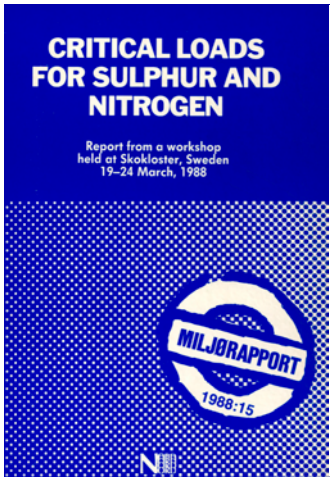
resolutions of the conference was to establish an annual World Environment Day on 5 June – a 'special day' that is still celebrated today, almost half a century later – but numerous recommendations were made and an action plan drawn up.

Prior to the conference, the secretariat had asked participating governments to prepare a national report on the state of environment in their countries, and had invited submission of papers and case studies on particular topics. Well before the conference, Sweden circulated as examples its own national report and a case study titled 'Air pollution across national boundaries: the impact on the environment of sulphur in air and precipitation', which built upon the more formal report Dr Odén had compiled a year after his headline-grabbing newspaper article.

As a result, by the end of 1972 the Organisation of Economic Cooperation and Development (OECD), which at that stage consisted of 19 European member countries plus the United States, Canada, Japan and Australia, had started a collaborative project to measure the long-range transport of air pollution over western Europe, with 11 OECD countries taking part. The project findings, released in 1977, confirmed that sulphur compounds were indeed being transported across borders and affecting the air quality of neighbouring countries.

Other projects conducted by individual countries focused on the environmental and health impacts of acid rain and air pollution. In 1979 the World Health Organisation published its first environmental health criteria for sulphur oxides and suspended particulate matter, and 30 countries and the European Union signed the world's first multilateral agreement on limiting air pollution – the Convention on Long-range Transboundary Air Pollution (CLRTAP) – negotiated under the auspices of the United Nations Economic Commission for Europe (UNECE).

The United States and Canada were among the signatories of CLRTAP, but they also signed their own Memorandum of Intent to develop a bilateral agreement on transboundary air pollution in 1980, having been engaged in a cross-border dispute over acid rain. In the same year, the US Congress passed the Acid Deposition Act, which established the 10-year National Acid Precipitation Assessment Programme (NAPAP).



The critical load concept was adopted for the Convention on Long-range Transboundary Air Pollution in 1988. The critical load was defined as 'a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge'. The quantitative estimate is expressed as the total atmospheric deposition of sulphur, nitrogen or other pollutants in kilogram per hectare per year.

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Dieback of forests in North America and Europe in the 1980s was thought to be due to acid rain, but later attributed to the effects of drought and invasive pests.

During the early 1980s, media attention on acid rain ramped up following extensive dieback of forests in both North America and Europe, particularly in the 'Black Triangle' of the Communist Bloc nations Poland, East Germany and Czechoslovakia, where outdated power stations were emitting massive quantities of air pollutants. Ultimately, however, NAPAP and European research programmes concluded that there was insufficient evidence to attribute the forest dieback to acid rain, and it was more likely caused by the 'double whammy' of drought and invasive pests.

Nevertheless, the effects of air pollutants on human health and aquatic ecosystems had been well established. In 1985 the CLRTAP's Helsinki Protocol was adopted to reduce European sulphur emissions or their transboundary fluxes by at least 30% from 1980 levels, and a similar protocol was adopted for nitrogen oxides in 1988. Canada also launched its Eastern Canada Acid Rain Programme in 1985 with reduction targets to achieve a regional cap on sulphur dioxide emissions, and in 1990 the Amended Clean Air Act was enacted to reduce emissions of sulphur dioxide and nitrogen oxides in the United States. The two countries signed a bilateral Air Quality Agreement in March 1991 to deal with acid-forming emissions and other transboundary air pollutants.

Additional protocols introduced during the 1990s committed countries to more stringent emission limits. Today, thanks to this collaborative approach in tackling the problem, emissions of sulphur dioxide have been reduced by 80–95% from 1980s levels in both Europe and North America, and those of nitrogen oxides by 50–65%.

Written by Sue Matthews drawing on the following reference and numerous other sources.

Grennfelt P, Engleryd A, Forsius M et al. 2020. Acid rain and air pollution: 50 years of progress in environmental science and policy. Ambio 49: 849–864. https://doi.org/10.1007/s13280-019-01244-4

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