Acid Rain

—why it is a concern

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EPA 089/04: This document replaces the EPA Information Sheet No. 22, 'Acid Rain' (January 2001). It explains what acid rain is and the adverse affects it has upon humans and the environment, and provides information on how acid rain can be reduced.

Introduction

Australia has not experienced the problems caused by acid rain in other countries around the world. The emissions produced in this country are, in a global context, relatively small, and our geographical position isolates us from pollution caused by others.

However, being aware of the risks and keeping polluting emissions to a minimum now will help to ensure that acid rain does not become a concern for Australia and South Australia in the future.

Pure rainwater is normally acidic, partly because carbon dioxide in the atmosphere is dissolved in it. The level of acidity is measured by pH[1]—and normally, pure rainwater has a pH of 5.3.

Other particles in the atmosphere such as pollutants can lower the acidity level of rain so that it falls below the generally acceptable level of between 5 and 6—and then the rainwater is referred to as acid rain.

What is affected by acid rain?

Acid rain—or 'acid deposition' as it is correctly called—not only has an adverse effect on environmental ecosystems, but also affects human health and many of the materials, such as building stone and textiles, that we use in our daily lives.

[1] pH: The potential hydrogen, or pH, scale is used to describe acidity and ranges from 1 (most acidic) to 14 (most basic), with a pH of 7 being neutral.

Ecosystems

Acid rain has had major ecological consequences in other parts of the world. Some lakes in countries such as Sweden have become so acidic, from acid rain resulting from pollution in other countries, that they are no longer able to support fish life.

Acid rain also has the potential to affect tree and plant life by direct contact with the plants, and also by modifying the acidity of soils—for example, mobilising toxic aluminium in the soil.

Different soils react differently to acid rain depending on their buffering ability, which is their ability to withstand large changes in pH. For example, soils covering granite will be affected more than soils covering limestone.

Health

Nitrogen oxides and sulphur dioxide in acid rain have been linked with various health problems—particularly eye irritations, and lung disorders such as asthma and bronchitis.

These effects can be compounded by the presence of other irritants, such as smoke and aerosols. Nitrogen oxides are also a major contributor to the formation of ozone in the lower atmosphere, which can also have detrimental health effects on human beings (see EPA 90/04—*Photochemical smog*).

Another obvious health consideration is the indirect effect on resources such as food and water, which can become contaminated.

Materials

Acid rain can have varying and damaging effects on many different materials (see table below). The damage done, for example, to ancient stone buildings is irreversible and hence damages the cultural environment of an area. A further consideration is the cost of replacement and repair of many structures and objects that are still in use today.

The effects on various materials of acid deposition (source: McCormick 1997)

Material	Effect	Principal air pollutants	Other factors
Metals	Corrosion, tarnishing	SO, acid gases	Moisture, air, particles, salt
Building stone	Surface erosion, soiling, black crust formation	SO, acid gases	Mechanical erosion, salt, particles, moisture, CO_2, temperature, vibration, micro-organisms
Paints	Surface erosion, discolouration, soiling	SO, H_2S	Moisture, ozone, sunlight, particles, mechanical erosion, micro-organisms
Paper	Embrittlement, discolouration	SO	Moisture, physical wear, acid used in manufacture
Photographic materials	Small blemishes	SO	Moisture, particles
Textiles	Soiling, reduced tensile strength	SO, NO	Moisture, particles, light, physical wear, washing
Paints	Surface erosion, discolouration, soiling	SO, H_2S	Moisture, ozone, sunlight, particles, mechanical erosion, micro-organisms
Leather	Weakening, powdered surface	SO	Physical wear, residual acids used in manufacture
Rubber	Cracking		Ozone, sunlight, physical wear

What is in acid rain?

The major contributors, called ‘precursors’, to acid rain are the common air pollutants: sulphur dioxide (SO_2) and the nitrogen oxides (NO_X)—nitric oxide (NO) and nitrogen dioxide (NO_2).

Through a variety of chemical reactions, shown below, these gases form sulphuric acid and nitric acid, which are the two acids responsible for acid rain.

How is acid produced?

Nitric oxide can react with oxygen (O_2) to form nitrogen dioxide, which can be broken down again by sunlight (hυ) to give nitric oxide and an oxygen radical (O):

2NO	+	**O_2**	→	**$2NO_2$**		
NO_2	+	**hυ**	→	**NO**	+	**O**

This oxygen radical then enables the formation of ozone (O_3):

O	+	**O_2**	→	**O_3**

The presence of ozone causes the formation of more nitrogen dioxide by its reaction with nitric oxide:

NO	+	**O_3**	→	**NO_2**	+	**O_2**

Or the oxygen radical reacts with water to give the hydroxyl radical (OH):

O	+	**H_2O**	→	**2OH**

This radical then reacts with nitric oxide to give nitrous acid (HNO_2) and nitrogen dioxide to give nitric acid (HNO_3). It also combines with sulphur dioxide (SO_2) to produce sulphuric acid (H_2SO_4):

HO	+	**NO**	→	**HNO_2**
NO_2	+	**HO**	→	**HNO_3**
SO_2	+	**2HO**	→	**H_2SO_4**

Where do the ‘precursors’ come from?

While nitric oxide and sulphur dioxide are produced biogenically (in nature), there are major anthropogenic (man-made) sources of both these polluting gases.

Sometimes, natural production of the gases is much higher than human production, but these natural emissions tend to be spread over large areas, dispersing their effects, while the man-made emissions are concentrated around the source of their production.

Biogenic sources

In nature, bushfires, volcanic eruptions and the decay of organic matter produce significant amounts of sulphur dioxide. Nitrogen oxides are also generated by bushfires as well as by microbial processes (in soil) and lightning discharges.

Anthropogenic sources

Nitrogen oxides are produced mainly from the burning of fossil fuels, such as petrol in cars and from power stations burning coal. Sulphur dioxide is formed primarily in the burning of (sulphur-containing) coal and fossil fuels, and in metal smelters.

In Adelaide in 2000, an estimated 66% of nitrogen oxides (including NO and NO_2) came from motor vehicles, with a further 20% from fuel combustion. Petroleum refinery processing produced 40% of the sulphur dioxide emitted to the atmosphere, with motor vehicles contributing 22% and fuel combustion 15%.

How are the acids deposited?

Acidic pollutants are deposited on the ground either in a wet form through rain, fog or snow, or as dry matter, such as gases or particulates, falling directly from the atmosphere to the ground.

The term 'acid deposition' describes all these possibilities and therefore is generally preferred to 'acid rain'.

Environmental problems from dry deposition tend to occur closer to the source of the pollution, but wet deposition can occur up to hundreds of kilometres away, in a different region or country, because microscopic aerosol droplets can be carried in clouds.

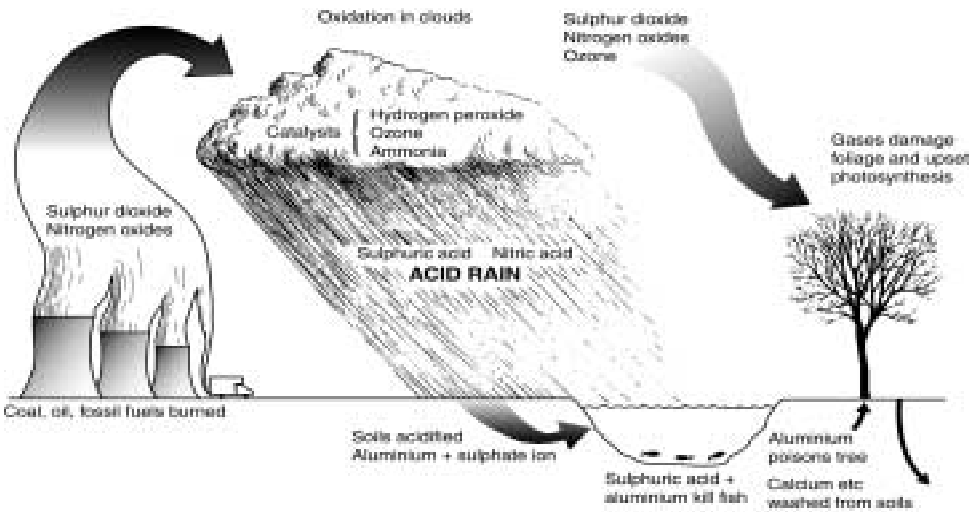

Diagram of the 'acid deposition' process (reproduced with permission from New Scientist *Inside Science* © RBI: 5 November 1987. *http://www.newscientist.com*)

How we can reduce acid rain

The most effective way to reduce the incidence of acid deposition is to reduce the emission of its causes—the 'precursors', nitrogen oxides and sulphur dioxide.

Nitrogen oxide reduction

The main method of lowering the levels of nitrogen oxides is by a process called 'catalytic reduction', which is used in industry and in motor vehicles. For example, a catalytic converter fitted to a car's exhaust system will convert much of the nitric oxide from the engine exhaust gases to nitrogen and oxygen. In Australia, all motor vehicles built after 1985 must be fitted with catalytic converters.

Nitrogen is not in the actual fuels used in motor vehicles or power stations; it is introduced from the air when combustion occurs. Using less air in combustion can reduce emissions of nitrogen oxides.

Temperature also has an effect on emissions—the lower the temperature of combustion, the lower the production of nitrogen oxides. Temperatures can be lowered by using processes such as two-stage combustion and flue gas recirculation, water injection, or by modifying the design of the burner.

Sulphur dioxide reduction

There are several methods to lower the sulphur dioxide emissions from coal-fired power stations. These include simple methods of prevention, such as using coal with a low sulphur content and physical coal cleaning.

However, where sulphur dioxide exists in greater quantities, more complex methods are needed to reduce emissions and these can include processes such as 'flue gas desulphurisation' and 'fluidised bed combustion'.

Coal sulphur content

Most Australian coals have a sulphur content of 0.1–1%, which is quite low by world standards. Traditionally, black coal, with a sulphur content of approximately 1%, has predominantly been used in Australia. Leigh Creek coal, mined in South Australia, is a lignite A coal with a sulphur content of 0.4%.

Physical coal cleaning

Coal can be cleaned because sulphur in coal is often in the form of mineral impurities, such as pyrites, and these can be separated from the coal. The more finely coal is crushed before use, the more impurities such as sulphur that are removed from it.

Flue gas desulphurisation

Flue gas desulphurisation is based on using limestone to absorb the sulphur dioxide (see the equation below) and is one of the most effective methods of removal. However, the process generates solid wastes (calcium sulphates, $CaSO_3$ and $CaSO_4$) which require disposal.

$$CaCO_3\text{ (limestone)} + SO_2 \xrightarrow{H_2O,\ O_2} CaSO_3 + CaSO_4 + CO_2 + H_2O$$

Fluidised bed combustion

In this process, the coal is crushed and passed into a fluidised 'bed' for combustion. The bed consists of fine particles of an absorbent material such as limestone. Hot air is passed through it and this causes the particles to behave as though they were a fluid (fluidised).

The sulphur dioxide can then be absorbed by the limestone particles in the bed. Fluidised bed combustion can be operated at lower temperatures and therefore produces less nitrogen oxide, but once again, solid waste is created and requires disposal.

References

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FURTHER INFORMATION

Legislation

Legislation may be viewed on the Internet at: *www.parliament.sa.gov.au/dbsearch/legsearch.htm*

Copies of legislation are available for purchase from:

Government Information Centre	Telephone:	13 23 24
Lands Titles Office, 101 Grenfell Street	Internet:	*shop.service.sa.gov.au*
Adelaide SA 5000		

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