CHAPTER 1

The presence of sulfuric and nitric acids has lowered the pH of rain to such an extent in the northern hemisphere, particularly in Europe and Northern America, that considerable damage to the natural and built environment has resulted.

Plants can be adversely affected by acid rain in several ways. Direct exposure of foliage to high acid concentrations causes damage that affects water loss from the leaves and photosynthesis. Protective coatings of leaves are also damaged and important ions are leached from the leaves, disrupting chemical processes such as chlorophyll synthesis.

An environmentally unfriendly effect

Plants can also be damaged indirectly through the impact of acid rain on soils. Low pH rain can speed up the leaching of essential metal ions, such as magnesium and potassium, from soil and the mobilisation of potentially toxic metal ions such as aluminium, lead, zinc and copper. Such removal and mobilisation produces stress in plants, possibly leading to death. (See Chapter 5.2, page 324). These effects are not as severe for alkaline soils that have the capacity to neutralise acids.

…his is why I chose this source because it dealt with some …nvironmental issues with …aving high quantities of toxic metals (e.g. lead) mobilised, which is what the Cosmos said biodegradable plastics will do.

> Leaching is the dissolution of particular minerals from a 'host' medium such as rock or soil, with their subsequent removal from the host.

professional, educated language

This is a key part of an entire ecosystem that caused chain effects.

…evere environmental effects.

Free aluminium ions can also disturb the defence mechanisms that plants use to fight disease and damage bacteria that decompose vegetation and recycle plant nutrients. They also restrict the extraction of oxygen by fish through their gills by adhering to the gills, leading eventually to suffocation.

Mobilised toxic metal ions can also be transported in solution into sources for drinking water such as dams and wells, with the potential to affect human health.

Not directly an environmental result, but it is something that is a problem. Anyway, toxic substances in water sources is an environmental effect.

Fish populations are adversely affected by inputs of acid to bodies of water. Eggs and fry are particularly sensitive to low pH. With reduction in pH of water, fish suffer from excessive loss of sodium from the gills.

…hese sections are …relevant to the topic … only a side …ssue to what the chapter …eals with, i.e. acid rain

Limestone and marble building stone contains calcium and/or magnesium carbonates that are readily attacked by sulfuric and nitric acids in acid rain. The insoluble carbonates are converted to more soluble sulfates and nitrates and the surface of the stone is eaten away with detail of sculptured stone being lost.

$$CaCO_{3(s)} + H_2SO_{4(aq)} \longrightarrow CaSO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

$$CaCO_{3(s)} + 2HNO_{3(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Calcium sulfate is slightly soluble in water and can dissolve in the moisture in cracks in the carbonate stone. When the moisture evaporates, a crystalline deposit of gypsum, a hydrated form of calcium sulfate, $CaSO_4.2H_2O$, forms in the cracks. The volume of these crystals is greater than the calcium carbonate it has replaced and the subsequent expansion enlarges the cracks and eventually causes fracturing of the stone.

Sandstone is a building stone in which grains of quartz, SiO_2, are held together by a natural 'cement' of calcium carbonate or iron (III) oxide, Fe_2O_3. Both of these basic compounds are converted to soluble salts by the action of acids in acid rain. The dissolving of the 'cement' weakens the structure of the sandstone.

$$CaCO_{3(s)} + 2H^+_{(aq)} \longrightarrow Ca^{2+}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

$$Fe_2O_{3(s)} + 6H^+_{(aq)} \longrightarrow 2Fe^{3+}_{(aq)} + 3H_2O_{(l)}$$

Acid rain also increases the rate of corrosion of steel and aluminium used in structures such as bridges and towers. It effectively dissolves the metals at a slow rate.

$$Fe_{(s)} + 2H^+_{(aq)} \longrightarrow Fe^{2+}_{(aq)} + H_{2(g)}$$

Acid rain also dissolves zinc oxide coating on galvanised iron.

$$ZnO_{(s)} + 2H^+_{(aq)} \longrightarrow Zn^{2+}_{(aq)} + H_2O_{(l)}$$

 – An educational source, improving its credibility

Australian Academy of Science

MAKING PACKAGING GREENER – BIODEGRADABLE PLASTICS

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Key text

This topic is sponsored by the Australian Government's National Innovation Awareness Strategy.

Biodegradable plastics made with plant-based materials have been available for many years. Their high cost, however, has meant they have never replaced traditional non-degradable plastics in the mass market. A new Australian venture is producing affordable biodegradable plastics that might change all that.

Our whole world seems to be wrapped in plastic. Almost every product we buy, most of the food we eat and many of the liquids we drink come encased in plastic. In Australia around 1 million tonnes of plastic materials are produced each year and a further 587,000 tonnes are imported. Packaging is the largest market for plastics, accounting for over a third of the consumption of raw plastic materials – Australians use 6 billion plastic bags every year!

Plastic packaging provides excellent protection for the product, it is cheap to manufacture and seems to last forever. Lasting forever, however, is proving to be a major environmental problem. Another problem is that traditional plastics are manufactured from non-renewable resources – oil, coal and natural gas.

Plastics that break down

In an effort to overcome these shortcomings, biochemical researchers and engineers have long been seeking to develop biodegradable plastics that are made from renewable resources, such as plants.

The term biodegradable means that a substance is able to be broken down into simpler substances by the activities of living organisms, and therefore is unlikely to persist in the environment. There are many different standards used to measure biodegradability, with each country having its own. The requirements range from 90 per cent to 60 per cent decomposition of the product within 60 to 180 days of being placed in a standard composting environment.

The reason traditional plastics are not biodegradable is because their long polymer molecules are too large and too tightly bonded together to be broken apart and assimilated by decomposer organisms. However, plastics based on natural plant polymers derived from wheat or corn starch have molecules that are readily attacked and broken down by microbes.

Plastics can be produced from starch

Starch is a natural polymer. It is a white, granular carbohydrate produced by plants during photosynthesis and it serves as the plant's energy store. Cereal plants and tubers normally contain starch in large proportions. Starch can be processed directly into a bioplastic but, because it is soluble in water, articles made from starch will swell and deform when exposed to moisture, limiting its use. This problem can be overcome by modifying the starch into a different polymer. First, starch is harvested from corn, wheat or potatoes, then microorganisms transform it into lactic acid, a monomer. Finally, the lactic acid is chemically treated to cause the molecules of lactic acid to link up into long chains or polymers, which bond together to form a plastic called polylactide (PLA).

PLA can be used for products such as plant pots and disposable nappies. It has been commercially available since 1990, and certain blends have proved successful in medical implants, sutures and drug delivery systems because of their capacity to dissolve away over time. However, because PLA is significantly more expensive than conventional plastics it has failed to win widespread consumer acceptance.

Plastics can also be produced by bacteria

Another way of making biodegradable polymers involves getting bacteria to produce granules of a plastic called polyhydroxyalkanoate (PHA) inside their cells. Bacteria are simply grown in culture, and the plastic is then harvested. Going one step further, scientists have taken genes from this kind of bacteria and stitched them into corn plants, which then manufacture the plastic in their own cells.

What's the cost?

Unfortunately, as with PLA, PHA is significantly more expensive to produce and, as yet, it is not having any success in replacing the widespread use of traditional petrochemical plastics.

Indeed, biodegradable plastic products currently on the market are from 2 to 10 times more expensive than traditional plastics. But environmentalists argue that the cheaper price of traditional plastics does not reflect their true cost when their full impact is considered. For example, when we buy a plastic bag we don't pay for its collection and waste disposal after we use it. If we added up these sorts of associated costs, traditional plastics would cost more and biodegradable plastics might be more competitive (Box 1: Life cycle analysis).

Biodegradable and affordable

If cost is a major barrier to the uptake of biodegradable plastics, then the solution lies in investigating low-cost options to produce them. In Australia, the Cooperative Research Centre (CRC) for International Food Manufacture and Packaging Science is looking at ways of using basic starch, which is cheap to produce, in a variety of blends with other more expensive biodegradable polymers to produce a variety of flexible and rigid plastics. These are being made into 'film' and 'injection moulded' products such as plastic wrapping, shopping bags, bread bags, mulch films and plant pots.

Mulch film from biodegradable plastics

The CRC has developed a mulch film for farmers. Mulch films are laid over the ground around crops, to control weed growth and retain moisture. Normally, farmers use polyethylene black plastic that is pulled up after harvest and trucked away to a landfill (taking with it topsoil humus that sticks to it). However, field trials using the biodegradable mulch film on tomato and capsicum crops have shown it performs just as well as polyethylene film but can simply be ploughed into the ground after harvest. It's easier, cheaper and it enriches the soil with carbon.

Pots you can plant