Phosphorus from sewage — without chemicals

As you nurture your tomatoes with expensive fertiliser — a large part of it the phosphorus that our old soils lack — reflect a moment on the fact that authorities spend large sums on chemicals to precipitate this same nutrient from sewage to prevent eutrophication of our rivers and lakes.

Efforts by scientists around the world to develop cheaper methods of removing nutrients from sewage have met with mixed success. Now Australia's first full-scale treatment plant that uses a cheaper process with bacteria removing the phosphorus is operating successfully at Ballarat, Victoria.

The plant, which has been treating waste equivalent to that from a population of 75 000 since April 1988, removes the nutrient at a fraction of the cost of comparable chemical treatment. In collaboration with CSIRO and Monash University, the Ballarat Water Board has built a plant that 'conditions' bacteria to store phosphorus in their cells. When the sludge is removed from the system, the bacteria and their phosphorus store are removed with it.

Eutrophication and phosphorus levels

In the same way that garden vegies thrive on liberal handfuls of nitrogen/phosphorus/potassium fertiliser and pastures respond to regular applications of superphosphate, algae and other water plants grow rapidly in lakes fed by creeks and rivers rich in nutrients. This 'cultural' eutrophication poses a world-wide problem, manifesting itself in choked water bodies and stagnant polluted water.

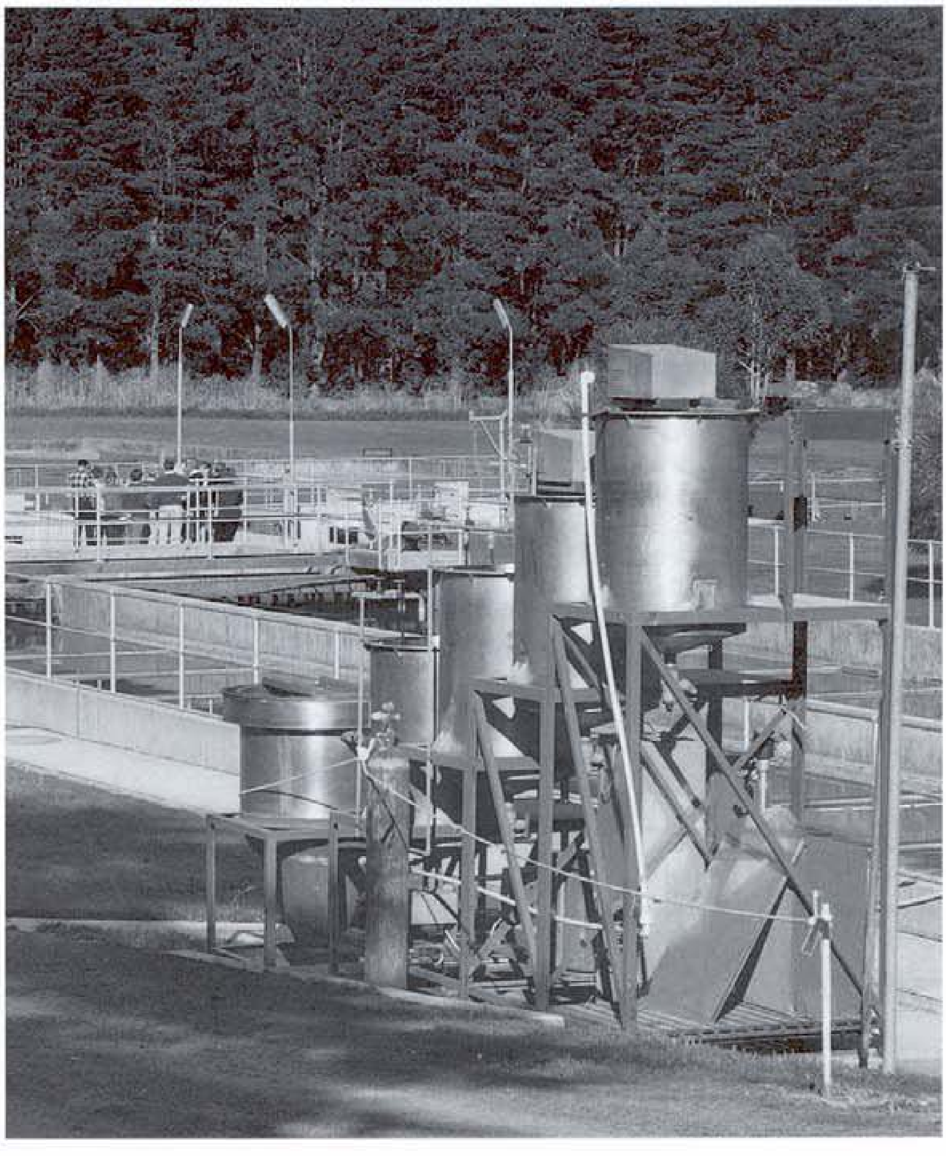
Phosphorus, the prime culprit, can be introduced into lakes as run-off from pasture, forests, and other fertilised land. But these sources generally contribute low concentrations in an insoluble, particulate form. More important are the 'point sources' — sewage outlets and drainage from intensive agricultural enterprises — that contain high concentrations of water-soluble phosphorus.

Phosphorus concentrations that cause eutrophication vary from country to country and lake to lake, making appropriate standards difficult to set. The major problem is differences in the turbidity and colour of the water. For example, compared with those elsewhere in the world, many of our rivers contain very murky water (it carries large amounts of fine sediment, colloidal clay, and dissolved substances from plants). This murkiness reduces growth of algae, since light cannot penetrate very far (see *Ecos* 30). However, when water is stored the murkiness is greatly reduced, making our reservoirs more like overseas lakes.

The Australian Environment Council has recommended that phosphorus concentrations should not exceed 50 μg per litre in lakes used for recreation and 20 μg per litre for potable supplies. The Council has suggested that, where water bodies approach these levels, sewage discharges into them should aim for less than 1 mg total phosphorus per litre.

Getting the effluent from treatment plants down to such a content is technically quite simple. Usually, phosphorus and that other problem nutrient, nitrogen, are removed from municipal sewage in the last

The pilot plant installed at Ballarat — four completely mixed tanks in series (the last two of which were aerated) followed by a clarifier.



The full-scale biological phosphorus-removal plant designed by CSIRO stretches across the centre of the picture. The main elements are labelled.

of three stages of treatment. A primary treatment removes rags, sticks, grit, and other solids; a secondary one removes the biological oxygen demand. A number of secondary treatment techniques exist, but the most common process mixes raw sewage with an activated (bacterially rich) sludge in special aerated tanks.

The usual — but expensive — method of removing phosphorus in the tertiary stage is chemical precipitation caused by adding lime or metal salts. The Molonglo treatment works in Canberra, for example, handles the waste from a population of more than 250 000 and spends about $900 000 a year on chemicals to remove phosphorus and heavy metals from it.

The high cost has provided considerable incentive to search for cheaper solutions. *Ecos* 60 reported on one biological alternative that replaces the secondary and tertiary stages of waste-water treatment — the use of large swamp plants such as club-rushes growing in a substrate of gravel. The process installed at Ballarat uses an entirely different biological approach.

Working with bacteria

Mr Bill Raper, leader of the Biological Purification Project in the CSIRO Division of Chemicals and Polymers, has been collaborating with the Ballarat Sewage Authority and the Department of Microbiology, Monash University, since 1983, when they set up a team to determine the potential of biologically enhanced phosphorus removal in Australia.

In the early stages, the team directed their attention to discoveries in the United States and South Africa, which had resulted in phosphorus being removed biologically there, although the mechanisms involved in the process were not completely understood. The Australians began with a pilot plant, designed and installed by CSIRO at Ballarat South Treatment Plant. Samples of treated sludge were studied at Monash University.

In conventional treatment plants, the accepted practice had been to maintain aerobic conditions in the effluent during secondary treatment. It was believed that if the oxygen was cut off the bacteria that perform the treatment process would die.

But in recent years scientists have found that this is not strictly true. Sewage naturally contains a diverse range of bacteria — some aerobic, some anaerobic, and some facultative (that is, they can choose a digestive route that suits the circumstance). The metabolism, and therefore the efficiency, of some bacteria can actually be speeded up if they are starved of oxygen for a while. In Australia, that discovery has formed the basis of the AAA treatment process (alternating aerobic and anaerobic digestion) that was developed largely from research by CSIRO's Dr Yen Ip (see *Ecos* 44).

Research by scientists in the United States and South Africa had already shown that anaerobic conditions at an early stage in the treatment process sometimes gave other benefits, including a marked increase in phosphorus removal in later aerobic stages. In their Ballarat project, Bill Raper and his colleagues used this knowledge to refine a system that could consistently produce effluent containing 0·2 mg of phosphorus per litre from influent concentrations that fluctuated between 5 and 13 mg per litre.

The essential bacteria in the Ballarat process that respond to these contrasting environments can store phosphorus within their cells in the form of polyphosphate (Pn) granules. Interestingly, although the Ballarat plant has been working successfully for 2 years, it is still not completely clear why the presence of anaerobic stages encourages the Pn bacteria to grow. For, despite success in operating plants, the scientists have not been able to reproduce exactly the same results in laboratory experiments with pure cultures of *Acinetobacter*, the bacteria thought to be responsible for phosphorus removal in overseas plants.

Overseas it is widely believed that a sequence of activities something like the following occurs. Under anaerobic conditions, the *Acinetobacter* bacteria rapidly absorb acetate (their preferred substrate) and, with energy obtained from changing intracellular Pn to phosphate, convert it to a form that can be metabolised in aerobic conditions. (Other bacteria are unable to use acetate quickly under anaerobic conditions, giving *Acinetobacter* a competitive advantage if anaerobic stages are present.) In the aerobic stage the bacteria replenish their Pn pool from phosphorus in the system. In this way, provided the bacteria reproduce sufficiently rapidly to remove the incoming phosphate, when the sludge is removed from the system the phosphorus is removed with it.

The operational success of the Ballarat Plant has encouraged more research. Mr Raper's team and colleagues from Monash University's Department of Microbiology — supported by a $300 000 grant from the Australian Water Research Advisory Council — are now working on ways to refine the process further so that both nitrogen and phosphorus can be removed biologically.

Early work with a CSIRO pilot plant showed that this can be done efficiently after the introduction of a recirculating process — currently the subject of a patent application — that ensures raw sewage is pre-fermented before it is treated in anaerobic and then aerobic tanks. Previous unsuccessful processes in Australia did not have this pre-fermentation phase.

But, even at this stage of development, biological treatment at Ballarat has proved its worth. Compared with the cost of a conventional aeration plant using alum for phosphate removal, reductions in both capital and chemical costs are saving over $1 million per year.

David Brett

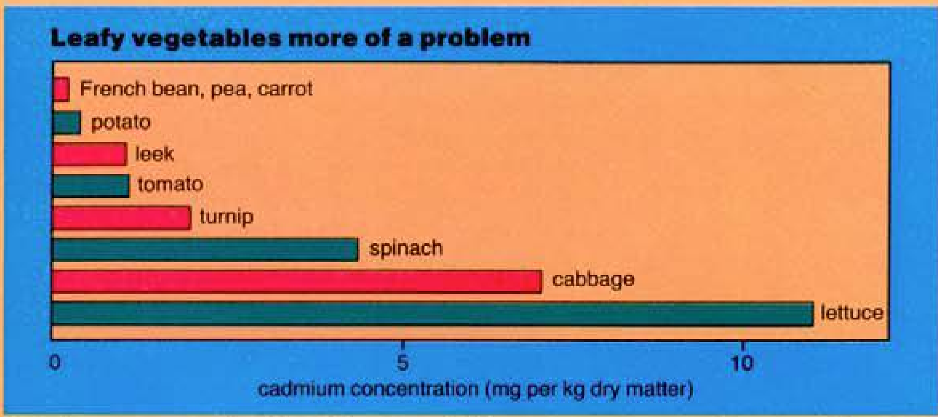
More about the topic

The effect of primary fermentation on biological nutrient removal. R.C. Bayly, A. Duncan, J.W. May, N.H. Pilkington, W.G.C. Raper, and G.E. Vasiliadis. *Proceedings, Australian Water and Wastewater Association 13th Federal Convention, Canberra, 6–10 March 1989.*

Heavy metals in soils and their environmental significance. K.G. Tiller. *Advances in Soil Science*, 1989, **9**, 113–42.

'Guidelines for the Use of Sewage Sludge on Agricultural Land.' A.S. Awad, A.D. Ross, and R.A. Lawrie. (New South Wales Department of Agriculture and Fisheries: Sydney 1989.)

Sludge — prospects for recycling



Cadmium concentrations in edible parts of different crops grown in the same soil.

Huge amounts of sewage sludge are produced world wide — about 6 million tonnes (dry weight) each year in the European Community countries alone. In New South Wales the annual production of wet sludge exceeds 1 million tonnes. Overseas, the distribution of sludge on land is gaining increasing favour among farmers, who welcome it as a source of nutrients and as a soil conditioner. Surprisingly, few sludges have been used this way in Australia — most are dumped at sea or used for land-fill.

The exceptions include a granulated heat-treated sludge from the Bolivar treatment plant near Adelaide and the ash from incinerated sludge produced at the Lower Molonglo Water Quality Control Centre in Canberra. The Canberra plant treats its sewage with calcium oxide and ferric chloride to stabilise the organic matter and precipitate phosphate and heavy metals. Until recent changes in the quantity of chemicals used, the plant managers have been selling the lime-rich ash as an effective acid-soil ameliorator.

In New South Wales, where sludge recycling is in its infancy, the Department of Agriculture and Fisheries has just released guidelines for using sludge on agricultural land. It is carrying out research — including water, soil, plant, and animal testing — on several commercial farms so that safe and sustainable uses for sludge can be developed.

The list of nutrients found in sludge seems to make it an attractive target for recycling enthusiasts. For example, sludge from the Ballarat process is particularly rich in phosphorus; when dry it contains 4–6%, or about half as much as superphosphate.

Ecos 39 reported research by Mr Paul de Vries of the CSIRO Division of Soils, who supported the use of sewage sludge as a fertiliser. As he pointed out, provided it is sterilised by heat to eliminate disease organisms and leached to eliminate excess soluble salts, and no leafy vegetables are grown on land treated with waste containing heavy metals like cadmium, many sludges will make perfectly good fertiliser.

Nevertheless, some caution is needed because the quality of sludge varies greatly — even from the same treatment plant. Before we grow our lettuces in soil mixed with it, the concentrations of nutrients and pollutants must be assayed in each batch so that its suitability for land distribution can be assessed.