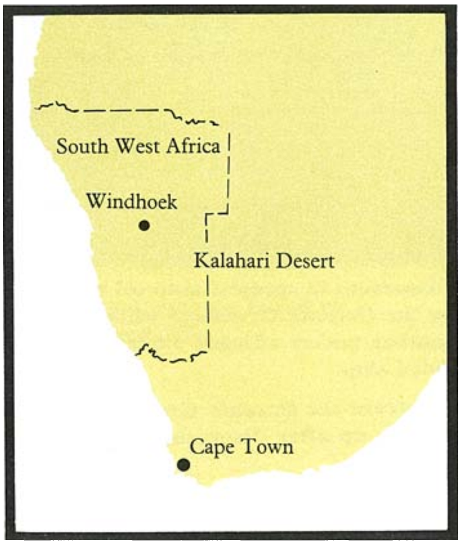
Re-using sewage water

Each day some 2000 million litres of water flow out of Australia's sewers into the sea. Each litre has been used only once since it left the storage reservoirs in the hills. If this water could be purified and used again, it could reduce our demands on natural water sources quite considerably. The question is, can we make the sewage water clean enough to allow re-use?



Four main uses for this water come to mind, depending on its purity. It could be re-used for:

- domestic purposes
- irrigating crops and pastures
- recharging the groundwater supply
- supplying water for industrial processes

Most people find the idea of drinking purified sewage revolting, but undoubtedly this must come about sooner or later, especially in arid regions. Our distrust of drinking sewage is indeed well founded; it can carry too many parasites and diseases—for example, roundworms, tape worms, bacterial infections, and virus diseases like hepatitis and possibly poliomyelitis. Any purifying system that produces water for drinking must be foolproof, and that sounds a tall order. Yet the 60 000 inhabitants of Windhoek—a city located at the edge of the Kalahari Desert in South West Africa—have become quite used to the idea. Because of a severe water shortage they drank purified sewage for 4 years from 1966, apparently with no ill effects. Recycled sewage supplied about one-third of the municipal water supply during the driest seasons.

The city's authorities did not achieve this recycling by depending entirely on traditional biological methods of purifying sewage. The Windhoek treatment plant included an extra stage that used a mixture of physical and chemical purification techniques. Similar additional physico-chemical treatment stages are now in operation in a number of other cities in the United States, to protect rivers from phosphorus and nitrogen pollution, although as yet none recycle water for domestic use. Here in Australia, a hybrid system is now being built to protect the waters of the Murrumbidgee River from Canberra's sewage.

In the long run it should be possible to use the physico-chemical treatments direct, and perhaps to eliminate biological treatment altogether.

Gaining experience

A few years ago, Dr Don Weiss, who is now Chief of the CSIRO Division of Chemical Technology, instigated a study intended to give Australia first-hand experience of operating such physico-chemical plants under Australian conditions. With the assistance of the Melbourne and Metropolitan Board of Works, the Division's Water Purification Section, led by Mr Bob Swinton, set up a pilot plant at the Board's sewage works at Lower Plenty. Sewage entering this works consists almost exclusively of household waste from residential areas.

Mr Swinton and his colleagues built their plant from the plans of a similar pilot plant that had been installed at Pretoria in South Africa. They obtained the specifications from Dr G. J. Stander, former Director of the South African National Institute of Water Research, who designed it. The chemical processes involved are very simple (although combining them all into one plant makes things rather more complicated).

Once Mr Swinton and his colleagues have gained operating experience with the plant, they hope to be able to make improvements that will increase its

Most people find the idea of drinking purified sewage revolting, but undoubtedly this must come about . . .

efficiency and reduce its costs. The plant began operating in 1973.

The design should be able to cope with raw sewage (and indeed the similar one at Pretoria does so). Nevertheless, to begin with the team decided to operate the plant on sewage that had passed through a settling tank, since there are practical difficulties in dealing with solids like sticks and rags in a small pilot plant. It will be fed raw sewage later on.

First, adding hydrated lime to the sewage liquid raises the pH to 11·5, and this precipitates out most of the colloidal organic matter, heavy metals, and phosphate in the sewage as a sludge that is collected by flotation or settling. The high pH also kills practically all worm eggs, bacteria, and viruses present. The urea in the sewage will already have been converted to ammonia in the sewers. The high pH allows this ammonia to be removed as the gas by spraying the effluent through a strong current of air in a stripping tower.

At this stage the effluent contains only low levels of organic matter, bacteria, viruses, phosphate, and ammonia. Treating it with carbon dioxide then reduces the pH and precipitates out the remaining lime as calcium carbonate. Added iron salts coagulate the precipitate, which is settled and finally filtered off in a sand bed.

Detergents are then removed by passing air through the treated effluent in a tank. The detergents form into a foam that can be skimmed off the surface. Finally, absolute safety from disease organisms is achieved by chlorinating the water, and then passing it through a column of activated carbon. The activated carbon column also absorbs toxic chemicals like pesticides, and removes any remaining colour, taste, or odour.

Pros and cons

A plant like the experimental one at Lower Plenty has the advantage that in a mild or warm climate it can produce clean water that can be used by industry, or can be discharged into streams or fresh-water lakes without causing pollution problems. The water should even be safe to drink, provided virus infections can be completely eliminated. Such treatment plants also cover less land and cost less to build than conventional biological ones, and they aren't affected by heavy metals and other poisons.

But the plants do still have disadvantages compared with biological ones. For example, they use large quantities of lime and activated carbon, which must be bought, and they produce larger amounts of sludge, which must be disposed of. Also ammonia strippers will not operate efficiently at temperatures below 10°C, so in cool climates some other method has to be found to remove nitrogen from the sewage.

Most of the lime used finishes up as calcium carbonate in the sludge, and it is feasible to convert this back to lime by incinerating the sludge if the scale of the operation is large enough, and indeed this will be done at the new Canberra treatment plant. The sewage phosphate also converts some of the lime to calcium phosphate, and this would accumulate as the lime was re-used. Thus it may be possible to use the sludge as a fertilizer once the phosphate level has risen enough.

Research teams at the CSIRO Division of Chemical Engineering, universities, and some companies are looking into producing cheaper activated carbon from local coal to replace the currently imported type.

At present the purified water would cost more than water from the traditional sources of supply like the reservoirs near our capital cities. Even so, it would probably be cheaper to produce re-usable water from sewage by these processes than to remove the salt from sea-water. Mr Swinton foresees that, to begin with, the main uses for such plants will be in remote mining towns or other communities located in arid regions.

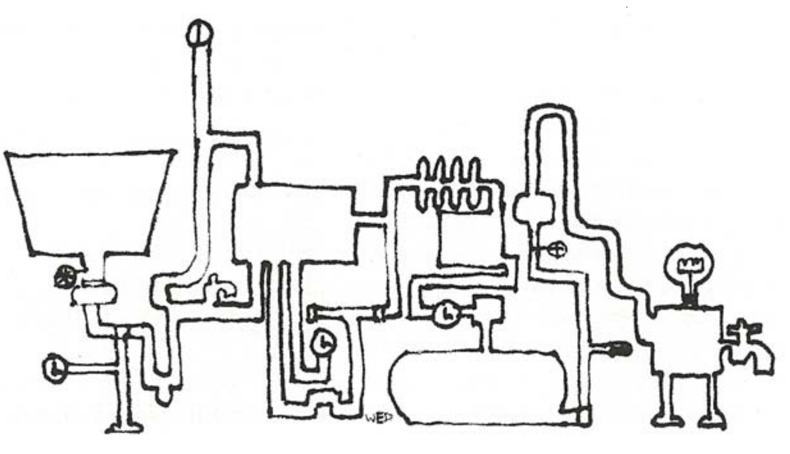
In the meantime there are the other possible uses already mentioned for the sewage waters of varying degrees of purity produced by conventional biological plants—agricultural irrigation, aquifer recharge, and re-use by industry.

Sewage for agriculture

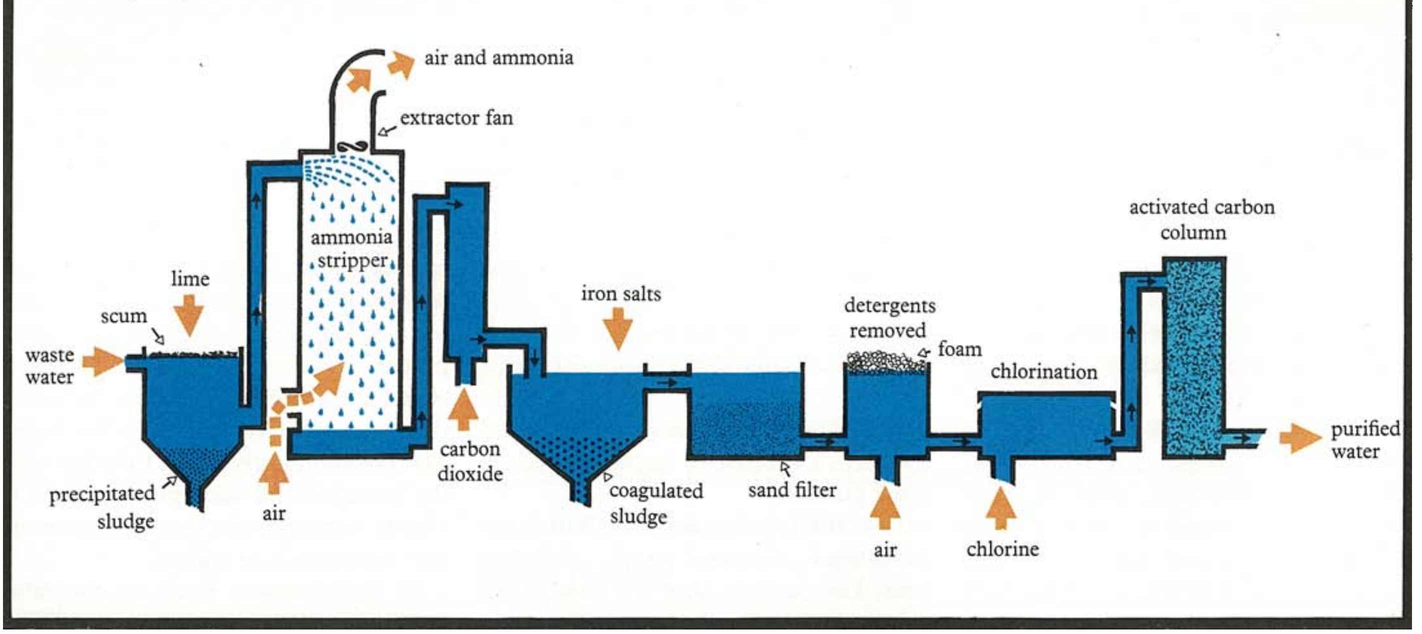
Using sewage in agriculture is, of course, anything but new. Raw (untreated) sewage contains both water and plant nutrients, and the Chinese were using it as a source of water and fertilizer more than 4000 years ago. Today one-third of Paris's vegetables are grown on sewage farms.

On Melbourne's very successful Werribee Sewage Farm, begun in 1892, high-quality cattle and sheep have also been grazed on sewage-irrigated pastures for more than 70 years using what's called the land filtration system. Here the raw sewage is irrigated onto the pastures through channels and furrows, and it becomes purified by organisms in the soil as it percolates through. A system of drains collects the cleaned water and discharges it into Port Phillip Bay.

The snag with the system is that the



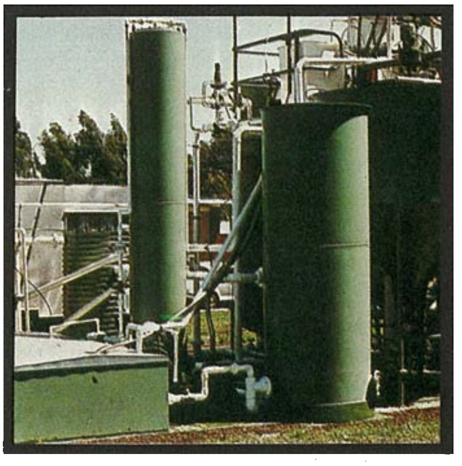
How the pilot plant works



least demand for irrigation water comes in winter. At this time of year the flow of sewage is greatest because more rainwater leaks into the sewers. Other purification methods less efficient at removing phosphorus and nitrogen have to be used in winter to cope with the surplus water, and growths of weed offshore from Werribee can become a nuisance.

In South Australia, small quantities of effluent from Adelaide's Bolivar sewage plant are being piped on a trial basis to producers of horticultural crops. In this State the effluent may be trickle- or furrow-irrigated onto grape vines, vegetables that will be cooked, and those salads (such as tomatoes) that do not come into direct contact with the water around their roots. Effluent from the city's Glenelg plant has been used for irrigating public lawns and gardens for more than 40 years. Last summer it was used for irrigating four golf courses, one golf driving range, eight ovals, one public caravan park, one bowling green, one set of tennis courts, 40 ha of public lawns, and Adelaide airport.

Near Perth, Mr Glyde Turton of the CSIRO Division of Land Resources Management is experimenting with trickle-irrigating radiata pines with effluent that has already received biological treatment from the new Beenyup treatment plant. The pines are growing on a local deep yellow coastal sand that needs heavy applications of fertilizer to obtain good growth. Mr Turton had hoped that the effluent would supply all the nutrients that the pines needed as well as their water



The pilot plant at Lower Plenty.

requirements. But growth after 5 months indicated trace element deficiencies. Adding small amounts of copper, manganese, and zinc to the effluent before irrigation seems to have solved the problem, and the most heavily irrigated trees had grown to a satisfactory height of 2·7 m 20 months after planting.

Aquifer recharge

Another way of using sewage water would be to pump it back into underground aquifers that have become depleted through over-use. The water intended for pumping back into aquifers needs to be clean and free of salts and toxic chemicals used by industry, since groundwater is often used as a source of drinking water. The groundwaters beneath the Footscray area of Melbourne and the Botany Bay area of Sydney have become polluted over the years through trade waste being pumped into them. Pumping purified sewage water into depleted aquifers has the great advantage that the water would remain there long enough to guarantee that all disease-causing viruses had died—conventional biological treatment by itself cannot guarantee this.

South Australia gave considerable thought to recharging aquifers near Adelaide with water from the new Bolivar sewage treatment plant. But the scheme did not go ahead since, with salinity levels of up to 1600 mg per litre, the effluent is too salty. Saltiness is also one of the factors limiting the water's use for irrigation purposes.

A high salt content in purified sewage water can come from any of three sources—the human gut, washing powders, and from saline groundwater leaking into the sewers. Most of the salt in the Bolivar effluent leaks in as salt groundwater. But increasing saltiness would tend to limit the number of times water could be recycled even when salt groundwater didn't enter the sewers.

Effluent from Adelaide's Glenelg plant has been used for irrigating public lawns and gardens for more than 40 years.

Taking out salt

At the Division of Chemical Technology in Melbourne a team of scientists, led by

Conventional sewage treatment – a thumbnail sketch

The invention of sewage treatment was very much the child of necessity. The industrial revolution compounded an already horrifying sanitation problem in the cities of Europe and North America, and by the end of the 19th Century these countries were seriously doing something about it. In the United Kingdom, the Royal Commission on Sewage Disposal was formed in 1898. It sat for 15 years, and produced 10 reports. To this day its recommendations on the levels of bacterial cleanliness and organic matter in sewage discharged into rivers are used as a yardstick by many countries, including Australia.

Sewage usually consists of a mixture of household and industrial wastes. Its chemical content varies from place to place, depending on the amount of local industry and what the local water board will accept in its sewers. Existing sewage purification treatments nearly all depend on the biological action of bacteria and other single-celled organisms. These can easily be killed by toxic chemicals and antibiotics— bringing the sewage treatment plant to a standstill. Toxic trade wastes therefore have to be disposed of by means other than discharging them down the sewers.

Traditionally, sewage treatment has consisted of one or two stages. First, the raw sewage receives primary treatment, in which rags, sticks, grit, and other solids are screened off or passed through disintegrators. Oil and grease are skimmed off or coagulated, and excrement and food scraps are settled out as a sludge. Breaking this sludge down by bacterial action in the absence of air gives methane gas and a compost-like solid material.

Secondary treatment of the sewage effluent follows. In this stage nearly all of the remaining organic waste is broken down by bacterial action to give an effluent containing some bacteria and viruses, some organic matter, and nitrate and phosphate.

A number of secondary treatment techniques exist, but nowadays the activated sludge process is the one most commonly used. In this process a concentrated biologically active sludge breaks down the sewage in special aerated tanks.

Much of the sewage discharged into the oceans that surround this continent only has primary treatment. Provided the outfall pipe is long enough, the sea washes the discharged sewage away reasonably effectively.

Nutrient 'pollution'

Inland towns and cities usually discharge their sewage effluents into watercourses, and increasingly people are becoming aware of the problem of eutrophication in our lakes and reservoirs.

Eutrophication is the process in which phosphorus, nitrogen, and other plant nutrients—often discharged from sewers —cause 'blooms' of algae and other plants to grow in the water. Deterioration of the value of the lakes for recreation, for aesthetic pleasure, and as a domestic water supply often follows. In extreme cases fish die through lack of oxygen. The 'death' of Lake Erie in North America is the most notorious case of eutrophication.

Nearer to home, tests independently carried out by CSIRO and the New South Wales Water Conservation and Irrigation Commission have suggested that eutrophication is occurring in Burrinjuck reservoir as a result of pollution from Canberra's Weston Creek sewage works. Dr John Kirk, Dr Colin Williams, and Mr Paul Jakobsen did the CSIRO tests.

White scum of dead algae on Burrinjuck reservoir—Canberra's sewage effluent caused the algal growth.

Located on the Murrumbidgee river 30 km downstream of Canberra, Burrinjuck reservoir is used mainly as a source of irrigation water, and for boating, fishing, and swimming. Some shire councils obtain their drinking water from downstream of the dam.

Both surveys have indicated inorganic phosphorus levels in the surface waters of 80–100 μg per litre close to where the Murrumbidgee enters the reservoir, and levels of 40–50 μg per litre in the middle of the lake. Also, nitrogen levels in the middle agreed, being in the range of 300–340 μg per litre maximum. Current international opinion regards pollution levels of 20 μg of inorganic phosphorus per litre and 300 μg of nitrogen per litre as the threshold for eutrophication.

Stopping plant nutrients from getting into rivers and lakes requires a 'tertiary' treatment in addition to the secondary biological one. The technique most commonly used here in Australia (and at Weston Creek) is to hold the water that has received secondary treatment in ponds long enough to allow algal blooms to grow on the ponds. The algae thus use up some of the nutrients before the effluent is discharged. The method is cheap, but not very effective.

For instance, at a point a short distance downstream from where the effluent from the Weston Creek sewage works enters the Murrumbidgee, the CSIRO research group has detected inorganic phosphorus levels of 228 μg per litre. At a similar point the Department of Housing and Construction has recorded average springtime levels of 430 μg per litre. Upstream, both groups of researchers found that the inorganic phosphorus level is generally less than 10 μg per litre.

A new sewage works, the Lower Molonglo Water Control Centre, is being built at Canberra. It is designed to reduce pollution of the Murrumbidgee to a very low level, and it will supersede the Weston Creek works. This new sewage treatment plant is a hybrid: it uses the physico-chemical technique of adding lime to purify the water and remove phosphate, followed by a biological one to use up the nitrogen.

Advanced waste water treatment. D. M. Philp. *Water*, 1974, **1** (2), 8–16.

Dr Brian Bolto, is looking into using the CSIRO–ICI Sirotherm desalination process to reduce the salt content of sewage effluents. Sirotherm uses special resins to trap the dissolved ions that cause saltiness. Simply washing the resins in clean hot water allows them to be used again and again.

The Sirotherm research team expects the main use for the process in the near future will be removing salt from brackish waters from lakes, rivers, and bores that contain not more than 3000 mg of dissolved salts per litre. Sea-water is 10 times more salty, and Sirotherm cannot cope with this.

However, salinity levels of the saltier Australian sewage effluents are well within Sirotherm's range. Testing the process on purified sewage has only been proceeding for a short time, but so far trials with effluent from the physico-chemical plant at Lower Plenty have been satisfactory.

Industrial re-use

At first sight, industry may be able to make considerable use of purified waste water. It uses huge quantities of water each year. Disease-causing bacteria and viruses present in waste water would not be such a problem in industrial use as in domestic use, but some disinfection would be required. Many industrial processes need water that is free of grit and low in salts, and doesn't contain corrosive chemicals that may damage the plant. Certain other chemicals need to be absent also, depending on the particular process for which the water is required. For example, traces of phenols make water unsuitable for paper-making when the paper is to be used with stored foodstuffs.

But suitable sites for new reservoirs are becoming increasingly difficult to find . . .

In practice, substituting purified sewage for the mains water supply for industrial purposes would usually be difficult in our existing large cities. The problem is that the sewer network and the industrial areas are already established, and the sewage outfalls and industrial complexes are often far apart. It would therefore cost sewage authorities a great deal of money to pipe the purified water back to industry. Nevertheless, it may eventually be feasible to pipe water from Sydney's Malabar outfall back the five or so kilometres to the industries of Botany Bay.

The Melbourne and Metropolitan Board of Works is considering piping effluent from its new South-eastern Purification Plant at Carrum to the developing industrial complex at Westernport. After use by industry at Westernport, the water would be returned to the pipeline that will connect the purification plant to the ocean outfall 55 km away at Cape Schanck.

So far, water shortages have not become acute in any of our major cities—except occasionally during long droughts. But suitable sites for new reservoirs are becoming increasingly difficult to find, and sooner or later other sources of water will have to be found. Recycling the water in sewage should be one effective way of staving off water shortages.

More about the topic

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SEWCO, SLURP, and LUST

At the CSIRO Division of Building Research, the systems research group led by Dr John Brotchie has, for the last 6 years, been looking into using computer models to aid town planners. Their most comprehensive model is TOPAZ, which can be used to give answers to a large number of town planning problems. The researchers have also developed two sub-models, concerned with the cost of connecting burgeoning city suburbs to the main sewer network.

Aptly known as SEWCO and SLURP, these two models are intended to help planners to look at different aspects of the problem. SEWCO gives an idea of costs for trunk sewers at the planning stage, while SLURP covers sewage treatment and likely water pollution problems.

Dr Ron Sharpe of the systems group is now expanding these models to produce LUST, a new model. LUST will cover additional factors like the supply of water, stormwater drainage, and later electricity and gas.

SEWCO's cost projections may be used to evaluate the layouts of alternative sewer networks, and the alternative locations of treatment plants for various urban development patterns.

In two studies—one of Melbourne and another of idealized cities of various sizes—the researchers used 'typical' costs supplied by the Melbourne and Metropolitan Board of Works for putting in sewer networks near Melbourne. SEWCO could be applied to other cities, given the right information from the relevant local authority.

The researchers have studied sewer network costs in cities of different shapes. Supplying this service appears to be only slightly more expensive in cities developed as corridors ($39 per head for trunk sewers at the costs then prevailing) than in compact ones ($34 per head). The group has not yet costed sewer networks for satellite and linear cities.

Currently, the group is working along with the Melbourne and Metropolitan Board of Works to develop techniques for planning more efficient releases of serviced land.

Estimation of economics of scale of sewerage systems for cities of different size using a cost model. P. Ahern and J. F. Brotchie. *Institution of Engineers Conference on Computers in Engineering, Sydney, Papers*, 1974, 78–82.