Spectrum

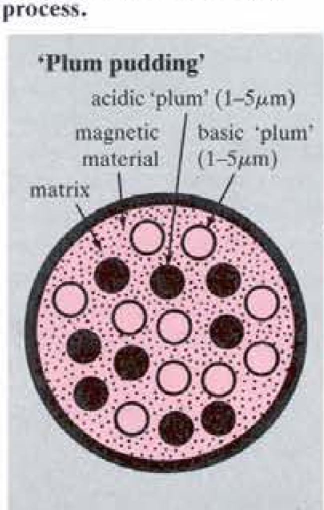
Desalinating a million litres a day

Brackish bore water, transformed into clean potable water by contact with special ion-exchange resins, should begin contributing a million litres to Perth's daily water supply next year.

The plant that will do the job, now undergoing final testing, was built at a cost of \$1·2 million at Leederville, a Perth suburb, as part of the National Water Treatment Systems Development and Demonstration Centre. It is demonstrating that Sirotherm desalination, previously employed as a batch process, can work very effectively under continuous operation using a novel magnetic particle arrangement.

Sirotherm is an ion-exchange technique; resin beads remove the salt ions from the water, and a regenerating step strips the ions from the resin, enabling its re-use. The Sirotherm system is unique in using hot water to regenerate the resin.

A tiny bead of magnetic Sirotherm resin. The acidic plums adsorb sodium ions; the basic ones adsorb chloride ions. Hot water reverses the process.



The continuous Sirotherm desalination plant at Leederville, W.A. Its twin columns (adsorber on the left, hot regenerator on the right) can treat 1 ML a day.

Ion-exchange resins are normally regenerated with chemicals, commonly acids or bases.

Batch Sirotherm has been tested at plants around Australia for more than a decade. The process was invented at the CSIRO Division of Chemical and Wood Technology, and developed in collaboration with ICI Australia Operations Pty Ltd.

Sirotherm resins take the form of tiny beads that resemble microscopic plum puddings. Each bead, about 300 μm in diameter, contains two sorts of 'plums' embedded in a matrix permeable to both water and salt. The acidic ones, microparticles of polyacrylic acid, adsorb sodium ions; and the basic polyamine microparticles adsorb chloride, sulfate, and bicarbonate ions. The reaction is reversed at higher temperatures when water increasingly dissociates into H^+ (acid) and OH^- (alkali), displacing the adsorbed ions.

The key to achieving the advantages of continuous operation has been to give the ion-exchange resins magnetic properties. This has been done by incorporating particles of iron oxide into the matrix to make the beads magnetic. The oxide is the same sort that is used in recording tape. A strong magnetic field permanently magnetizes the beads at the time of their manufacture.

Because of the magnetization, the beads clump together and settle quickly when suspended in water. If it weren't for the clumping, the beads would need to be made larger so that the process water would not sweep them away.

(In countercurrent ion-exchange systems, such as continuous Sirotherm, resin beads must resist an upward water flow — see the diagram. At Leederville, water rises through the columns at about 6 mm per second. Stirrers in the columns keep the resin and water mixed.)

The magnetic beads are smaller than their non-magnetic equivalents and, because of their enhanced surface area, have a much higher reaction speed. Consequently, smaller quantities of resin are required.

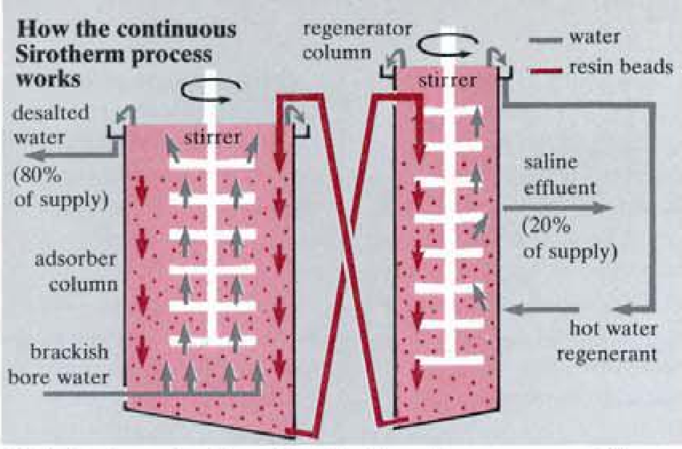
This neat scheme also forms the basis of magnetic dealkalization resins reported in *Ecos* 40.

Desalination using conventional ion-exchange resins runs into problems with the high cost of the chemicals (acid and alkali) needed to regenerate the resins. Regeneration also creates additional salt that must be borne by the environment.

The advantage of Sirotherm regeneration is that the driving force is low-grade heat, not chemical energy (although some energy is required, to operate pumps). No chemicals are used, except for small amounts of acid or alkali to adjust pH. The effluent contains virtually only the salt removed in the first place.

Continuous operation, made possible by using magnetic beads, leads to further significant advantages over the batch approach. The system uses less energy because it involves an adsorber vessel that is kept hot and a regenerator one that is kept cold (see the diagram), rather than a single unit subjected to cyclic heating and cooling: it yields more desalted water; and optimum operating conditions are simpler to maintain.

A batch system uses a fill-and-draw sequence for the regeneration step, from which it is hard to exclude oxygen. Sirotherm resins, when hot, are degraded by oxygen, so continuous operation makes life easier in this respect. Fortunately, Leederville's bore water contains no dissolved oxygen, so the only pretreatment needed is to take out some hardness ions and to remove dissolved nitrogen, which otherwise tends to form bubbles that transport beads where they are not wanted.



Resin beads moving down the adsorber column remove salt from brackish bore water moving up. The spent resin is taken to the regenerator column, where hot water washes out the salt and refreshes the beads. The regenerated beads are returned to the adsorber column to recommence the cycle.

Recent research has come up with resins that don't degrade so easily, but they haven't been developed past the laboratory bench. Such a development opens up the possibility of doing the adsorption stage in huge open tanks.

The Perth demonstration plant is a joint project between CSIRO, the Water Authority of Western Australia (WAWA), and private industry. The federal government provided $1 million for capital works, the WAWA provided the site and operating costs, and Austep Pty Ltd designed the plant after winning a tender to develop, demonstrate, and market the process.

The plant began continuous operation late last year. It takes water direct from underground (which contains 1350 mg of total dissolved solids per L, and comes up at 40°C) and produces water with a salt content of less than 500 mg per L. The yield of product water is 80%, meaning that some 20% of the water intake is heated and used for washing salt out of the resin.

Although a source of waste heat would normally be harnessed to heat the regenerator vessel, in this case natural gas has been used for convenience and ease of measurement. Heat at 100°C regenerates the resin and, after that's done, heat exchangers recover much of this energy. Even when prime fuel is used as a heat source, the system's operating cost appears competitive with the alternative processes of reverse osmosis and electrodialysis.

But waste heat, say from a diesel generator, would do. For example, Sirotherm scientists calculate that the heat from the cooling jackets of two 600-kW generators would suffice for the desalination of a megalitre of brackish water a day, in which case the heat requirement could be met at no extra cost.

However, the main advantage of the new process is the lower capital cost for large-scale plants of 20 ML per day and above.

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Continuous ion exchange using magnetic micro-resins: the continuous Sirotherm desalination demonstration plant. B.A. Bolto, E.A. Swinton, N.H. Pilkington, E.J. Fish, and N.V. Blesing. *Proceedings, International Convention of the Australian Water and Wastewater Association and the Water Pollution Control Federation, Melbourne, April/May 1985*, 282–9.

Other ion-exchange resins with magnetic properties

The magnetic properties of the Sirotherm ion-exchange resins described here have only been used to enhance the settling rate of the tiny particles. However, the CSIRO scientists are also using strong magnetic fields to attract particles of magnetic ion-exchange resin and recover them from slurries and sludges.

In collaboration with ICI Australia Operations Pty Ltd they have developed a magnetic resin with strong-base properties. The resin strongly adsorbs dissolved organic material (colour) from Murray River water when mixed with and suspended in it. Workers at the State Water Laboratories in Adelaide have shown that the water is then far easier to clarify by the conventional alum process.

With funds from the Australian Water Resources Council (AWRC), the scientists are also looking at ways to integrate the processes. After resin is stirred with the water, the alum can be added immediately or in a subsequent step.

The resin (which is expensive) must be recovered and regenerated with brine. It is likely that magnetic means will enable this to be done economically. Magnetic drum separators, as used in the Sirofloc water clarification process described in *Ecos* 31, appear promising.

The scientists have also made a magnetic resin with strong-acid properties, which attracts the heavy metals from sewage sludge.

This allows the sludge to be spread safely on land as a useful fertilizer. Again, the problem is to efficiently separate the resin from the sludge before it can be regenerated and re-used. The AWRC is providing money for this investigation too.

In metal processing, magnetic beads may be able to recover metals from leach liquors in the same way. They could also scavenge trace metals from mine waters or effluents.

Other possible applications arise in the food industry, where certain components need to be removed from fermentation slurries. A magnetic carbon with selective adsorption properties has been produced that can do this.

Bird's eye view of goose nests

The wetlands of the Top End harbour a rich variety of water birds, especially ducks and geese. One of the most numerous and most distinctive is the magpie, or semipalmated, goose — so called because of its pied markings and the very small webs on its feet.

The late Dr Harry Frith of CSIRO and Dr Stephen Davies, formerly of CSIRO and now Director of the Royal Australasian Ornithologists' Union, carried out the earliest studies of these birds during the 1950s and early 1960s. By then, magpie goose colonies had become much less widespread than they were at the beginning of the century.

The bird's breeding range used to extend from the Fitzroy River in Western Australia, around the northern coast, to at least as far south as Grafton, N.S.W. It also took in areas of

Magpie geese in flight.