A wet residue disposal pond near Alcoa's Kwinana refinery.

A 'dry' disposal area at Kwinana, showing the cracking sun-dried red mud.

Industrial wastes with potential

On the Swan coastal plain, in the south-western corner of Western Australia, three Alcoa refineries, along with a refinery owned by the Worsley Consortium, generate about eleven million tonnes of bauxite residue each year — twice the weight of the alumina produced in the refining process.

Western Australia has the dubious distinction of producing more than 40% of the Western world's 'red mud' from bauxite processing, due to the peculiarities of the Darling Range ore. Because this ore is so low grade, with its 2:1 ratio of waste to alumina produced, the refining process produces more red mud here than in other countries, where the ratio is usually about 1:1.

At the moment, the Western Australian refineries pump the residue — as a slurry of solids in caustic solution — into large holding ponds. The solids settle and most of the caustic solution is recycled. Pumps and drainage pipes remove additional caustic solution over a period of years. The industry finally reclaims ponds by covering the residue mud with a layer of the coarser residue sand and growing pastures on them.

The ponds present some environmental risks to surrounding areas. At Alcoa's Kwinana refinery, small amounts of caustic solution have leaked through minor defects in the clay layer lining the ponds, and have contaminated groundwater beneath the ponds. Furthermore, after pumping of the ponds stops, winter rains can flood them, bringing caustic solutions to the surface.

The ponds tie up quite a bit of land between them. The present area covered by red mud ponds at the three Alcoa refineries is about 650 hectares. This area increases at a rate of 40 ha annually.

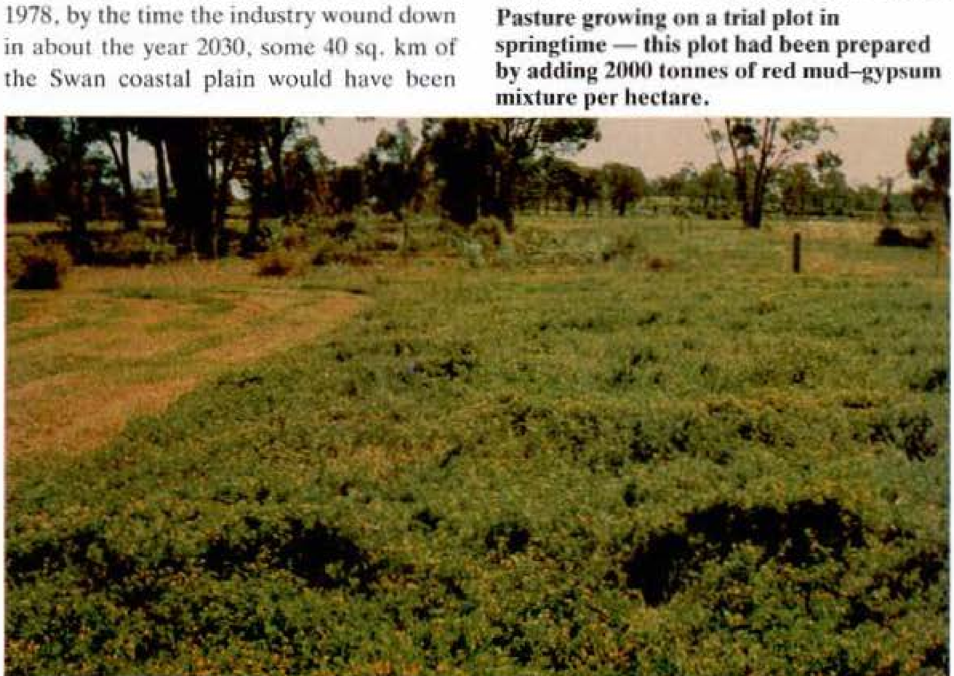
Dr Mike Thornber of the CSIRO Division of Mineralogy and Geochemistry estimated that, with the waste practices used before 1978, by the time the industry wound down in about the year 2030, some 40 sq. km of the Swan coastal plain would have been covered to a depth of 20 metres. About 23 million tonnes of caustic soda would have been used in the processing. Now, improved caustic recovery from the mud and better disposal procedures are improving the situation.

The residue consists of two fractions — sand and finer red mud. The sand component quickly lets the highly alkaline caustic pass through it. But the fine red mud holds a lot of chemically combined and dissolved caustic, and is more difficult to 'clean'.

Some has been used to make bricks, but not enough to substantially reduce the disposal problem. Possibly a discovery by Dr Jim Barrow of the CSIRO Division of Animal Production in Perth — that red mud can be used to improve local soils — will help matters.

Soil amendment

The three Alcoa refineries on the Swan coastal plain — at Kwinana, Pinjarra, and Wagerup — lie 30, 80, and 100 km south of



Pasture growing on a trial plot in springtime — this plot had been prepared by adding 2000 tonnes of red mud–gypsum mixture per hectare.

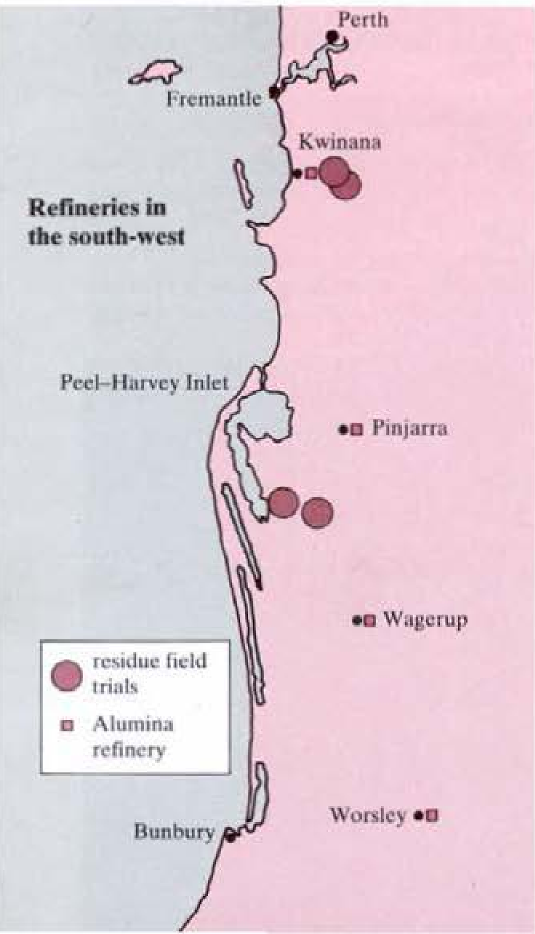
Perth respectively. Soils in the region consist of coarse acid sands that cannot retain water and added fertilizers. Further, some of the soils are difficult to wet as they repel water.

Dr Barrow's interest in red mud began when he was researching the pollution of coastal recreational areas by fertilizer constituents, particularly phosphates. Farmers in the area have to add large quantities of phosphates to the porous sandy soils to try to make them productive. These eventually leach into the groundwater and out into areas like the Peel–Harvey Inlet, causing suffocation of the marine life there through excessive growth of algae.

Dr Barrow suspected that the fine alkaline red mud from alumina processing could be used to counter the problems posed by acid sandy soils. He set up laboratory and pot trials to study the effects on pasture plants of adding red mud filter-cake — obtained by filtering red mud slurry — to the coastal plain soils.

It rapidly became clear that the red mud, even after filtering, was too alkaline to use on its own, since it contained large amounts of the alkaline salts, sodium carbonate and sodium hydroxide. The solution to this problem came from another waste product — gypsum.

Large amounts of waste gypsum are produced as a by-product of phosphate-fertilizer production at Kwinana. Until a few years ago, manufacturers discharged it into the sea, but this ceased after authorities realized that phosphate and cadmium in the gypsum caused pollution problems.



Reclaiming dried mud–gypsum mixture from a drying bed for use in soil-amendment trials.

When Dr Barrow mixed gypsum (hydrated calcium sulfate) with caustic red mud, the highly alkaline substances were neutralized, leaving limestone and dissolved sodium sulfate. Not only had he found a means of disposing of the gypsum, he had also found a way of buffering the red mud to give it a much lower alkalinity.

This buffering effect had additional significance. His laboratory studies had shown that, if the red mud was acidified, the more acid it became, the more strongly it retained phosphate. On the other hand, the more alkaline the mud was, the more strongly it retained potassium and cadmium. Dr Barrow felt that the presence of lime, precipitated from the gypsum, buffered the red mud at a convenient point on the scale — not so acid that low availability of phosphorus might be a problem, but alkaline enough so that cadmium was not very available and potassium was held against leaching.

In glasshouse pot trials, Dr Barrow found that medics could be grown on the modified red mud, particularly with the addition of phosphate, potassium, and manganese. But residual sodium sulfate seemed to limit the growth of other species such as clovers. Dr Barrow believes that this problem arose because the red mud was leached too quickly to remove sufficient sodium sulfate.

Later experience in the field showed that the slower leaching caused by rain seemed to be more effective at washing the sodium sulfate out. This, however, generates the new problem of additional sodium sulfate in the groundwater. But, as Dr Barrow pointed out, the consequence of a once-only dose of salts would be a reasonable price to pay to prevent the more serious phosphate problem.

To test red mud application on a larger scale, Mr Sam Ward of Alcoa set up field trials during 1982–84, using red mud from the Kwinana refinery and waste gypsum from a nearby superphosphate works. In experimental plots, Mr Ward, and Mr Warren Tacey and Mr John Summers, also of Alcoa, incorporated from 200 to 2000 tonnes of gypsum-treated residue per hectare into sandy soils typical of those in the Peel–Harvey estuarine system. They then planted medics and subterranean clover pasture on the treated plots.

The treatment significantly increased second-year pasture yields on all sites. The amended red mud, which has a loamy texture, increased soil water and potassium retention, and the legumes' *Rhizobium* nodulation.

'Red mud' can be used to improve local soils.

The Alcoa team had also set up special micro-plots on treated areas to collect leachate after rainfall. On these plots, they spread superphosphate to supply up to 270 kg of phosphorus per hectare — 15 times the normal application rate — to gauge the residue's ability to retain that nutrient. Their results proved that this ability was, indeed, high enough to prevent phosphorus loss into groundwater, even at very high application rates.

What are the practical possibilities? Mr Don Glenister, Alcoa's Residue Development Manager, has suggested two possible courses of action. One is to cover a lot of country quickly with a low level of residue to reduce phosphorus loss and pollution of the Peel–Harvey estuary. This would require additions of up to 200 tonnes per hectare. But such levels don't help increase pasture productivity through improved soil texture and water retention. For that to happen, you need applications of between 500 and 2000 tonnes of treated red mud per hectare of pasture soils. These levels would

Spreading the mixture onto a trial plot ...

... and mixing it into sandy soil using an earthmoving 'scraper'.

virtually replace the existing sandy topsoil with a new loamy one.

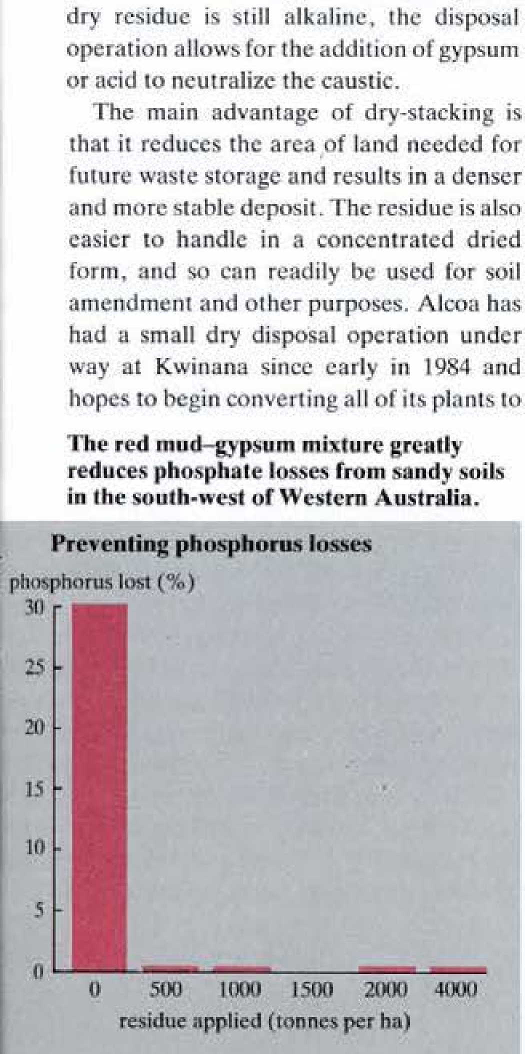
At this point, cost efficiency doesn't look good. Transporting the residue to farms and spreading it on land costs much more than storing it. So bauxite residue used in this way is not likely to absorb more than a small proportion of the total amount produced.

Dry disposal

One of the alternatives being considered by Alcoa is dry waste disposal. The technique involves distributing the residue in layers onto drying beds, where the sun dries it. The dried mud may be stacked on top of existing residue deposits rather than disposed of in new slurry ponds. Although the dry residue is still alkaline, the disposal operation allows for the addition of gypsum or acid to neutralize the caustic.

The main advantage of dry-stacking is that it reduces the area of land needed for future waste storage and results in a denser and more stable deposit. The residue is also easier to handle in a concentrated dried form, and so can readily be used for soil amendment and other purposes. Alcoa has had a small dry disposal operation under way at Kwinana since early in 1984 and hopes to begin converting all of its plants to dry disposal within the next few years. The Worsley Consortium refinery has already begun dry stacking bauxite waste.

The red mud–gypsum mixture greatly reduces phosphate losses from sandy soils in the south-west of Western Australia.



Nevertheless, in places like the Peel–Harvey Inlet area, the possible benefits of treated-residue application — increased productivity and a cleaner estuary — can't be dismissed. Alcoa is carrying out research into alternative methods of residue treatment for soil application, including mixing red mud with the acid effluent from titanium refining.

The titanium dioxide refining company, S.C.M. Chemicals, has a refinery at Australind, some 70 km from Wagerup. The Western Australian government is collaborating with Alcoa to investigate the feasibility of co-disposal.

Titanium processing leaves a residue of sulfuric acid and ferrous sulfate, or 'copperas'. At Murdoch University in Perth, a team headed by Dr Goen Ho has found that copperas-neutralized red mud has excellent phosphate-adsorption capacities. In one trial, they mixed a small amount of this red mud with leachate from heavily fertilized farming areas and found that the mixture removed up to 97% of the dissolved phosphate.

Dr Ho has also been investigating the environmental impact of red mud and its use in pollution control. The very qualities that make the red mud useful for agricultural purposes are being applied to pollution problems.

With the assistance of Perth's Metropolitan Water Authority, Dr Ho has been devising a technique for purifying sewage effluent so it can be used to recharge groundwater. Recharging of groundwater is usually carried out by pumping previously treated effluent through a spreading (or 'recharge') basin, in which the soil further filters the effluent. But sandy soils filter inefficiently. Dr Ho discovered that the addition of treated red mud to the soil increased the filtration rate of heavy metals, bacteria, and viruses from the effluent. He believes that this use of red mud could even be extended to lining rubbish tips to prevent leaching of pollutants into groundwater.

The main problem associated with the use of treated red mud is the addition of salts, especially sodium sulfate from gypsum-treated mud, to soils. Dr Ho observed that — due to soil porosity and high winter rainfall — most of these salts leached into the groundwater during the first year of treatment, and became diluted and dispersed to safe concentrations.

As Mr Glenister points out, the idea of using bauxite residues on soils is still a radical one. The long-term effects of treated red mud have yet to be evaluated. And equitable transportation cost-sharing arrangements — between State departments, refineries, and farmers — would have to be worked out. But the benefits of increased pasture productivity, useful employment of industrial wastes, and a cleaner environment may make the red mud hard to refuse.

Mary Lou Considine

More about the topic

Possibility of using caustic residue from bauxite for improving the chemical and physical properties of sandy soils. N.J. Barrow. *Australian Journal of Agricultural Research*, 1982, **33**, 275–85.

Soil improvement with bauxite residue. W.H. Tacey, S.C. Ward, K.J. Summers, and N.J. Barrow. *Journal of Agriculture (Western Australia)*, 1984, **3**, 92–3.

Phosphorus movement through sandy soils and groundwater in the Peel–Harvey catchment area. I. Cameron and G.E. Ho. *Department of Conservation and Environment, Western Australia, Bulletin* No. 160, 1984.

Growth and fertilizer requirements of annual legumes on a sandy soil amended with the residue from bauxite refining. S.C. Ward. *Reclamation and Revegetation Research*, 1983, **2**, 177–90.