Red mud: cutting pollution and boosting yields

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Contents

55  Red mud - cutting pollution and boosting yields

60  Developing improved varieties of subterranean clover

66  Biological control of doublegee
67  Israeli weevil could help fight doublegee
69  Doublegee decline and the dock aphid
71  Fungi may be another weapon

73  New medics show promise in the northern wheatbelt

77  Holding our edge in noodle wheat

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A by-product from the refining of bauxite ore in the South-West is proving a bonus for agriculture.

When spread over the land, not only is it improving soil quality, but it is helping to prevent leaching of phosphorus and the consequent massive algal blooms in the waterways.

Bauxite residue is also showing considerable promise in human and animal effluent disposal systems, composting urban waste, sewage treatments and as a road base. Western Australia is now in the forefront of this research which is attracting world-wide interest.

Background

Four alumina refineries are located in Western Australia, which together produce more than 14 million tonnes of bauxite residue a year and provide a major management issue for refining companies such as Alcoa of Australia.

Finding a practical use for the residue, commonly known as red mud, has become a challenge for many, and in 1982 Dr Jim Barrow at CSIRO in Floreat Park showed that it could be used to improve the sandy soils of the State's South-West.

When spread thickly over the ground (up to 2000 t/ha or 20 cm thick) using heavy earthmoving equipment, bauxite residue virtually eliminated the leaching of phosphorus from the soil.

At about the same time in Germany, research was showing that much smaller quantities (20 t/ha or a 0.2 cm layer) of bauxite residue improved the soil's retention of phosphorus by 50 to 70 per cent. While not answering the disposal question, application at these levels appeared useful for agriculture and the environment.

Recent trials by Alcoa of Australia, the Department of Agriculture and the Chemistry Centre of Western Australia have confirmed that Western Australian bauxite residue can both improve phosphorus retention of sandy soils and increase the growth of pasture and vegetables.

Nature of bauxite residue

Bauxite ore, the raw material for aluminium, is mined in the Darling Range then crushed and treated with hot caustic soda. About a third of the original ore is removed as alumina, leaving the bauxite residue. The residue is a mixture of fine silt called red mud, and a fine red sand.

The red mud component of the residue is proving the more useful to amend sandy soils. It has a pH above 11 (strongly alkaline) because of residual caustic soda present and is equivalent in alkalinity to 10 per cent calcium carbonate or agricultural lime. The final soil pH will depend on the amount of bauxite residue added, the initial pH and the ability of the soil to resist change.
With the opening of the Dawesville Channel, we need to halve the phosphorus flow into the estuary to reduce the algal blooms. To achieve this only about 20 t/ha of bauxite residue will need to be applied to most sands in the catchment.

After a Public Environmental Review, the Environmental Protection Authority (EPA) recently approved the use of bauxite residue as a soil additive in the Peel-Harvey catchment. Approval is restricted to existing farming and commercial horticulture, however the EPA is prepared to consider other applications and areas.

Productivity gains

After 20 t/ha of bauxite residue was applied to pasture, productivity improved by 1 t/ha dry matter or about 25 per cent (see top graph). However gains depend on the initial pH and soil productivity.

Bauxite residue has been applied to horticultural soils at between 50 and 250 t/ha, depending on the initial soil condition and the types of crops to be grown. The benefit is mainly limited to reducing phosphorus loss from relatively new enterprises on the grey sands. Older market gardens have already built up their soil fertility and few gains are expected from the addition of bauxite residue, although turf growers have reported improvement.

The residue should retain the phosphorus for at least five years and probably longer on most sandy soils. It is not yet known how long the improvement in pH will last for lighter red mud applications of 10 to 80 t/ha, but research is continuing.

How much to apply

Being alkaline, bauxite limes the soil. It is important to avoid overliming pastures because trace elements such as manganese, zinc and copper then become less available. After liming or applying bauxite residue, extra trace elements may have to be applied.

TOP GRAPH: Clover hay production rose by about 20 per cent when red mud was spread over the pasture at 20 tonnes per hectare.

BELOW: Phosphorus concentration in the stream flow from treated and untreated catchment.

When spread on, or combined with sandy soils it has several benefits:

- The finely crushed residue has a very large surface area that is rich in iron and aluminium oxides and captures phosphorus.
- The remaining alkaline material (from the caustic soda) may reduce the availability and mobility of the phosphorus in solution and simultaneously increase the pH of acid soils.
- The residue improves soil water retention and reduces water repellence by increasing the soil surface area.
- It may improve the use of potassium fertiliser.

Algal problems

Phosphorus from gardens, farm land, piggeries, dairies and sewage treatment plants on the Peel-Harvey catchment's coastal plain enters the streams and drainage system. This phosphorus eventually reaches the Peel Inlet and Harvey Estuary causing development of extensive algal blooms.

Trials have shown that when sandy soils in the catchment were treated with red mud at 80 t/ha the run-off water contained 70 per cent less phosphorus in the first year (see lower graph).
Red mud being spread on farmland.

A paddock at Amarillo near Mandurah appears red after a recent dressing with bauxite residue. Some people have expressed concern about the aesthetics of top dressing with red mud, but it usually disappears after a year.

To avoid overliming, the amount of bauxite residue applied should be based on the soil pH and its resistance to change (pH buffering capacity).

When bauxite residue is applied to pasture at about 20 t/ha it appears as a thin surface film. The existing pasture is not smothered and does not need to be re-established. The residue is lightly harrowed into the soil at the end of summer to avoid disturbing the pasture. Pasture management then continues as before although some initial superphosphate may need to be applied. About 200 kg/ha of superphosphate is often needed in the first year, but this will depend on the amount of phosphorus present as shown by a soil test.

More bauxite residue can be applied to horticultural soil than pasture because it can be mixed more deeply. The exact amount will depend on the initial pH, the history of the site and the crops to be grown. Rates between 50 and 250 t/ha are being investigated.

**Costs**

Bauxite residue is bulky. Application costs depend on distance from the stockpiles at Kwinana, Pinjarra and Wagerup.

Extraction from stockpiles costs less than $1.50 per tonne but if gypsum is required the cost rises to more than $2.50 per tonne. Transport is about 10 cents per tonne per kilometre; loading adds another 50 cents per tonne and spreading costs between $1.50 and $2.50 per tonne.

For a property 25 km from a stockpile, the cost would be about $6/t or $60 to $120/ha when applied at 10 to 20 t/ha.

**Where bauxite residue can be used**

Bauxite residue improves the phosphorus retention of sandy surfaced soils because they contain few fine materials. Both the deep sands and sands over clay lose phosphorus rapidly because of poor retention at the surface.

The coastal plain of the Peel Inlet and Harvey Estuary catchment covers about 190,000 ha. About 90,000 ha may benefit from bauxite residue.

Red mud being spread on farmland.
These alternative septic systems have been patented. They have been approved by the Western Australian Health Department and are being installed in several shires. Interstate local government authorities are also interested.

The Meredith Trial
A large sub-catchment at Meredith, west of Harvey, comprising 4,000 ha has been treated with bauxite residue. About 30,000 tonnes of residue has been transported from the nearby Alcoa Wagerup refinery and spread at about 20 t/ha on most of the farmed and fertilised land. This will be a large scale trial to monitor the performance of the red mud in retaining phosphorus and to assess side affects. The amount of phosphorus leaching from the catchment is expected to be halved.

The Meredith project has been funded mainly by Alcoa and a National Landcare grant. It is a cooperative venture involving input from the Meredith Land Conservation District Committee, local councils, the Department of Conservation and Land Management and the Department of Agriculture.

Future research
Trials have begun to find the best fertiliser rate for soils spread with bauxite residue. We also need to know how much longer fertiliser will last on these soils and whether other fertilisers behave in a slow release manner like phosphorus.

When applied at 250 t/ha, the pH increase has lasted for more than 10 years. Applications below 250 t/ha have not been in place long enough to determine the rate of pH change, but are being monitored.

Different methods are being developed to neutralise bauxite residue to reduce its pH and salinity. These will lower the pH of the residue so it can be used on land planted to potatoes and other crops that have problems associated with high alkalinity.

Effects on heavy clay soils are also being investigated.

Non-agricultural uses
New, on-site effluent disposal systems that use bauxite residue have been developed to replace the conventional septic tank and leach drain. Conventional leach drains can pollute the groundwater with nutrients and microbes when the water table is high.

These sandy soils are responsible for up to half of the 140 tonnes of phosphorus that flow into the estuary each year. Applying bauxite residue could reduce the amount of phosphorus leaching into the estuarine system by up to 30 tonnes each year.

Composting and mulching
The manufacture of useable compost from municipal waste is currently limited by its contamination with heavy metals from items such as lead or nickel-cadmium batteries. It is impossible to reverse this contamination.

Mixing bauxite residue with the compost reduces the mobility of heavy metals and other contaminants which then reduces their availability to plants and the soil solution.

Bauxite residue at less than 30 per cent by volume, is mixed with municipal waste before composting. Composted rubbish for use in landscaping will make an alternative to landfill. The final compost is denser and more stable than conventional compost and the organic matter lasts up to five times longer. This bauxite residue compost retains...
nutrients and moisture extremely well, and its use will also help reduce water use and pollution.

Use of bauxite residue in composting is being investigated in a joint venture between Alcoa of Australia, Perth City Council, the Western Australian Government and Murdoch University.

Another trial has started at the Pinjarra sewage treatment plant where phosphorus-rich, treated effluent had been discharging from ponds into a stream that flows to the Murray River and into the Peel-Harvey estuary. The annual discharge contains about two tonnes of phosphorus.

The effluent stream is being diverted and pumped onto a four-hectare artificial basin lined with bauxite residue (amended with 5 per cent gypsum) at 750 t/ha and rotary hoed to a depth of 25 cm. Grass will be grown on the basin to harvest the nutrients captured from the effluent by the bauxite residue.

The first winter inundated the ponds and made it impossible to grow pasture, however the bauxite residue reduced phosphorus discharge by more than 70 per cent. Performance of the system in reducing nutrients and other contaminants will be monitored for five years.

Storm water basins
Lining of storm water infiltration basins with 35 per cent bauxite residue reduces nutrient loss from residential subdivisions. The bauxite residue is rotary hoed into the basins to a depth of 30 cm and the surface lightly compacted. This reduces the nutrient run-off and the biochemical oxygen demand (BOD) which can result in oxygen being consumed in streams and killing fish. It also reduces suspended solids or particles which smother water life and reduce light levels in streams. Many inorganic pollutants such as heavy metals are also removed.

Dairy effluent ponds
Dairy effluent ponds have been constructed for use in clay soils in areas which are often irrigated and have a high water table. Compact effluent treatment systems are needed in these situations because of the high land value and proximity of drains to milk sheds.

The ponds store fresh effluent from which the liquid is allowed to evaporate. (This is used later as a fertiliser.) As a safety measure, red sand channels have been constructed to prevent phosphorus and other nutrients reaching the drains in case of overflow.

Road base
Bauxite residue can also be substituted for construction materials such as road base. This reduces the need for quarrying. ☑

Further reading