



Let me start by thanking the AMEC organising committee for the opportunity to present an overview of my research interest over the past 30 years – beneficial re-use of mining wastes. From what started as little more than a subject of academic interest, the area has grown in recent years to the point where it can influence the development of the Swan Coastal Plain for generations to come.



The structure of this presentation is to briefly discuss on site use of mine waste before moving on to the main focus, which is beneficial re-use by third parties at off site locations. We then need to discuss the distinction between a material being classified as a 'waste' or 'product', as the regulatory framework for use of 'wastes' or 'products' are very different – particularly when it comes to assigning liability when the materials are not used appropriately.

Yesterday, we heard David Smith discuss the Strategic Assessment of the Perth and Peel Regions or SAPPR. One anticipated outcome from this assessment is establishment of planning procedures that promote the availability of waste derive materials to supplement supply of basic raw materials for the development of Perth into the Peel region as it becomes a city of 3.5 million people by 2050.

I will then present a brief overview of results from field trials assessing the use of three mine waste products for amendment of sandy soils on the Swan Coastal Plain to minimise leaching losses of phosphorus from fertilisers.

ON SITE USES FOR MINE WASTE

- Road base
- Clean fill
- Hardstand
- Concrete
- Waste storage embankments & uplifts
- Rehabilitation



3

Opportunities for Mine Waste Utilisation in Western Australia

Most mine sites make use of a large proportion of mine waste for their own needs. In fact, the trend for new base metal projects to utilise deep underground mining methods rather than commencing operations with a deep open pit can lead to a shortage of construction materials.

Examples of on-site use of mine wastes include:

- Road base for construction of haul roads and access roads.
- Clean fill for accommodation and processing facilities
- Hardstand areas such as the ROM pad, contractors yards.
- Aggregate for concrete.
- Clay, tailings & rock materials are used for water storage dams and uplifts of tailings storage facilities.
- And finally for rehabilitation requirements such as abandonment bunds and rehabilitation of waste landforms and disturbed areas.

OFFSITE USES FOR MINE WASTE

- Road construction - road base & aggregate
- Fertilisers - copper, manganese & zinc
- Acid neutralising applications - treatment of acid mine drainage & acid sulfate soils
- Pozzolanic materials (Fly Ash) - cement & concrete production
- Nutrient removal - domestic waste water & stormwater treatment systems
- Soil amendment



4

Opportunities for Mine Waste Utilisation in Western Australia

Moving to offsite uses:

- Main Roads often approaches mine sites in remote areas to supply materials for road construction in preference to establishing a new quarry or gravel pit. Benign mine waste can be used for road base, creek and river crossings and crushed aggregate for sealing.
- Some mine wastes are being used by fertiliser companies for adding trace elements to their products – usually copper, manganese and zinc. It is important to have these materials tested because there are regulations that limit allowable concentrations of toxic heavy metals such as cadmium, lead and mercury.
- Some alkaline mine wastes, such as bauxite residue, have been used for treating AMD and acid sulfate soils.
- The use of pozzolanic materials such as Fly Ash from coal combustion power stations for concrete production is widespread around the world. There are large stockpiles of fly ash from the Muja and former Kwinana power stations which are not being used because of concerns of elevated heavy metals contents.
- Iron and calcium rich mine wastes such as bauxite residue, crushed laterite and basic slag are being used in WA to strip nutrients from domestic waste water and stormwater treatment systems.
- And finally for amendment of sandy soils, which is an application that is effectively unique to the southwest of WA.

REGULATORY FRAMEWORK

Waste Or Product?

- Department of Water (DoW). Water Quality Protection Note 50 (June 2010). Soil amendment using industrial by-products to improve land fertility:
 - A general guide on obtaining environmental approval for substantial application of industrial by-products used for soil amendment.
 - **Proven benefit:** correct deficiencies in fertility and moisture retention, adsorb otherwise mobile contaminants such as phosphorus, improve soil structure by the addition of compost, alter soil pH or foster ion exchange.
 - **Risks to the environment:** soil and/or water acidity or alkalinity; salinity; excess nutrient application, water run-off or leaching, radioactive materials, heavy metals, plant or animal toxins and pathogens.



5

Opportunities for Mine Waste Utilisation in Western Australia

As mentioned at the start of the presentation, the labelling of a material as either a 'waste' or 'product' has significant implications for both the supplier and end-user.


In 2010, the Department of Water issued Water Quality Protection Note 50 as a guide for Soil Amendment Using Industrial By-Products to Improve Land Fertility.

This note presented information on the process for obtaining environmental approval for substantial application of industrial by-products used for soil amendment.

It also describes the requirement for a proven benefit, which may include correcting deficiencies in fertility and moisture retention, adsorbing otherwise mobile contaminants such as phosphorus, improving soil structure by the addition of compost, altering soil pH or fostering ion exchange.

It then discusses risks to the environment that need to be considered include altered soil and/or water acidity or alkalinity; salinity; excess nutrient application, water run-off or leaching, radioactive materials, heavy metals, plant or animal toxins and pathogens.


REGULATORY FRAMEWORK



Waste Or Product?

Department of Environment Regulation (DER) Guidance Statement: Regulating the use of waste-derived materials (November 2014):

DER will develop and publish material guidelines for the production and use of different WDMs, for example, fill materials and construction products. Where a material guideline for a particular WDM has not been developed and issued by DER, DER may assess and make a determination on the production and use of a WDM on a case-by-case basis, subject to DER's priorities and resources. DER will consider only submissions which include the information required and in the form detailed in a guideline, which is currently under development.




6

Opportunities for Mine Waste Utilisation in Western Australia

DER is currently working on a regulatory framework to promote the development of waste-derived materials for beneficial re-use. In November last year, they released a Guidance Statement: Regulating the use of waste-derived materials.


DER will be the agency responsible for regulating Waste-Derived Materials. WDM's approved for use as soil amendments will be referred to as "Soil Products".

SAPPR PROJECT



Strategic Assessment of the Perth & Peel Regions (SAPPR)

- Protection of supply of basic raw materials:
 - Sand
 - Limestone
 - Clays
 - Hard rock
 - Gravels



7

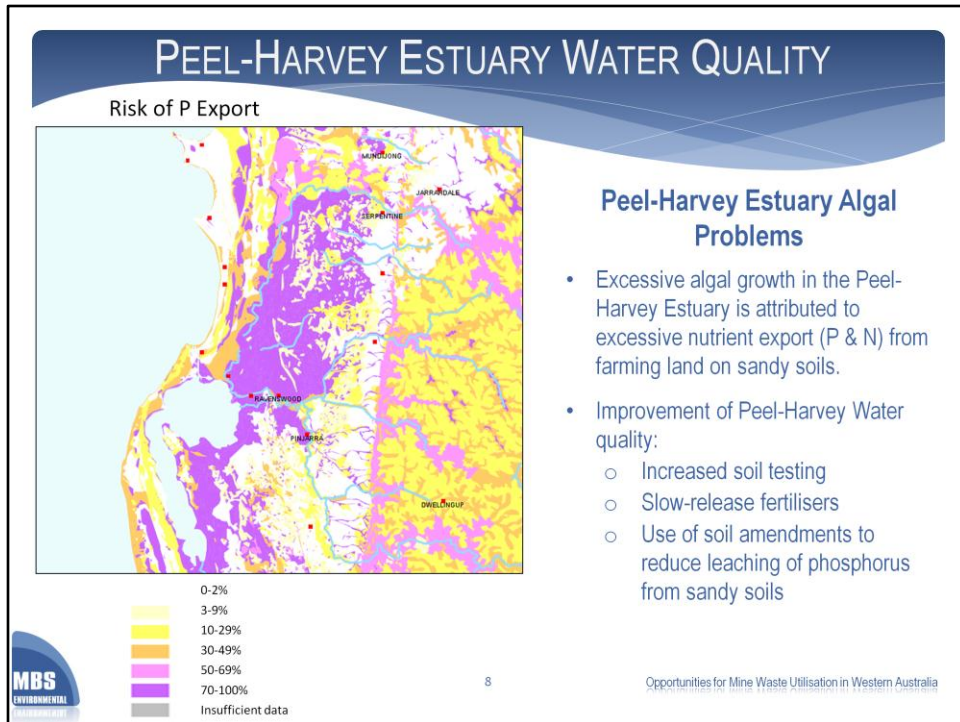
Opportunities for Mine Waste Utilisation in Western Australia

On to the SAPPR Project.

Believe it or not, Government has identified a real risk that the Perth metropolitan area may actually run out of clean sand, despite being located on one of the largest sand plain deposits in the world.

The problem is that Perth has historically been preferentially developed on the higher ground, for example Mt Hawthorn, Mt Lawley, Mt Pleasant, Mt Claremont and Doubleview, rather than low-lying areas which were often swamps infested by mosquitoes or used by market gardeners to grow vegetables. As a result, much of the basic raw materials such as clean sand and limestone that formed the high land is quarantined because of urban development.

As the city expands, we now in-filling much of the low-lying areas. There is a general requirement that all new developments require a soil depth of at least two metres above the maximum known water-table. This places a huge demand for clean fill – up to 20,000 cubic metres per hectare. The government has recognised the need for greater planning to ensure the supply of cheap, high quality basic raw materials – including sand, limestone, clays for brick-making, hard rock and gravels meets the predicted demand.



Another important driver is the need to improve water quality in the Peel-Harvey Estuary. A major study in the 1980s identified leaching of phosphorus from fertilisers applied to sandy soils on the Swan Coastal Plain as the major cause of nuisance algae in the Peel-Harvey Estuary. The Dawesville Channel was built to increase flushing of nutrients to the sea, but it was also recognised that fertiliser usage had to be reduced by at least 50%.

Options investigated include:

- Increased soil testing
- Slow-release fertilisers
- Use of soil amendments to reduce leaching of phosphorus from sandy soils.

FILL AND CONSTRUCTION MATERIALS

Requirements for clean fill & various construction materials near Kwinana*:

- James Point Port, Stage 1: 0.3 Mt of fill and 3 Mt of materials.
- Kwinana Quay Project: 7 - 22.4 Mt of fill & 3.6 - 4 Mt of materials.
- Keralup Development: 0 - 10 Mt of fill & 1 Mt of road materials.
- Wungong Urban Water: 16.5 Mt of fill & 0.4 Mt of road materials

Potentially Useful Materials:

- Fly ash and bottom ash from power production.
- Slag from HiSmelt steel production.
- Phosphogypsum from fertiliser production.
- Foundry sand.
- Construction and demolition debris.
- Cement kiln dust and lime kiln dust.
- Bauxite residues - "Red Lime" and "Red Sand"TM (ReadyGrit®).



* Centre for Sustainable Resource Processing Project 3B3:
Kwinana Industrial Inorganic By-Product Re-Use.

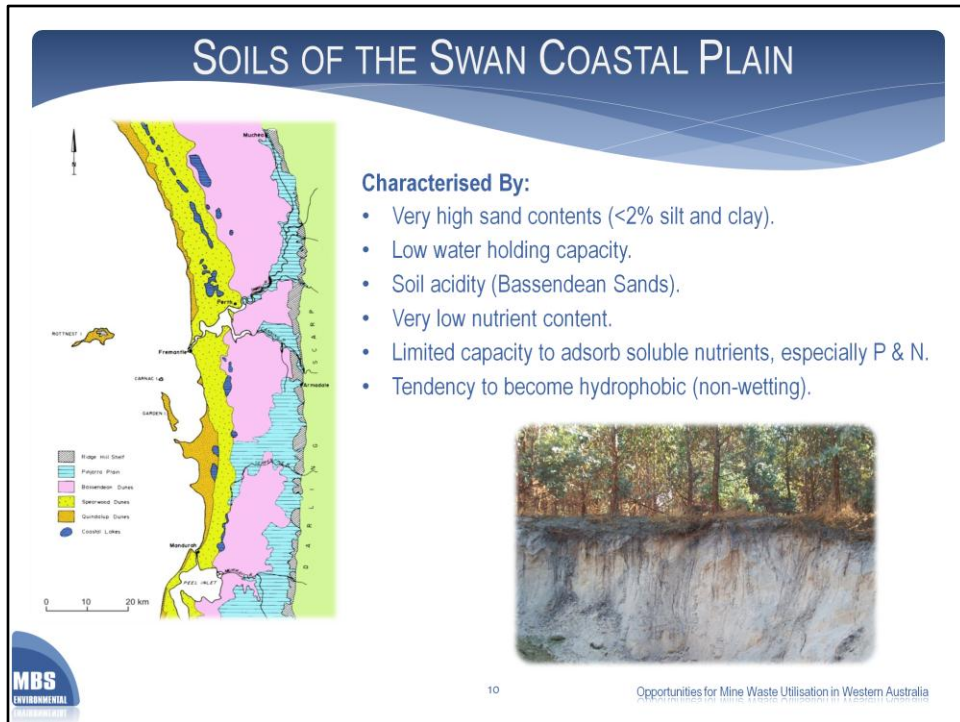
9

Opportunities for Mine Waste Utilisation in Western Australia

These are some figures to demonstrate the projected requirements for clean fill and various construction materials near Kwinana:

- These four project alone have requirements for approximately 40 million tonnes of fill and construction materials.

Potentially useful waste materials identified by the Centre for Sustainable Resource Processing include fly ash and bottom ash from power production, slag from the HiSmelt steel process, phosphogypsum from fertiliser production, foundry sandy, construction and demolition debris, cement kiln dust and lime kiln dust and several bauxite processing residues. These photographs show a test pad constructed by Alcoa in Wellard to test the geotechnical properties of a sand product from their Kwinana plant known as Red Sand or Ready Grit.



A few words on the soils of the Swan Coastal Plain, which are arguably the most nutrient impoverished soils in the world.

The Swan Coastal Plain comprises a series of three sand dune sequences which increase in age with distance from the coast. They vary in age from the coastal Quindalup Dunes which are only several thousand years old, to the yellow Spearwood Dunes and finally the Bassendean Dunes which are up to 250,000 years old and among the oldest soils in the world.

As a result of their extended history of weathering and leaching, they are characterised by:

Very high silica sand contents.

Very low water holding capacity.

Soil acidity in the Bassendean Dunes – the Spearwood Dunes range from slightly acidic to slightly alkaline, while the Quindalup Dunes are alkaline due to their lime content.

The Bassendean sands, or silver loams as they are known by farmers, are unique because of their ability to leach soluble phosphorus – most other soil types contain iron and aluminium which are very effective at locking up phosphorus from soluble fertilisers.

The Bassendean sands also have the unusual characteristic of becoming hydrophobic or non-wetting.


SOILS OF THE SWAN COASTAL PLAIN



This slide shows typical examples of the Quindalup, Spearwood and Bassendean sands – noting the non-wetting properties of the grey Bassendean sands. This problem can be effectively overcome by increasing the clay content above 3%.

BAUXITE PROCESSING RESIDUES

"Red Mud" or Alkaloam®	"Red Sand" or ReadyGrit®	"Red Lime"
<ul style="list-style-type: none"> - A mixture of iron oxides & silica from extraction of bauxite ore with caustic soda (Bayer Process). - Characterised by high alkalinity & relatively high silt content. - Has been trialled as a soil amendment for sandy soils in the Peel Harvey Catchment since the 1980s (pasture and vegetable crops). 	<ul style="list-style-type: none"> - Similar to "Red Mud", but most of the particles are sand-sized (>0.3 mm). - Has been trialled as a substitute for limestone in road construction (Main Roads) - Has been investigated as fill for industrial land developments (Landcorp). - Has been trialled for use as a top-dressing sand and bunker sand. 	<ul style="list-style-type: none"> - Produced as a by-product from the process of converting sodium carbonate to sodium hydroxide for the Bayer process. - Has a very high Neutralising Value (calcium carbonate & tri-calcium aluminate). - Has been trialled as a substitute for agricultural lime.



12

Opportunities for Mine Waste Utilisation in Western Australia

Extraction of alumina from bauxite using the Bayer Process produces approximately six tonnes of residue for each tonne of alumina.

Alcoa produces three residues:

Red Mud or Alkaloam – which is a fine textured highly alkaline by product consisting mainly of iron oxides and silica. It has been trialled as a soil amendment for sandy soils in the Peel Harvey Catchment since the 1980s for pasture and various vegetable crops.

Red Sand" or ReadyGrit® - which is similar to Red Mud, but has been processed to separate the sand-sized fraction.

It has been trialled by Main Roads as a substitute for crushed limestone in road construction, and has been investigated as fill for industrial developments for Landcorp. It has also been trialled for use as a top-dressing sand for recreational turf as well as bunker sand for golf courses as it complies with the US Professional Golfers Association's stringent criteria for bunker sand and greens.

Alcoa also recovers a lime product, christened "Red Lime" in a process to convert recovered sodium carbonate back to caustic soda by adding quick lime. It has a very high Neutralising Value and has been assessed in field trials as a substitute for agricultural lime.

USE OF BAUXITE RESIDUE FOR ROAD CONSTRUCTION



13

Opportunities for Mine Waste Utilisation in Western Australia

Here are a few photographs showing Red Sand being used for road construction southeast of Mandurah.



These photographs show Red sand being used to top-dress the oval at Fairbridge Farm, which is owned by Alcoa.

Previous attempts to top-dress the oval using yellow sand were not successful because the sand was blown away by strong prevailing easterly winds.



As you can see from the top left photograph, the oval was in much better condition after a couple of months.

We have also looked at rejuvenating golf course fairways by injecting Red Sand and compost blends into the soil profile.

And the bottom right photograph shows a bunker at Kwinana Golf Course constructed with Red Sand.

MINERAL SANDS PROCESSING RESIDUES

NUA (Neutralised Used Acid) or Ironman Gypsum:

- Produced by neutralising a sulphuric acid solution containing high concentrations of iron & manganese with lime.
- Main components are gypsum, iron oxides & manganese oxides.
- Has a very high adsorption capacity for soluble phosphorus.
- Has been characterised by CSIRO to evaluate potential risks associated with low-level heavy metal & radionuclide contaminants.
- Has been trialled as an amendment for sandy soil on turf farms.



Another product we have assessed is a residue from mineral sands processing known as NUA – for neutralised used acid – or IronMan Gypsum.

It is produced by neutralising a sulfuric acid leach solution containing dissolved iron and manganese with lime.

The main components in this dark fine solid material are gypsum, iron oxides and manganese oxides.

It has an extremely high adsorption capacity for removing soluble phosphorus.

It has been characterised by CSIRO and other to evaluate potential risks associated with low-level heavy metal and radionuclide contaminants.

Most of the field work has been directed at its use as a soil amendment on turf farms.

LIME AMENDED BIOCLAY®

Lime Amended BioClay® or LaBC:

- Sewage at the Subiaco Waste Water Treatment Plant is treated with lime to form a sterile stabilised product known as Lime Amended Biosolids (LAB).
- LAB & other forms of biosolids are approved for agricultural use under controlled conditions.
- LAB is also blended with lateritic clay overburden ('oxide') waste from the Red Hill Waste Facility to produce LaBC.
- LaBC is characterised by high pH (~13), a moderate nutrient content (N, P and trace elements) & a moderate capacity to adsorb soluble phosphorus.
- Has been studied in laboratory trials by ChemCentre and field trials conducted by Water Corporation in the Ellen Brook catchment.



17

Opportunities for Mine Waste Utilisation in Western Australia

The final product I wish to discuss is a sewage treatment product developed by the Water Corporation.

- Sewage at the Subiaco Waste Water Treatment Plant is treated with lime to form a sterile stabilised product known as Lime Amended Biosolids.
- LAB and other forms of biosolids are approved for agricultural use under controlled conditions.
- LAB is also blended with lateritic clay overburden waste from the Red Hill Waste Facility to produce LaBC. The clay material is effectively 'oxide' waste produced at most gold mines in the Goldfields region.
- LaBC is characterised by high pH (~13), a moderate nutrient content (N, P and trace elements) and a moderate capacity to adsorb soluble phosphorus.
- Has been studied in laboratory trials by ChemCentre and field trials conducted by Water Corporation in the Ellen Brook catchment.

LABC APPLICATION



18

Opportunities for Mine Waste Utilisation in Western Australia
ANALYSED FOR WASTE UTILISATION IN WESTERN AUSTRALIA

This photograph shows a typical Bassendean Sand in Ellen Brook after it has been amended with LaBC applied at rates of 50 and 100 tonnes per hectare.

LABC APPLICATION



19

Opportunities for Mine Waste Utilisation in Western Australia

Does it work?

The plot on the left has not been treated with LaBC, but received a typical application of fertiliser. The plot on the right was treated with 50 tonne of LaBC per hectare without any additional fertiliser. The difference in plant growth is quite obvious.

ELLEN BROOK FIELD TRIAL

Three Products Assessed:

- NUA at rates of 10, 20 & 50 t/ha.
- Alkaloam at rates of 10, 20 & 50 t/ha.
- LaBC at rates of 50 & 100 t/ha.



Trial Assessed By:

- Leachate quality (pH, EC, alkalinity/acidity, nutrients & metals) in samples collected from installed lysimeters.
- Plant growth (dry matter yields).
- Uptake of nutrients & metals by plants.
- Changes in soil chemistry at 0-10, 10-20, 20-30 & 30-40 cm.



20

Opportunities for Mine Waste Utilisation in Western Australia



For the remainder of the talk, I will quickly present the results of a field trial set up by the Swan River Trust in partnership with ChemCentre and DAFWA to evaluate benefits and potential risks for these three products at a trial site in Ellen Brook.

Three products were assessed:

- NUA at rates of 10, 20 & 50 t/ha.
- Alkaloam at rates of 10, 20 & 50 t/ha.
- LaBC at rates of 50 & 100 t/ha

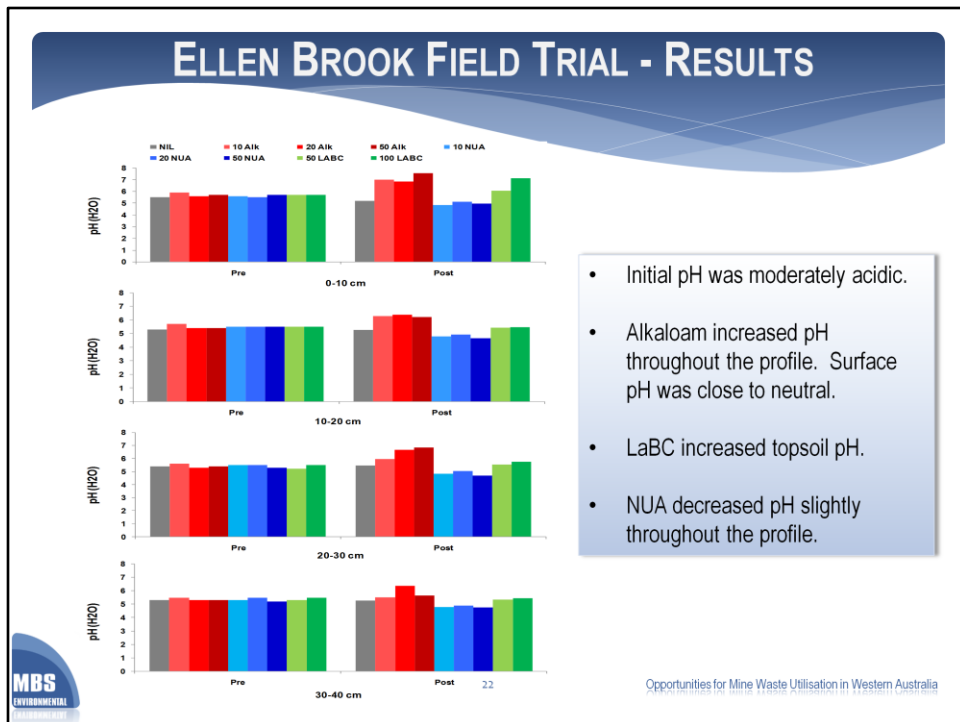
The trial was assessed by measuring:

- Leachate quality (pH, EC, alkalinity/acidity, nutrients and metals) in samples collected from installed lysimeters.
- Plant growth (dry matter yields).
- Uptake of nutrients & metals by plants.
- Changes in soil chemistry through the soil profile.

ELLEN BROOK FIELD TRIAL



In addition to the small treatment plots shown in the previous slide, the treatments were replicated in 50 metre strips that are clearly visible in this Google Earth image – the dark strips being treated with NUA.



And now for some of the results:

This slide shows results for soil pH at four depths through the soil profile.

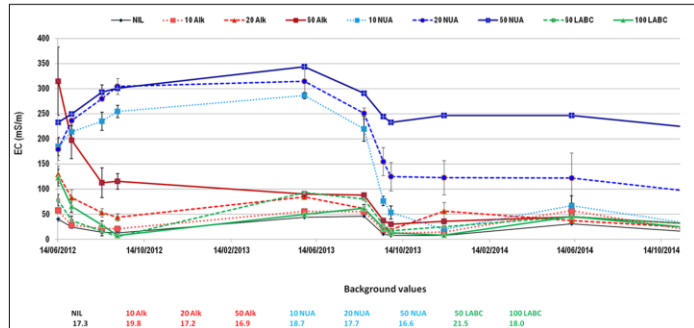
The charts on the left show that the soil prior to amendment was moderately acidic, with pH values around 5.0 throughout the profile.

Alkaloam was very effective at neutralising this acidity – with pH of the topsoil increasing to 7 at the highest rate. There were significant pH increases throughout the profile to a depth of 40 cm.

Although NUA is a circum-neutral to slightly alkaline product, there were slight decreases in soil pH throughout the profile.

Use of the highly alkaline LaBC product increased topsoil pH to neutrality, but there was very little change in subsoil pH after 1 winter – the alkalinity of LaBC is less soluble than the alkalinity in Alkaloam.

ELLEN BROOK FIELD TRAIL - RESULTS



- "First flush" leachates were slightly saline, especially NUA at all rates and Alkaloam at 50 t/ha.
- EC values of leachates from Alkaloam and LaBC plots decreased with time.
- EC values of leachates from NUA plots corresponded to dissolution of gypsum.



23

Opportunities for Mine Waste Utilisation in Western Australia

This chart shows the electrical conductivity of leachates over a three year period.

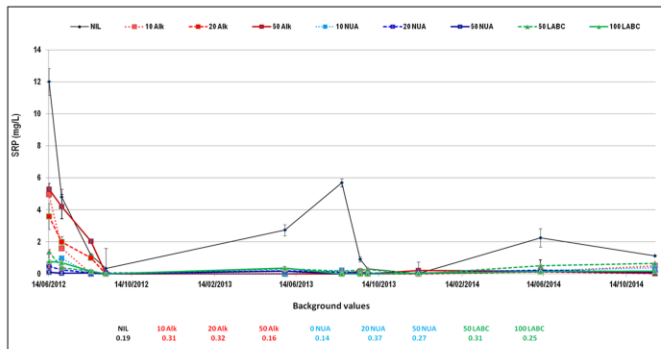
EC values of leachate from the NIL plots were very low throughout the trial : effectively rainwater in – rainwater plus nutrients out.

"First flush" leachates were slightly saline, especially NUA at all rates and Alkaloam at the highest rate.

High EC's throughout the first year for all three NUA rates is due to the "wash out" of gypsum.

Alkaloam, LaBC and the lowest NUA rate leachates were close to background by the third winter.

ELLEN BROOK FIELD TRIAL - RESULTS



- Winter "first flush" concentrations of soluble reactive phosphorus (SRP) from the unamended plot were very high.
- Concentrations of SRP were lower for all amendment treatments, especially in the second and third years.
- The initial effectiveness for reducing P leaching increased in order Alkaloam < LaBC < NUA.



24

Opportunities for Mine Waste Utilisation in Western Australia

This is probably the most important slide – it shows the concentrations of soluble phosphorus in leachates over three years.

The problem with current fertiliser practices is clearly evident in this slide – the initial concentration of P in leachate from the NIL treatment, which received a typical application of fertiliser in autumn was 12 mg/L – about 100 times higher than the target value in river water of 0.1 mg/L.

Concentrations were lower for all amendments in the first winter, especially NUA and LaBC.

Very low concentrations were recorded for all amendments in the second and third winters. The improvement was attributed to greater incorporation of the amendment after the first year – the initial amendments were only top-dressed and not ploughed in to the soil.

CONCLUSIONS

- Some mine wastes possess physical & chemical properties that make them suitable for beneficial re-use.
- There is no standard process for reclassifying waste materials to products. The proponent needs to demonstrate to all stakeholders that they are fit for purpose & can be used with minimum risk to human health & the environment.
- Urban & industrial development of the Perth & Peel regions may limit the quantity & quality of basic raw materials such as clean fill, sand, limestone, gravels and clays.
- Alumina refining & mineral sand processing industries are well positioned to supply materials required for sustainable development of the Perth & Peel regions.



25

Opportunities for Mine Waste Utilisation in Western Australia

In Conclusion:

Some mine wastes possess physical and chemical properties that make them suitable for beneficial re-use.

Currently there is no standard process for reclassifying waste materials to products. It is up to the proponent to provide evidence to demonstrate to all stakeholders that they are fit for purpose and can be used with minimum risk to human health and the environment.

Urban and industrial development of the Perth and Peel regions may limit the quantity and quality of basic raw materials such as clean fill, sand, limestone, gravels and clays.

And finally, alumina refining & mineral sand processing industries are well positioned to supply materials required for sustainable development of the Perth & Peel regions.

ACKNOWLEDGEMENTS

Contributions of the following organisations are acknowledged:

- Alcoa World Alumina Australia.
- Water Corporation.
- ChemCentre.
- Swan River Trust.
- Iluka Resources.
- Department of Agriculture and Food.
- MBS Environmental.



I would like to acknowledge the following organisations for their contributions over the years:

Thank you for your attendance

MBS ENVIRONMENTAL

4 Cook Street

West Perth WA 6005

Tel: (08) 9226 3166

Fax: (08) 9226 3177

Email: info@mbsenvironmental.com.au

Web: www.mbsenvironmental.com.au



27

Opportunities for Mine Waste Utilisation in Western Australia

Thank you for listening – any questions?