1. INTRODUCTION

This project supported research on mine tailings in both the People's Republic of China and in Australia. In the People's Republic of China, research on tailings stabilisation and revegetation was conducted through the Maanshan Institute of Mining Research, in collaboration with the Maanshan Iron and Steel Company. In Western Australia, the project contributed to research and training on strategies for revegetating gold tailings at the Boddington Gold Mine. This project was a collaboration between the Centre for Land Rehabilitation (UWA), Murdoch University, Boddington Gold Mines, and Alcoa World Alumina – Australia.

2. SUMMARY OF RESEARCH OUTCOMES

Research in P.R.C. was successful in developing vegetation strategies for the tailings material and also demonstrated that chemical stabilisation of the surface was technically and economically possible. The research conducted and the outcomes generated are described in detail in attached Appendices, both for the component conducted in the People's Republic of China (Appendix 1) and that in Western Australia (Appendix 2). A summary is presented below.

2.1 Metallurgical Mine Tailings Rehabilitation Research

Research at Maanshan focused on constraints to vegetation establishment, or on developing chemical dust suppression, in order to stabilise the surface of tailings generated from the beneficiation of iron ore. Dust generated from the tailings surface has been recognised as an air quality issue in the local area.

2.1.1 Revegetation

Principle constraints to plant growth on the tailings material were:

- drought stress, reflecting high summer temperatures in air and soil
- poor capacity to hold water for plant growth, reflecting the sandy texture of the tailings, and
- low organic matter and nitrogen deficiency

As a result, drought tolerant plant species must be selected for revegetation, and nutrients must be applied. Plant species recommmended included *Trifolium repens*, *Cynodon dactylon*, Crossing Chinese Pennisetum and *Amorpha fruticosa*. A combination of shrubs and grasses was recommended to achieve rapid soil cover and extensive root development.

2.1.2 Soil reconstruction

- clay materials stripped during open pit mining were suitable as substitute topsoils, avoiding additional disturbance from topsoil stripping
- the optimum depth of clay as 'soil' was 20 cm

2.1.3 Potential contaminants in soil and vegetation

- only Cd in the tailings exceeded environmental quality standards
- drainage water from the tailings area was good quality and could be used for irrigation
- plant material grown on the tailings was suitable as feedstuff

2.1.4 Dust suppression using chemical stabilising agents

- a compound known as 'GL-1 Inorganic Surface Hardener' successfully stabilised the tailings surface, even with exposure to rain, freezing, high temperatures and large temperature changes
- the compound is relatively simple, and economic to produce

2.2. Gold Residue Rehabilitation Project at the Boddington Gold Mine

Research in this project included plant establishment, plant nutrition, hydrology, and soil physics and chemistry. It was centred on a large field experiment in which various depths of topsoil and subsoil were placed on 'oxide' gold residue. The research aimed to increase understanding of the operational issues of spreading topsoil on residue, together with vegetation growth and plant-water-use on the various soil treatments. The make-up of the vegetation community best-suited to this unique soil environment is unknown, therefore a wide range of plant species were included.

2.2.1 Machinery access and site trafficability

- it was predicted through modelling studies, and demonstrated in practice, that vehicles with low ground-pressure could move safely over the residue mass. These included a specially-adapted 'multi-spreader', and wide-tracked dozers
- multiple passes of earth-moving scrapers over localised areas did soften the hard residue surface and highlighted the need for care in planning machinery use on the residue

2.2.2 Vegetation establishment and growth

- respread topsoil was essential for establishment of vegetation from seed. Seedling establishment on bare residue was extremely poor.
- after two growing seasons, vegetation growth was superior on plots receiving the shallowest layer of topsoil, suggesting that early access of plant roots to the tailings was an advantage
- plant diversity and density were similar in all treatments
- Best-performing plant species included those from local vegetation communities, as well as species from other areas which were adapted to salinity and or water-logging.
- vegetation grew most strongly on areas with added compost, in response to the additional nutrients it contained

2.2.3 Soil development

- added gypsum (30 or 60 tonnes) decreased the pH of the residue by more than one pH unit
- addition of gypsum reduced exchangeable sodium from 24 to 3 cmol/kg in the surface 10cm
- the depth of amelioration due to gypsum addition was greatest (50-100cm) near cracks in the residue mass
- salinity of the upper 10 cm of the residue has declined since the soil layers were spread, but some seasonal increases in salinity in shallow topsoil have occurred during the dry summer period
- plant roots preferentially explored coarse-textured layers, voids, cracks, or planes of weakness in the residue, rather than areas of massive fine-textured material

2.2.4 Water quality and modelling water balances

- surface run-off from the plots is less than anticipated, with the network of cracks in the residue providing a preferential path for water flow
- water run-off quality is within prescribed guidelines for livestock water quality and is neutral to slightly alkaline
- dye tracers can be used to define how water moves within the residue profile, the extent to which layers of cracks are connected and movement of salts in the cracks
- modelling has predicted that a seasonal wetland will develop in a low-lying depression in the middle of the residue area

2.2.5 Postgraduate and undergraduate research, and communication of outcomes

- funding for this project has included support for a PhD student, and has provided the basis for a successful application to the Australian Research Council for an additional PhD scholarship. Both students are based at UWA.
- the research project has supported 13 undergraduate research students in 3 years, from both Murdoch University and UWA
- outcomes from the research were presented at 'Soils 2000 - Conference of the Australian Soil Science Society (WA Branch)' and at 'Remade Lands 2000 - International Conference on the Remediation and Management of Degraded Land' (Appendix 3)
- the research site has hosted international researchers from United Kingdom, Colombia, Germany, Switzerland, India, Canada, New Caledonia, Belgium and Indonesia
- international mining representatives and regulators from the United States, Ghana, Mali, Tanzania, South Africa, France India and the Caribbean have visited the site as an example of best-practice residue rehabilitation

3. TRAINING

Mr Shen Yuan Wei, a Senior Engineer from the Maanshan Insitute of Mining Research spent 12 months at UWA in 1999 / 2000, learning concepts and techniques in soil science and plant nutrition (Appendix 4).

3.1 Research Training Program

As the basis for his research training, Mr Shen completed an extensive program of physical and chemical characterisation of iron ore tailings and soils from the Mt Tom Price mine of Hamersley Iron Pty Ltd. Substantial assistance was received from Hamersley Iron for this research training. A report describing this research is attached (Appendix 5).

3.2 Short Courses Attended

In addition to training in research techniques, Mr Shen was able to attend a selection of relevant short courses and workshops offered by the Centre for Land Rehabilitation and by the Soil Science & Plant Nutrition Group. These included:

- *Environmental Monitoring for Mining* - a two-day short course focusing on the principles and latest technology for water, soil, vegetation, fauna, air, and noise monitoring (September, 1999)

- *Soil Technology for Contaminated Land* - a five-day course dealing with classification and chemistry of soils, assessment and remediation of contaminated sites, and relevant legislation (November, 1999)

- *Soil Biological Fertility* – a two-day workshop focused on the potential for maximising the biological fertility of soil and its benefit to crop production and soil sustainability (February 2000)

- *Soil Science and Plant Nutrition Seminar Series*, the weekly series of seminars were conducted during semesters 1 and 2

4. INSTITUTIONAL VISITS

4.1 Visit by Assoc. Prof. David Jasper to MIMR

Assoc. Prof. David Jasper (Director, CLR) visited the Maanshan Institute of Mining Research on October 13 and 14, 2000. During the visit, Assoc. Prof. Jasper and scientists from MIMR inspected the 'simulated field plots' at the research institute. A range of plant species were being assessed for their ability to grow in the tailings material (see attached MIMR Report).

The field experiment site on a tailings dam belonging to GuShan Iron Mine was also inspected. At this site, a range of treatments using the surface stabilising agent 'GL-1 Inorganic Surface Hardener' were being compared. This compound was effectively binding the surface material and thus minimising dust generation. Its performance in laboratory conditions was supported in the field experiment, which exposed it to actual environment conditions.

4.2 Visit by Personnel from MIMR and GuShan Iron Mine to Western Australia

In November 2000, Mr Wang Yun Min (Vice-Director, MIMR), Mr Nie Ai Cheng (Manager, GuShan Iron Mine) and Mr Cai Shu Ren (Maanshan Iron and Steel Company) visited the Centre for Land Rehabilitation. Major activities over the four days were as follows:

- The group visited the Boddington Gold Mine, accompanied by Assoc. Prof. David Jasper and Ms Li Jian (UWA PhD student). Mr Warren McGrath (Project Co-ordinator) and BGM environment staff assisted in a tour of the mine and the residue rehabilitation experiment. The various soil treatments and revegetation strategies were discussed in detail and were of great interest to the MIMR group.
- Visit to the Australian Centre for Geomechanics (Professor Yves Potvin, Director; Ms Christine Neskudla, Centre Administrator).
- Travelled to Pilbara to visit the operations of Hamersley Iron at Paraburdoo, Channar and Dampier, with Mr Rod Davies (Hamersley Iron) and Mr Jianbo Shen (UWA Visiting Researcher).
- Visited WA China Technical and Economic Research Fund, Perth (Mr David Bachmann, Mr Peter Ciosis).