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Land & Water Link

Oxygen probe boon for mining

Australia's mining industry is well known for setting international benchmarks for good environmental management. It's not an easy job. One of the worst problems the mining industry faces is sulfidic mine waste oxidising and – together with water – forming sulfuric acid.

Leaching of sulfuric acid into surface water and groundwater is highly damaging to the environment. Dr Brad Patterson, an environmental chemist with CSIRO Land and Water says, 'Currently, managing these wastes costs the Australian mining industry around $60 million a year'.

'The conventional response to this problem has been to try and prevent water and oxygen from reaching the sulfidic wastes by covering them with either a blanket of earth or synthetic covers.'

Even though this treatment is a good start, it is still possible for oxygen to penetrate the covering. Until recently, it has been difficult and costly for industry to monitor the ongoing effectiveness of covering sulfidic mine wastes. Some remote mine waste sites might only be tested for the presence of oxygen once or twice a year.

Now, a CSIRO-developed probe that addresses this problem will greatly improve the mining industry's ability to minimise contamination from mine wastes.

Photo: Bill van Aken

The oxygen probe is convenient, effective and inexpensive. Tests at a Western Australian site show that the probe can survive under the most corrosive conditions of high acidity. It can provide a continual and reliable monitoring system from remote sites linked by mobile phone and modems to data collection centres in regional and city centres.

With accurate measurements of the oxygen concentration in covered mine wastes, the mining industry can move swiftly to prevent environmental damage. CSIRO's contribution to the environmental standards of the Australian mining industry is likely to have flow-on benefits around the world, as the probe is suitable for use in most mine sites.

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Measuring the health of Adelaide's coastal waters

CSIRO will coordinate a major investigation into the ecological health and sustainability of Adelaide's coastal waters on behalf of the South Australian Government.

The study has been commissioned in response to concerns about the condition of Adelaide's rivers and coastal waters, says Manager of the CSIRO Environmental Projects Office, Dr David Fox. 'It will be conducted in three stages over a four-year period. CSIRO through the Environmental Projects Office has been commissioned to undertake Stage 1 of this study with the view to implementing the full scope of works for subsequent stages.

'Working closely with South Australian state agencies, we will study a wide range of chemical, physical and biological processes in the water systems, to assess their current condition and to see how sustainable they are. In the first instance, we will be investigating sea grasses and sediment transport', explains Dr Fox.

The Adelaide Coastal Waters Study will focus on an area of the Gulf of St Vincent – from Point Gawler north of the city to Sellicks Beach in the south. Waters within 20 kilometres of the shoreline will be examined, including the Port River estuary.

The $4 million project will involve scientists from various research institutions including CSIRO Land and Water, CSIRO Marine Research and CSIRO Mathematical and Information Sciences. The project is being funded by SA Water, the SA Environment Protection Authority, Transport SA, the SA Coast Protection Board, three metropolitan Catchment Water Management Boards (Patawalonga, Torrens and Onkaparinga), Mobil Adelaide Refinery and TXU Torrens Island – with additional support from the SA Conservation Council and the Local Government Association.

'This study aims to set an excellent standard for the assessment of the human impact on coastal waters and environments', says Dr David Fox.

'It follows a similar project we carried out on Port Phillip Bay for the Victorian Government. There, we found that Melbourne's bay was basically in better shape than many people had thought – but continued care and sound management were needed to keep it in good condition.

'The Port Phillip Bay study set a world standard for this type of environmental assessment. It involved a team of marine biologists, sedimentologists, oceanographers, water experts, physicists, atmospheric researchers and chemical analysts.

'In the case of the Adelaide study,' says Dr Fox, 'the aim is to try to identify the main impacts that human activities have on the area's coastal aquatic processes and lifeforms'.

'We'll be measuring things like runoff from stormwater into the coastal zone, underground seepage, nitrogen emitted by vehicles and industry which dissolves into the sea, plus the effects of activities like boating and littoral construction – and assessing how the natural marine and estuarine systems, plants and animals cope with them.'

Photo courtesy of PIRSA Marine Habitat Program

Sampling the condition of seagrass beds in coastal waters off Adelaide in the Gulf of St Vincent

The study will seek to answer questions like:

- What will be the impacts on water and sediment quality (nutrients, chlorophyll, turbidity, toxicants) of turning off specific discharges from Wastewater Treatment Plants, or re-routing them, or achieving a specified decrease (or increase) in catchment/stormwater loads?

- What are the effects of current beach replenishment and coastal protection programs – or possible future alternative programs – on sediment balance, sedimentation on reefs, water quality and coastal ecosystems?

- What is the current rate and nature of seagrass loss, what are the principal processes determining seagrass loss rates, and how will those rates respond to proposed changes in management?

- What are the processes associated with seagrass regeneration and the effects of management action on them, and is it possible to reverse seagrass decline once the reasons for the loss are determined?

As a starting point, historical data and information will be used to pinpoint gaps in existing knowledge of chemical, biological and physical processes occurring in Adelaide coastal waters. Then the study will build on this, drawing on the combined expertise of a scientific committee to design and review highly focused research projects to fill these gaps.

The Adelaide Coastal Waters Study will be managed by Dr Fox and coordinated locally by David Ellis from CSIRO Land and Water's Waite Laboratories in Adelaide. The Adelaide office will coordinate the scientific investigation, act as a focal point for communication across the project team and agencies, collect and analyse the data and consult with the local community.

Dr Graham Harris, Chief of CSIRO Land and Water, is senior scientific adviser to the study.

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Silicon boosts sugar production

Photo: Bill van Aken

Adding plant available silicon to their soils will boost cane production by as much as 70% for some North Queensland farmers.

Joint research underway by scientists from CSIRO Land and Water based in Townsville together with scientists from the Queensland Bureau of Sugar Experimental Stations, indicates that the loss of plant available silicon is a key factor behind falling sugar yields.

Many soils in north Queensland are showing a dramatic decline in fertility due to long-term monoculture over the past 100 years. CSIRO scientist, Suzanne Berthelsen explains, 'Silicon levels are naturally low in the tropics because of the significant weathering due to the heavy rainfall and high tropical temperatures. Levels are further depleted by continuous planting and sugarcane's inherently high requirement for silicon.'

'It was difficult to pinpoint silicon depletion in the soils', says Suzanne, 'because sugarcane varieties growing in the region seem to have adapted to the declining levels by improving their ability to accumulate silicon.'

After testing the soil from various cane-growing areas in the wet tropics, it became clear there was a link between low soil silicon and low yields.

'The news was not good for cane farmers because we found through our soil tests that 67% of the soils under sugarcane in the Tully/Innisfail area alone are sub-optimal for silicon and sub-optimal to marginal for sugarcane production.'

In an effort to determine how best to replace lost silicon, a number of silicon-rich substances were tested. 'Yields improved dramatically. Some farms produced a very satisfying 70% more millable cane.'

'We knew that nitrogen, phosphorus and potassium were important for sugarcane growth, but the remarkable increase in sugar yields suggests that silicon is another vital plant nutrient. Silicon should now be treated as an integral part of any fertiliser strategy associated with cane production.'

Adequate silicon nutrition protects plants from insect and fungal diseases and prevents micronutrient toxicities and other nutrient imbalances. Silicon may also improve water-use efficiency and enhance root growth and structural strength.

'Now we need to find inexpensive sources of silicon to make soil enhancement viable for the growers.

'All of our experiments with different sources of silicon have show an improvement in yield, with the best results from calcium silicate slags imported from the United States. The slags produced more cane stalks, with a larger diameter and growing to a greater height. Good results were also obtained from the other, locally produced sources including cement, mill ash and cement building board by-product.

'With inexpensive, locally produced sources of silicon, the significantly increased yields could benefit the farmer as much as $1000 per treated hectare if sugar prices are at $260 a tonne.

'A very satisfying result', concludes Suzanne Berthelsen.

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'Silicon should now be treated as an integral part of any fertiliser strategy associated with cane'

Photo: Bill van Aken

Photo: Peter Franzmann

Tavurvur Volcano near Rabaul (PNG) which was sampled in the search for high temperature iron and sulfide oxidising micro-organisms

Search for the secrets of undiscovered lifeforms

Deep within a laboratory in Perth, CSIRO Land and Water scientists are searching for new lifeforms. If they can trace these creatures, they might in time persuade them to share with us the secret of extracting metals from ore in a way that causes less environmental damage than traditional smelting or pressure-leaching.

There are no guarantees that these lifeforms actually exist. After all, what are the chances of finding a living creature that lives in near-boiling water and eats ground-up rocks for breakfast? But the scientific team led by microbiologist Dr Peter Franzmann is hopeful that it can track them down and persuade them to work for us. And to begin their search, these scientists are not looking to the stars, but at rocks from right here on Earth.

Naturally, these are not your average rocks. They are samples that were collected from some of the most extreme environments that humans can reach: undersea volcanoes or 'hydrothermal vents'. And the lifeforms that Peter and his team are hoping to find are not bug-eyed monsters, but microorganisms such as bacteria or primitive archaea.

'The prize that we are looking for is mineral sulfide-oxidising bacteria that operate at temperatures between 80°C and 100°C ', says Dr Franzmann. 'By oxidising minerals at high temperatures, these bacteria could potentially increase the rate and yield of metals extracted from ore in a process called bio-oxidisation.'

Australia's mining industry, which generates $37 billion in mineral exports, is becoming increasingly sensitive to environmental issues, and to the necessity of reducing operating costs due to decreasing commodity prices, especially for extracting metals from low-grade ores. The major competing technologies for metal recovery from mineral sulfides are smelting, bio-oxidation and pressure leaching. Pressure leaching plants involve a high capital cost and are usually only cost-effective for mineral extraction from large, high-grade deposits. Smelting is becoming less favoured on environmental grounds.

Bioleaching is now becoming accepted in the industry as a viable alternative to other process options. Although it is considered to be the mineral extraction process that causes the least damage to the environment, the slow rate of the process when compared with other technologies is a barrier to its wider uptake.

The challenge for researchers is to increase bio-oxidation rates and metal yields, through bioprospecting for better strains of leaching microorganisms, better reactor design, genetic improvement of strains, improved processing methods and better understanding of the microbial process of leaching.

Peter explains, 'Previous research has shown us that both the rate and total yield of the biological release of copper from ores such as chalcopyrite can be improved if organisms that can oxidise the mineral at high temperatures, up to 70°C, are used. We want to push those limits even higher, up to 100°C'.

In 2000, a research voyage was launched to seek out undersea volcanoes and source new microorganisms that gain their energy through the oxidation of mineral sulfides at these temperatures, and through this process, release metals into solution. This project was the result of collaboration between researchers in CSIRO's Divisions of Land and Water, Minerals, Marine Research, Molecular Science, and Exploration and Mining – together with the

Photo: Peter Franzmann

Luke Zappia samples a shallow thermal marine spring in the vicinity of Rabaul (PNG)

Geological Survey of Papua New Guinea. Collection was carried out with the approval of the Government of Papua New Guinea and PNGbioNET.

The cruise was centred in the undersea, volcanic region of the Bismark Sea, to the north of the main island of Papua New Guinea. The researchers also collected from the island of Lihir, which contains a geothermally heated gold mine with rock temperatures of about 100°C at the mine wall, and from the vicinity of the active Tavurvur Volcano near Rabaul.

Peter Franzmann and CSIRO Land and Water technician Luke Zappia were on the cruise, which turned out to be a memorable experience. Several potentially significant samples, teeming with fragile microbes, were retrieved from turbulent depths kilometres beneath the ocean surface where volcanic chimneys pump mineral fluids straight into the seawater amid gouts of smoke and steam.

Peter recalls, 'One of the samples we found was a huge undersea chimney – a giant black smoker, the biggest ever brought to the surface – retrieved from the bed of the Bismarck Sea. We have small sub-samples of this preserved in freezers for further study.'

Dr Franzmann's post-doctoral researchers Jason Plumb and Wendy Robertson are grappling with the difficult task of teasing the target microorganisms from the samples.

'Jason and Wendy are enriching for the bacteria that operate at the temperatures we need. We don't know what the success rate will be because this has not been done before. The early attempts are encouraging, but it has turned out to be difficult to obtain good growth of the target organisms, probably due to the tough conditions under which enrichments are made – a pH of less than 2.0 along with the high temperatures, with only ground-up rocks to dine on!'

Dr Franzmann concludes, 'This is science with a risk, but if successful, the rewards could be great.'

'Nonetheless, we think we have microorganisms growing under these conditions and we hope that as they reveal their secrets, we will have greater success.'

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Mapping the environment – from space

In the future, we will be turning to earth observing satellites in order to better understand our terrestrial land and water resources.

Dr Alex Held, a remote sensing specialist from CSIRO Land and Water, expects this to soon be the case. He will be working with images from a new 'demonstration satellite' that even now is circling the globe – analysing the data to test its application to environmental monitoring.

The first Earth Science New Millenium Satellite was launched by NASA in November last year, as part of the EO-1 (Earth Observing-1) mission, designed to showcase the potential of new sensor technologies for mapping and monitoring a number of features of the Earth's surface. CSIRO is participating in this NASA experiment as one of ten science teams, drawn from research institutes in the US, Canada, Singapore and Australia.

The Australian science team, led by Dr David Jupp from CSIRO's Earth Observation Centre, involves scientists from various CSIRO Divisions – Land and Water, Mathematics and Information Sciences, Forestry and Forest Products, Sustainable Ecosystems, and Exploration and Mining.

On board EO-1 is a sensor called 'Hyperion', developed by NASA and the US aerospace industry to highlight future potential for this technology. 'This is very exciting', says Dr Held, 'because it is the first time that such a sensor will be in space, and capable of producing repetitive images at a global scale'.

Hyperion is an 'imaging spectrometer'. It takes snapshots of the earth from space in hundreds of different spectral bands ('colours'). Imaging spectrometers can be used to detect and measure the quantity of specific chemicals, special minerals, sediments in water or special pigments in plants. If this is done in two dimensions in the form of an image, the chemical nature and location of materials on the ground can be accurately identified.

With the previously existing earth observing satellites, this type of analysis is very difficult to do in detail. EO-1, however, enables an unprecedented combination of high spatial and spectral resolution.

Under Dr Held's leadership, CSIRO Land and Water scientists will be testing environmental applications of the Hyperion data over specifically selected research sites.

'In particular we will be using the Hyperion data to evaluate its utility in mapping rainforests, mangroves and coral reefs in tropical Queensland, forest conditions in south-eastern Australia, arid and woodland vegetation in the Northern Territory and water quality in Moreton Bay, Queensland.'

Hyperion is the precursor for 'operational' satellites such as the proposed Australian ARIES-1 satellite, which will circle the globe for several years, mapping the world's resources and monitoring our changing environment.

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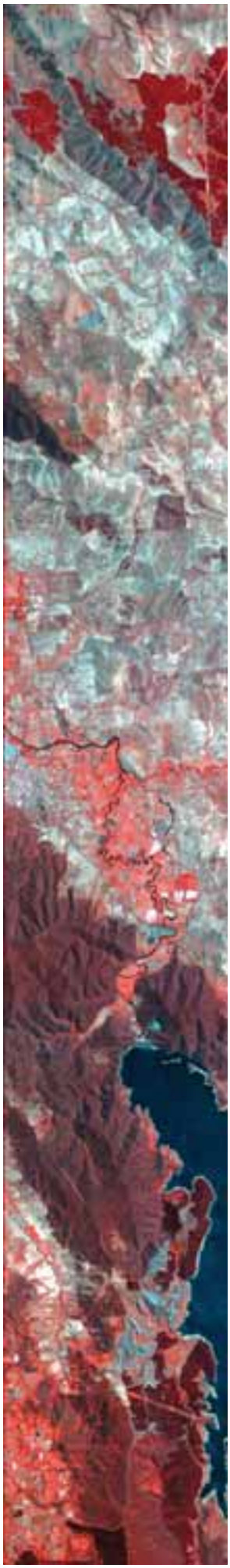

Tumbarumba research site, NSW. Satellite image courtesy NASA

Mallee farmers profit from sustainable cropping practices

Farmers in the Mallee regions of South Australia, New South Wales and Victoria are achieving higher profits together with environmental benefits, through intensive cropping systems and improved management practices.

The Mallee Sustainable Farming Project began four years ago, in a collaborative bid to determine whether there were limitations to productivity gains when trialing new farming practices in Australia's low rainfall Mallee region. Now it appears that low rainfall is the very factor underpinning the sustainability of this region – because it has been shown that with sound crop and paddock management farmers can both manage soil water and boost yields.

Through a series of research trial plots (Core Sites) at Waikerie (SA), Werrimull (Vic) and Euston (NSW) and monitored farmer paddocks (Focus Paddocks), researchers have assessed crop rotations, stubble retention, fertiliser rates, tillage and herbicide use for their effects on crop diseases, soil biota, wind erosion and groundwater recharge.

By monitoring productivity, water use efficiency and profitability on focus paddocks located in all areas across the Mallee, it has been possible to compare the economics of different farming options.

CSIRO Land and Water researcher Mr David Roget has been involved in the project from its inception. He points out that this has been a farmer-driven exercise. 'Two-way communication has been the key to setting up successful trials and is a critical element in interpreting the results and having outcomes adopted.'

David Roget says, 'We have found that farmers need to address five key issues if intensive cropping is going to be a success, and also that these issues need to be tackled on a paddock by paddock basis due to the inherent variability of many soil characteristics'.

'Firstly, farmers need to know the effective rooting depth and what is limiting it.' Rooting depth indicates the size of the bucket from which plants can extract water and nutrients. This determines the ability to store pre-season rainfall, to recover leached nutrients and to benefit from applied fertilisers. Root barriers such as boron and sodicity reduce effective rooting depth.

'Farmers also need to understand their deep nitrogen profiles. Nitrogen (N) is essential for productive plant growth, but it must be in the rootzone to be useful. Nitrogen availability varies markedly between paddocks due to differences in rotation, effectiveness of legumes, mineralisation rates and losses due to leaching. Deep nitrogen profiles help significantly in determining rotation choice and fertiliser requirement. Deep N measurements are more accurate the closer to sowing they are taken.

'Phosphorus levels are another vital ingredient', adds David. A very strong relationship between the level of plant available phosphorus (P) and water use

efficiency has been seen across the Focus Paddocks. At the Core Sites an increase from the district average of 10 kg P/ha to 15 kg P/ha has consistently shown yield and economic benefits.

'Early sowing is important for all crops in order to maximise the use of available soil moisture. It is especially important with break crops like canola, which should only be considered as opportunity crops and sown when there is an early break in the season and there are good levels of stored soil moisture.

'Finally', says David Roget, 'strategies for grass weed control are required if intensive cropping – especially multiple cereals – is going to be successful'.

He encourages farmers to work with local agronomists and advisers to interpret the five key issues for their soil types and rainfalls.

'We now have ample evidence that intensive cropping systems based on scientific advice is paying dividends for farmers in the Mallee, with higher yields, better gross margins and improved soils. The more intensive cropping systems with higher inputs results in a greater return of plant residues to the soil. This increases the soil microbial activity which aids in nutrient availability, disease suppression and erosion control.

David Roget emphasises, 'The environment is also a winner, as once we get the agronomy right – maximising water use and profitability – farmers will have the flexibility they need to focus on groundwater recharge issues. The use of short lucerne phases can be very effective for control of groundwater recharge in these low rainfall environments. These lucerne phases also provide valuable options for managing the build-up of herbicide resistant weeds and boosting soil nitrogen in more intensive farming systems.'

The project is supported by the Natural Heritage Trust, Grains Research and Development Corporation, Landcare Australia, Primary Industries and Resources SA, Natural Resources and Environment (Victoria), Land and Water Conservation (NSW), NSW Agriculture, South Australian Research and Development Institute, University of South Australia and Pivot Agriculture.

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Photo: John Coppi

Wheat and canola research trial plots at the Mallee Sustainable Farming Project Core Site at Waikerie, South Australia.

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Landmark publication on environmental flows

Significant decisions are being made on the allocation of water, water trading and management of water resources from Australian rivers.

A new book *Rivers as Ecological Systems: The Murray-Darling Basin* edited by CSIRO Land and Water's Dr Bill Young, and published by the Murray-Darling Basin Commission, brings together – for the first time – our knowledge on the relationships between river ecology and river flow.

'The knowledge upon which this book is based has been drawn from more than 1000 published papers, books and reports', says Dr Young. 'This comprehensive review of the literature has been complemented by interviews with 30 freshwater ecologists and geomorphologists, and represents our current synthesis of knowledge on this important issue.'

The book offers readers a unique summary of relevant information on environmental flows of rivers within the Murray-Darling Basin, emphasising the fundamental function of rivers and the connection between rivers, catchments and their flood plains and the habitats they provide for aquatic life.

'Australia's unique ecosystem, its birds, frogs, fish, mammals and freshwater plankton are a product of the natural cycles of wetting and drying', says Dr Young. 'These have all been significantly altered by river regulation and management.'

'It is now becoming clear that there is insufficient water to meet the needs of important ecosystems.'

The book – launched by Dr Roy Green, President of the Murray-Darling Basin Commission on 10 April – is the culmination of cooperation between the Murray-Darling Commission, Land and Water Australia, Environment Australia, CSIRO Land and Water, and the CRC for Freshwater Ecology.

Copies of the book are available from CSIRO Publishing
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