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Land & Water Link

Clues to Curing a Toxic Mix

To curb the pollution of soils and associated risks to human health and ecosystems, many countries have introduced regulatory guidelines based on risk assessment of individual contaminants. But as researchers in CSIRO Land and Water's Remediation of Contaminated Environments Program are finding, the mixture of contaminants in the soil may be even more critical than the concentration levels of a particular chemical.

For Drs Mallavarapu Megharaj, Rai Kookana, Ravi Naidu and their team, the starting point is the reality that soil is rarely contaminated with single pollutants.

Dr Megharaj observes, 'In soil environments, especially in agricultural ecosystems, organisms are often exposed to various combinations of pesticides, applied together or in tandem. Yet ecotoxicity tests are generally restricted to individual contaminants.'

Driven by the need to find better ways of assessing the real impact of complex mixtures of soil contaminants, the CSIRO scientific team has been investigating the interplay between toxicity and bioavailability, with some surprising results.

Trying to determine the toxicity of a mix of contaminants from a polluted site is far from easy.

Photo: Bill van Aken

One of the more vexing variables appears as parent chemicals break down and are then found together with their degradation products.

As CSIRO researchers found when they analysed the impact of long-term DDT pollution of soil, the presence and interaction of DDT residues such as DDE and DDD can exert a more noxious effect than the parent compound itself.

In another experiment to evaluate the toxicity of total petroleum hydrocarbons at a long-term contaminated site, the team discovered that some soil samples with medium levels of contaminants proved more toxic to microbial activity than other samples of highly contaminated soil.

As Dr Megharaj explains 'This demonstrates the critical importance of bioavailability in risk management and remediation. Bioassays must be used in conjunction with chemical analysis', he says, 'because they go beyond reporting on just the presence of a chemical, to reveal its bioavailability and biological effects. And these are the factors that matter in terms of risk assessment and remediation.'

Dr Megharaj also warns 'Because different pollutants affect living organisms at different levels and in many ways, we now recognise that no single bioassay is adequate. Given that bioavailability is species dependent, any monitoring program will need a battery of bioassays entailing a range of biological tests.'

In this quest to determine the impacts of contaminants, scientists have found an auspicious lead. Algae, and especially algal diversity, may prove to be the 'litmus test' that signals contaminant pollution in soils.

'Algae make ideal indicators because they are remarkably sensitive to a variety of toxicants, both organics and heavy metals', explains Dr Megharaj.

'For test purposes, they are easy to sample, simple to handle and quick to culture – making them relatively cheap and cost effective. Best of all, algae are abundant across a range of soil types and environments. In agricultural soils, one gram of soil may contain up to 300,000 algae.

'Being the primary producers at the bottom of the food chain, these beneficial soil organisms play a vital ecological role in sustaining a healthy environment.'

Ironically, as well as being remarkably sensitive indicators for monitoring soil pollution, algae also show promise as agents for remediation. The CSIRO research team is currently trialling their use in degrading highly persistent pesticides and contaminants.

By broadening our understanding of bioavailability and the effects of contaminant mixtures, especially in the context of the Australian environment, this work is contributing to more reliable risk assessment protocols and remediation options.

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Photo: Bill van Aken

Photo: Courtesy Gippsland Coastal Board

Gippsland Lakes Entrance, Victoria

Catchment Management Provides Key to Estuarine Changes

A collaborative study of the Gippsland Lakes conducted by CSIRO has enhanced our understanding of the changes affecting this unique aquatic ecosystem. According to aquatic scientist Dr Ian Webster from CSIRO Land and Water, 'The findings have demonstrated that continuing efforts to improve catchment management and reduce nutrients are critical to the long-term health of the Lakes'.

Located around 200km east of Melbourne, the Lakes comprise a vast network of coastal lagoons fed by a catchment area that stretches over large parts of central and east Gippsland, incorporating six major contributing rivers.

In the wake of European settlement in the 1840s, the Lakes' catchment areas have been modified by the clearing of lowland and foothill forests, draining of wetlands, and diversion of water from the rivers for urban, agricultural and industrial use. These changes have increased the delivery of nutrients and sediments to the Lakes and have altered the regime of freshwater inflow.

Catchment modifications, together with the creation of a permanently open Entrance to Bass Strait in 1889, have resulted in an aquatic environment that is substantially altered from its condition two centuries ago.

These changes appear to have caused degradation of the water quality throughout the Lakes. Recurring blooms of toxic blue-green algae (called Nodularia) have prompted widespread concern. The Lakes are also prone to extended periods of reduction in the oxygen content of the water on the bottom of the lakes (bottom water hypoxia). This condition occurs when bacteria consume detritus from algal blooms.

Not only have these water quality problems caused economic loss and threatened tourism opportunities, they have also had effects on the health of the ecosystem. Fish kills have occurred within the Lakes from time to time and impacts on bird life and other estuarine inhabitants are likely.

For environmental managers wanting to take action to improve water quality, the challenge has been to understand the workings of this complex ecosystem. Responding to this challenge, the Gippsland Coastal Board commissioned an environmental study to investigate the interactions between the mingling fresh and marine waters of the Lakes, and of the nutrients, sediments and organic matter that make up the Lakes environment.

Photo: Bill van Aken

This joint CSIRO and University of Melbourne project was funded by the Victorian Department of Natural Resources and Environment and a range of other stakeholders in the region, including private companies. The array of scientific expertise contributing to the study includes inputs from CSIRO Land and Water, CSIRO Marine Research, Monash University and Victoria's Marine and Freshwater Resources Institute. The study was managed by CSIRO's Environmental Project Office.

In trying to understand the processes at play in the Lakes, Dr Webster's team employed state-of-the-art modelling technology to simulate influences affecting water quality and algal growth. Two different models of the Lakes systems were constructed: a hydrodynamic model to simulate the flow and exchange of marine water and freshwater; and a biogeochemical model to simulate nutrient cycling, water quality, and algal growth.

Dr Webster explains 'We looked at the likely impacts of hypothetical changes to river discharge, nutrient loads and exchanges between the Lakes and the sea. We then simulated the response to these scenarios using previously gathered data on river flows, nutrient loads, and weather.

'It should be understood that the models are an aid to understanding system behaviour, so that we can assess the effects

of different options for ameliorating problems' adds Dr Webster.

The Gippsland Lakes Environmental Report, released by the Gippsland Coastal Board in November 2001, has confirmed that problems such as algal blooms are primarily related to changes in the amount and timing of nutrient additions to the Lakes.

'One of the important outcomes of the project', says Dr Webster, 'is that for the first time we can estimate the scope of the nutrient reduction required if we are to manage water quality and algal blooms. Also, we are able to assess the relative benefits of altering river discharge and the construction of a second entrance for improving the water quality of the Lakes.'

The study has important implications for managing the Lakes. It means that continuing to improve catchment management activities on land is the key to better managing nutrient inputs to this unique estuarine environment.

For further information:

Refer to the report available via the Gippsland Coastal Board website: www.vcc.vic.gov.au/gcboard/index.htm

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'Buried Water' Wins World Prize

CSIRO Land and Water scientists' work on water 'banking' has been honoured internationally with the awarding of the inaugural UNESCO International Water Prize for Innovation in Water Resources Management in Arid and Semi-Arid Areas.

The prestigious US$20,000 prize, named 'The Great Man-Made River International Water Prize' has been awarded to an Australian research group studying aquifer storage and recovery – a joint venture between CSIRO Land and Water and the Department for Water Resources, South Australia.

Dr Peter Dillon, Research Group Leader from CSIRO Land and Water, flew to Paris to accept the award on behalf of the group.

The research explores the use of aquifers to store urban stormwater and use of reclaimed water for re-use in irrigation.

While aquifer storage and recovery is not a new concept, what is unique about the work is the quality of the water injected. Scientists have been injecting water that is undrinkable into brackish and saline aquifers and from that, producing water that is suitable for irrigation.

The research group already has six sites of aquifer storage and recovery operating in the vicinity of Adelaide and several international-scale research projects on water banking with reclaimed water and drinking water underway.

The group has already run training courses in several countries and will host ISAR 4 – an international symposium on 'management of aquifer recharge for sustainability' in Adelaide from 22-26 September 2002.

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Photo: Bill van Aken

'Destruction of biodiversity and hence the destruction of global function is a major issue.'

Repairing Australia

Dr Graham Harris, Chairman, CSIRO Flagship Programs, spoke at the National Press Club on September 25 in Canberra on sustainability. An extract of his speech appears below.

Long-term sustainability for Australia is no longer just about conservation, or farming, or natural resource management – it is about the long-term competitive future of this nation. To remain competitive as a nation we need to improve Australia's economic performance and reduce our environmental impacts.

Business as usual is no longer an option. If we wish to fully address the sustainability of Australia we will need new science, new ways of operating, new incentive schemes and new economics. Above all we will need better integration of our effort.

Sustainability is about developing new tools to inform choices for landscape management, empowering communities to take decisions and then developing new competitive enterprises – environmental management is a global industry sector which is growing as fast as the Information Technology sector, and it is already much bigger.

This is an area where Australia is well placed. Our environmental science and ecology are world class. In a recent US analysis, CSIRO's work in environment and ecology was placed third and agricultural science fourth in the world in terms of scientific impact.

We are already far ahead of many countries in our ability to achieve positive outcomes. Thanks to progressive government policies and strong community involvement we are world leaders in our abilities to achieve sensible land and water management outcomes. Perfect we are not – we still have much to do – but because we are way out in front we face some new and unusual problems. Many have to do with our climate and unique animals and plants.

All the natural biodiversity of this planet is an important provider of many functions and services; like clean air and water, waste treatment, pollination, flood control and soil fertility. In many important and subtle ways biology rules the planet. Destruction of biodiversity and hence the destruction of global function is a major issue. Estimates of the value of what we call ecosystem services indicate that these services are worth far more than the global GDP.

In Australia alone, environmental problems caused by landscape destruction have been valued at about $65 billion by one recent study – and about $3 billion per annum by another. The world is run by natural laws – ignore those laws and we get problems. Just look at the landscape. We must develop a deeper understanding of the complexity and value of the natural world and we must continue to strive for better management outcomes.

Systems thinking

We now know that we require systems solutions to landscape problems at regional and catchment scales. We have to consider and balance many factors – land use, water quality and quantity, ecology and bio-diversity, human communities, economics at regional scales – if we are to build sustainable regional landscapes and communities. A single factor focus hasn't worked in the past – the evidence is written in the landscape.

The challenge to science is to integrate much of what we already know as well as do science at unprecedented scales. We need to understand how landscapes function and processes interact – and link catchments to waterways and to estuaries so that when we alter land use we can predict what will happen all the way downstream to the coast.

The really complex problems lie at regional scales, in that ghastly zone between global scales and paddocks – right where we need answers, but at inconveniently large scales for normal science. If we can get this right we can generate opportunities, jobs and wealth in rural Australia.

When we work at these scales we need to include the complexities of regional economics and the needs of the community as well as the ecology. Catch-

'The world is run by natural laws – ignore those laws and we get problems.'

Photo: Bill van Aken

ments have a nasty habit of not observing legal, institutional and governmental boundaries – thus institutional and governmental failures are a common cause of lack of progress.

The National Land and Water Resources Audit has given us numerous insights, including that much of our broad acre agriculture is only marginally profitable – the vast majority of the profit comes from only a small fraction of the land area, and most of this is irrigated land.

This intensification of agriculture is a rapidly developing international trend. There are enormous opportunities in this to design new kinds of profitable and sustainable landscapes, and new industries based around sustainability.

All of this isn't rocket science – it is much harder. If restoring the landscape were easy we would have done it already. This is a challenge more difficult than putting a man on the moon in a decade. This is ecosystem engineering – restoring centuries of damage in a few short decades.

'We need to fully empower regional communities to be able to deliver regionally sustainable solutions.'

Photo: Bill van Aken

We now realise that the solutions we seek actually lie between the present disciplines and institutional structures, for example to restore our rivers we need aquatic ecologists and hydrologists to work with economists and social scientists. We need a new science of integration and synthesis, new policy and new institutions. This is what is now termed 'Sustainability Science'.

New challenges

So what are some of the major challenges to repair the country?

We need rural and urban systems that deliver quality as well as quantity. We need landscape and land use patterns that sustain. We need integrated solutions that are practical and profitable. We need to leverage new forms of incentives. This means new land uses and industries that are profitable and which do not harm the environment. We should be 'farming without harming' and 'managing without damaging'.

Above all we need to fully empower regional communities to be able to deliver regionally sustainable solutions. With a judicious mix of social concern and financial incentives we can repair the damage and rebuild rural communities. There is a global niche in goods and services ready and waiting for a country able to deliver on this agenda.

We must educate and empower regional communities to use the knowledge at hand in creative ways. We must provide the resources and the financial incentives for those communities to take control of their futures and to lead us forward.

This approach will require innovation and learning in government/science and university institutions and societies. It will require the fusion of many different forms of knowledge coupled with tolerance and a willingness to listen. We need to invent new mechanisms to rapidly transfer knowledge and information needs across the science/policy/ community spectrum. We need much better integration.

There is an urgent need for leadership, for new partnerships and new alliances; and this will involve all jurisdictions – the entire community. We need to focus on the solutions to problems and the need for systems for integration and rapid learning. What we all need is a willingness to become more open, to become learning societies and individuals.

Repairing Australia will indeed require new science, new sociology and new economics – but perhaps more than anything else the biggest and most important challenge is to address the urgency of the problems Australia faces and to integrate science, society and the economy. With the necessary will, we can make Australia the envy of the world.

For copies of the full speech and further information:

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Photo: Bill van Aken

Outflow of drainage water from citrus orchard

Novel Solution for Cleaning Up Contaminated Water

CSIRO's land-based wastewater treatment system, FILTER, has been shown to reduce pesticide levels in drainage water in trials conducted in southern NSW.

The FILTER (Filtration and Irrigated cropping for Land Treatment and Effluent Reuse) system was originally developed by CSIRO research scientists, Dr Nihal Jayawardane, Mr John Blackwell and Dr Tapas Biswas to deal with the treatment and reuse of sewage effluent.

But it now appears that this system could also have potential in helping to deal with high pesticide levels in drainage water from irrigation farms.

Pesticide build-up can become an issue for irrigators through the summer irrigation months, as pesticide residue in the drainage water leaving farms must not exceed strict residue limits.

Prior to FILTER, the only management strategy available to farmers to meet Environment Protection Authority (EPA) limits was to hold water in on-farm storages for up to 60 days, or until pesticide levels dropped below the required limits.

However, CSIRO Land and Water experiments at Griffith have shown that FILTER's active soil barrier system is effective at removing the major rice and soybean crop production chemicals from drainage water *before* discharge.

The FILTER system can offer an alternative in some situations and soil types, says CSIRO Land and Water scientist Dr Tapas Biswas.

Dr Biswas says the trials show that the FILTER system, which is based on a close-spaced subsurface drainage system about one metre below the soil surface, is capable of successfully removing pesticides from drainage water.

'The pesticide contaminated water is initially applied to the FILTER plots with the drainage system closed. Later, the drainage system is opened to allow de-contaminated water to flow to the drains, "explains Dr Biswas".

'As the contaminated water percolates through the soil to the subsurface drains, the pesticides are absorbed and attached to the soil. This process removes the pesticide residues from the drainage water – literally "cleaning" the water.'

Natural processes occurring in the soil gradually break down the pesticides retained in the soil.

According to Dr Biswas, the FILTER system reduces pesticide residue loads in drainage water by 98 to 100 per cent for a range of chemicals including chlorpyrifos, endosulfan, molinate, atrazine, malathion and diuron. The end result is a concentration below current EPA discharge limits.

For farmers considering this system, there is the added benefit that the land used to install FILTER can be used for growing crops, rather than sacrificed, as is the case with withholding ponds.

Results of this research, which has been supported by funding from the Australian Centre for International Agricultural Research (ACIAR), Griffith City Council, Coleambally Irrigation Cooperative Limited and Murrumbidgee Irrigation Limited, have been presented internationally.

Having won an award at the Indian Chemical Engineering Congress in Calcutta in December last year and sparked widespread interest, including collaboration with the China Institute of Water Resources and Hydropower Research, the CSIRO team looks forward to further developing this novel solution to cleaning up pesticide contamination.

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Partnership Makes Progress in the Lower Burdekin

A collaborative initiative in Queensland is helping build the lower Burdekin's reputation as a dynamic regional economy by studying the long-term impact of current water use on the region's water resources. With support from a range of national and state agencies and regional industry bodies, representatives from local community, industry and government are working together with researchers to ensure a sustainable future for the Burdekin's groundwater systems.

A Townsville-based research team, led by CSIRO Land and Water scientist Dr Keith Bristow, is contributing by investigating the linkages between land management practices and the response of the underlying aquifer systems – part of the quest to understand and properly manage overall water resources.

To date, industry and communities in the Burdekin region have reaped the benefits of local groundwater systems with few restrictions on access to water. However, questions are being raised about the long-term effect of current management practices. In particular, care is needed in protecting the aquifer systems from excessive loading of soil-applied nutrient and chemicals. It is also vitally important to ensure that there is no inland migration of the saltwater wedge, which separates the salty ocean from the freshwater supplies of the underground aquifers.

'The aquifer is the heart of the system and its good health has been one of the main contributing factors to the Burdekin's success as a major sugar producer. If we harm the groundwater system then we may endanger the economy of the whole region', warns Dr Bristow.

Photo: Bill van Aken

Check valve to control the flow of irrigation water to sugar cane crop at Brandon in the Burdekin Irrigation Area

Over the next three years, CSIRO researchers will monitor water leaving the rootzone and entering the aquifer at several sites across the lower Burdekin. This work, combined with input from a range of other researchers and users working within the Lower Burdekin Initiative, will develop a better picture of the overall health and long-

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term sustainability of the Burdekin's groundwater and associated water systems.

The Lower Burdekin Initiative provides a framework to help facilitate communication, co-ordination and integration of the various water-related research projects underway in the region. As part of the drive to improve water use efficiency, the Queensland Rural Water Use Efficiency Initiative is working closely with farmers in the region to finetune their irrigation methods.

Irrigation development officer Peter Sutherland, who works with the Bureau of Sugar Experiment Stations in Brandon, has been analysing farm irrigation systems together with the farmers, and suggesting changes that could make a big difference. Most of the advice involves altering flow rates and the timing of irrigation. As Peter Sutherland has found, in some cases small changes to the way water is managed can lead to large improvements in crop returns.

While projects like these may lead to less water extraction from the aquifer, CSIRO's Keith Bristow explains 'we still don't know how the system will respond to these or other changes, especially in the longer term'.

Dr Bristow stresses that 'we must have a clear view of the big picture to see how the different components of the water balance fit together, and how changing one particular component will influence other components and impact on the long-term health of the groundwater system'.

'By working together to understand how the lower Burdekin water systems function, we can develop water management strategies that everyone understands and is keen to implement. The Lower Burdekin Initiative is an ideal vehicle to progress these issues.'

For more information:

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