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Putting waste to work

A CENTRE FOR INTEGRATED BIOWASTE RESEARCH PUBLICATION

Centre for Integrated Biowaste Research www.cibr.esr.cri.nz

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Update from the Programme Manager

Welcome to the Summer 2014 CIBR newsletter.

There have been a few changes in the CIBR group over the last few months.

I'd like to welcome the new Business Development Manager to the team, Dr Rob Lei from Scion, check out his profile on page 10. CIBR has also formed a Business Development Group to develop and implement growth opportunities for waste sector research.

Members of CIBR have been providing information on pathogens, heavy metals and organics for consideration by the "Organic Materials Guideline" Steering Group. Led by WaterNZ, this initiative will develop a framework for dealing consistently with organic wastes. The approach aims to recognise commonalities of organic waste; describe quality criteria for beneficial reuse, increase knowledge and streamline regulatory processes. This guideline will supersede, update or reference to existing guidelines and standards e.g. NZ Biosolids Guidelines, NZS4454 Composting Standard etc.

Congratulations to Morkel Zaayman who has been awarded a First Class Honours for his Master's thesis "Investigating Environmental and Health risks of Greywater use in New Zealand" – well done! Read about some of his work on page 8. Morkel is now undertaking a PhD with Dr Sally Gaw at Canterbury University, Dr Chris Tanner at NIWA, Dr Grant Northcott from NRC Ltd., and the CIBR team at ESR.

Lastly and most importantly CIBR is currently seeking input into our research strategy for the next three years. As well as engaging with the CIBR Advisory Group which includes representatives from a wide range of stakeholders, we are seeking wider input from industry stake-holders. If you would like to contribute to forming our research strategy or have any ideas on knowledge gaps or research projects then please let us know – you can email us on cibr@esr.cri.nz. We look forward to hearing from you!

I hope that you enjoy this quarter's newsletter and we wish you all the best for the holiday season.

Jacqui Horswell

Biowastes to convert former pine forests into cash-producing native ecosystems

By Brett Robinson

Some 1.8 million hectares of NZ soil is under pine plantations. This figure is rapidly decreasing as there is little economic incentive to replant timber crops that are worth less than one-fifth of their 1995 value (inflation-adjusted). Historically, pine forestry was an effective means of providing an economic return from low-fertility soils. This is no longer the case.

The growth of pine trees followed by logging often results in degraded soils, with depleted organic matter and low concentrations of plant nutrients. Conversion of former pine forests into productive farmland requires the continual application of mineral fertilisers at high rates. High rates of nutrient loss from such farmland can further degrade lakes, rivers, and groundwater.

We propose that such low-fertility degraded soils would be better restored to vegetation that provides an economic return off the land, while not requiring high nutrient inputs. Vegetation dominated by mānuka *(Leptospermum scoparium)* could produce honey that would add to NZ's burgeoning ($120M) mānuka honey industry. In areas such as Canterbury, that are less suited to mānuka growth, vegetation dominated by kānuka *(Kunzea ericoides)* could be established to produce essential oils. Depending on the region, mānuka and kānuka may develop spontaneously in the decades following the clearing of a pine forest. However, the time taken for such vegetation to produce an economic return may be prohibitively long.

Potentially, degraded soils that were formally under pine forest could be rebuilt using biowastes, which would increase the soil's water and nutrient holding capacity and provide essential elements to accelerate plant growth. Biowastes could include dairy shed effluent, municipal wastewater or biosolids. Dharini Paramashivam, a CIBR PhD student at Lincoln University, has shown that pine waste and some charcoals created from pine waste can significantly reduce the leaching of nitrates from biosolids, while significantly improving soil fertility. Dharini's research will allow high rates of biosolids to be used to rebuild degraded soils without endangering the quality of groundwater, lakes and rivers.

Preliminary experiments at Lincoln University and ESR have demonstrated that biowastes augment the growth of mānuka on most, but not all, degraded soils. Biowastes, such as biosolids, also change the quality of essential oils produced by these plants. The nature of these changes is the subject of PhD research undertaken by Saloomeh Seyedalikhani (pictured right). In her initial studies, Saloomeh aims to identify key factors in biowastes that can improve the production and quality of essential oils derived from mānuka, kānuka and other species. Biowastes may also change the amount and quality of mānuka honey produced on degraded soils, thus potentially augmenting NZ's burgeoning honey industry.

Minakshi Mishra (left) and Saloomeh Seyedalikhani (right) are investigating environmental and economic benefits of mānuka and kānuka production on soils amended with biowastes.

Interestingly, mānuka and kānuka can significantly affect the quality of soil amended with biowastes. Both species produce antiseptic chemicals, such as monoterpenes and polyphenols that may enter the soil environment. Jennifer Prosser and Roshean Fitzgerald demonstrated that these species increase die-off of pathogens in biosolids-amended soils. Their pioneering research has resulted in a PhD programme that will be undertaken by Minakshi Mishra (pictured left). Minakshi will elucidate the effect of mānuka on survival times of various pathogens that are associated with faecal-containing biowastes such as municipal effluent, biosolids and dairy shed effluent. Her research may enable the reuse of biowastes that are currently unacceptable for land application due to their high pathogen loadings. Her research may also mitigate some of the "yuk" factor often associated with the land application of biosolids.

The antiseptic properties of mānuka may affect soil microbes involved in nutrient cycling. Rachel Downward demonstrated *in vitro* that mānuka extracts significantly reduced *nitrification*, the conversion of ammonium into highly-leachable nitrate. This effect could reduce the amount of nitrate entering groundwater. Hannah Franklin and Roshean Fitzgerald demonstrated that kānuka suppresses the production of nitrous oxide from soil amended with dairy shed effluent. Nitrous oxide is greenhouse gas, some 300 times more potent that carbon dioxide. Lessening New Zealand's nitrous oxide emissions could reduce expenses incurred by climate change agreements. The environmental benefits of mānuka and kānuka are being investigated by Obed Lense as part of his PhD programme. Obed is working closely with Dr Juergen Esperschuetz.

Ultimately, our research seeks to return NZ's landscapes to native vegetation that generates cash on degraded soils. Further economic returns would be realised by reusing nutrient-rich wastes that would otherwise go to (expensive) landfills or be inappropriately disposed of. Unlike timber production or dairy farming, mānuka and kānuka production cannot easily be adopted by overseas competitors. Native vegetation may be a key player in NZ's economic future.

Publications

Hahner JL, Robinson BH, Zhong HT, Dickinson NM (2014). The phytoremediation potential of native plants on New Zealand dairy farms. *International Journal of Phytoremediation* 16(7-8), 719-734.

Mānuka – alleviating concern around microbial contamination of soil

By Jennifer Prosser

The ever increasing need for environmentally sound waste disposal has put pressure on society to investigate the recycling of organic wastes (biowastes). Biowastes are carbon-rich and contain high concentrations of valuable nutrients that can have high fertiliser value, and can be effective for the rebuilding of soil that has become degraded. However, many biowastes, such as those from human or animal excreta can be a vehicle for contaminants including human pathogens. Forests have been considered suitable for receiving organic wastes because they are not directly linked to the human food chain.

NZ native *Leptospermum scoparium* (mānuka) is already widely used in land restoration projects in New Zealand due to its hardy, tolerant nature. Both mānuka and a morphologically-similar species, kānuka *(Kunzea ericoides)* are pioneer species that colonise disturbed environments in New Zealand and South Australia. In addition, mānuka components have known antimicrobial properties and economic value through commercial production of honey and essential oil-related products. It is our suggestion that mānuka could be grown in waste-amended soil to mitigate microbial contamination. Although there is much research into the source of the antimicrobial activity of oils and honey from mānuka, there is little on the impacts of these antimicrobial properties on the wider soil environment. Preliminary studies conducted by the Centre for Integrated Biowaste Research (CIBR) indicate inhibition of pathogen growth and accelerated die-off of pathogens when in contact with mānuka components (Prosser *et al*., 2014). Currently we are further investigating the potential for antimicrobial properties of mānuka to mitigate environmental contamination from biosolids-borne pathogens in-situ.

Established pot trials containing perennial ryegrass *(Lolium perenne)*, mānuka *(Leptospermum scoparium)* and kānuka *(Kunzea ericoides)* (Fig. 1) were spiked with the pathogen indicator species *E. coli* and *Salmonella*, in two separate experiments. Die off of these pathogens in the soil underneath growing plants was assessed over time. Results show that *E. coli* and *Salmonella* survival is reduced in soil underneath mānuka (and kānuka) when compared to a pasture control (Figs. 2 and 3). Further still, the time taken to achieve 90 % reduction in *E. coli* was just 5 and 8 days for kānuka and mānuka respectively compared to 93 days for rye grass. These observed inhibitory effects are likely due to mānuka antimicrobial properties, the nature of which requires further investigation.

Figure 1. Potted plants of perennial ryegrass (Lolium perenne), mānuka (Leptospermum scoparium) and kānuka (Kunzea ericoides).

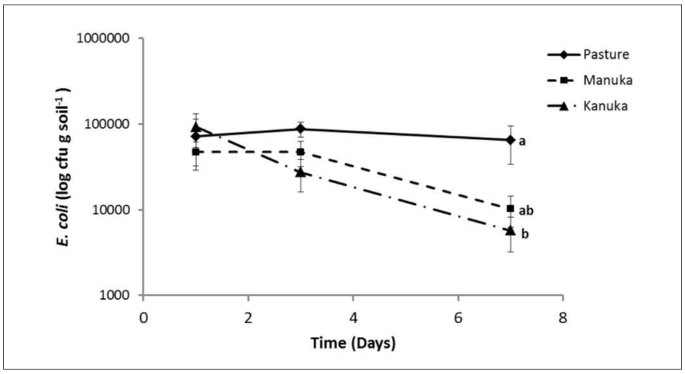

Figure 2. Survival of E. coli in soil samples from underneath pasture, mānuka and kānuka over a seven day experimental period.

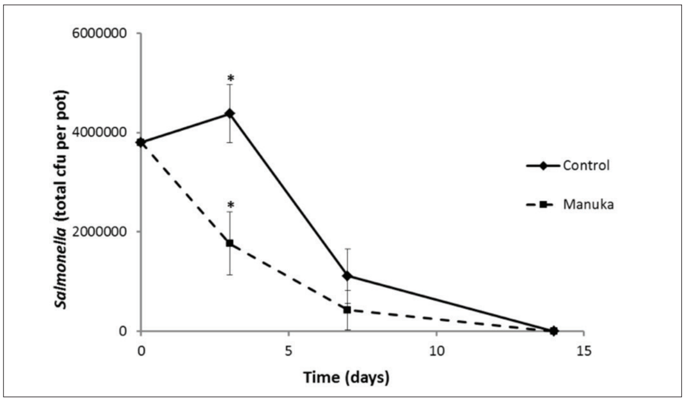

Figure 3. Survival of Salmonella in soil samples from underneath pasture and mānuka over a 14 day experimental period.

Publications

Prosser JA, Anderson CWN, Horswell J, Speir TW (2014) Can manuka *(Leptospermum scoparium)* antimicrobial properties be utilised in the remediation of pathogen contaminated land? *Soil Biology and Biochemistry* 75, 167-174

Welcome to CIBR . . . Robyn Simcock, Landcare Research.

Robyn Simcock jumped at the chance to join the CIBR research team in July. She's worked with Jo Cavanagh and Craig Ross over the last 10 years on a variety of commercial and government-funded projects in mine rehabilitation, harvested plantation forests and cities/motorways. CIBR allows her to bring experience and industry contacts across these strands together to focus on beneficial uses for biowastes. Organic materials produced during maintenance of urban areas (catchpit and road sweepings, tree prunings and greenwaste) can boost ecosystem services, particularly in degraded land. Parts of the USA and Canada require amendment of earth-worked areas with compost and/or organic mulches to boost storm water retention and vegetation growth. These amendments can also be used to manipulate soil chemistry and above-ground microclimates, favouring specific plants and ecosystems. Robyn is looking forward to exploring these opportunities with the CIBR team and end-users, including field trials to provide data underpinning NZ policies that increase beneficial reuses of biowastes.

UPDATE FROM THE CIBR SOCIAL AND CULTURAL TEAM

Current discussions in Kaikōura and research writing

Alan Leckie, Lisa Langer, Jamie Ataria, Jinny Baker and Joanna Goven

Following on from the Social and Cultural Update in CIBR Issue 7 (Winter 2014), the Kaikōura District Council (KDC) are discussing an option of spreading the aged stockpiled biosolids onto a 2 ha coastal site near the wastewater treatment plant, just north of Kaikōura. The KDC suggested planting the site with native species, including mānuka, following biosolids application.

While planting natives in soil amended with the biosolids was supported by the community, the KDC will need to assess the site and be confident that it is suitable for growing native seedlings because coastal sites present many challenges like sea spray, dry soil and wind.

In discussions with members of Te Rūnanga o Kaikōura, CIBR presented research knowledge at the monthly Rūnanga meeting in October. Previous research undertaken at the CIBR by key collaborator Brett Robinson and his team at Lincoln University, has shown that some of the negative effects of biosolids addition to soil can be mitigated by planting of mānuka. It has been demonstrated that mānuka can increase the die-off of biosolids-borne pathogens in soil; can interfere with the nitrogen cycle in soil, significantly reducing the evolution of nitrous oxide, a potent greenhouse gas, and reduce nitrate leaching that poses a threat to groundwater. Members of CIBR also presented existing knowledge on native seedling establishment, including the growth of mānuka as a possible species to allow apiarists to produce mānuka honey. Other native species that may be suitable for early establishment include karamu, ngaio, papauma, and pingao. One issue to ponder is that rehabilitation of sand dunes with native seedlings is an expensive option and sand sites often require the possible construction of barriers to limit sand accumulation around young plants.

The CIBR team are interested in providing further advice on biosolids application to the KDC and Rūnanga, native seedling establishment and environmental monitoring, if funding is available.

Members of the Social and Cultural team held a paper writing workshop in July to finalise a paper on the challenges facing transdisciplinary research. This paper analyses the tasks involved to bring social and biophysical scientists together within the Kaikōura case-study. It has been submitted to Futures.

Jinny Baker has prepared an excellent first draft of the Community Engagement Framework and fellow CIBR members are contributing to it. This document has been written to support the waste and wastewater management sectors, local government and engineers to have more structured conversations with their communities about waste and wastewater management issues in their area. It draws upon experiences of the CIBR group and community engagement on a number of social and biophysical science projects.

The Social and Cultural Team were very saddened to hear of the passing of Ngaire George. Ngaire was a leader in her community and a collaborator with CIBR in the Mokai case-study. E ngau kino nei te aroha – with heartfelt sympathy.

Acceptability of biosolids composts in Kaikōura: Results from a small study

Richard Yao, Lisa Langer and Alan Leckie

Richard Yao presenting the results of the willingness-to-pay study at a hui held in Kaikōura's Takahanga Marae on 4 March 2012

The acceptability and marketability of compost made with the addition of biosolids by communities has received very limited research attention in New Zealand. A small study was undertaken to provide some insights on the level of acceptability of biosolids compost in a New Zealand rural community.

Kaikōura is a small tourist district situated 180 km north of Christchurch. The Kaikōura District Council is currently considering reuse of a stockpile of biosolids that is situated next to the waste water treatment plant. As part of a government funded programme, CIBR conducted a study in the district to identify and investigate biosolids reuse options in consultation with the Kaikōura community. The community identified and supported three reuse options: (1) application to a nearby exotic plantation forest; (2) application to rehabilitate land with native plants; and (3) composting, using either open air composting or vermicomposting prior to being sold to Kaikōura residents (Langer *et al* 2013).

This report describes a small study which examined Option 3 above. A questionnaire was developed to examine if there is a market potential for the two types of compost that could be produced in the town; open air composting of green waste plus biosolids or composting of green waste with composting worms and biosolids (vermicomposting). The survey included questions on the level of community interest in trialling the two types of biosolids compost; the amount that people would be prepared to pay for a trailer load of compost; and the perceived willingness-to-pay of the households in the wider community.

In December 2011, CIBR organised a small hui in Kaikōura to consult key stakeholders on both a life cycle assessment and a cost benefit analysis of biosolids reuse options. The hui included a presentation providing participants with background on the presence of a stockpile of biosolids in Kaikōura and discussing open-air composting and vermicomposting as two alternatives being considered for reuse.

The questionnaire sought to find levels of acceptability of the 17 invited key stakeholders after the presentation. In January 2012, the questionnaire was supplied at a Te Rūnanga o Kaikōura monthly hui for additional responses and was completed by six additional members of the community. This provided a total of 23 completed questionnaires.

Respondents were asked if they would score their willingness-to-use either of the two types of composts using a 1–10 scale embedded in four options, from most restrictive ("I would not even touch it") to least restrictive ("I would use it on my vegetable garden"), with two intermediate options (would not or would use on trees with edible fruit). The respondents were asked to choose one option (Figure 1).

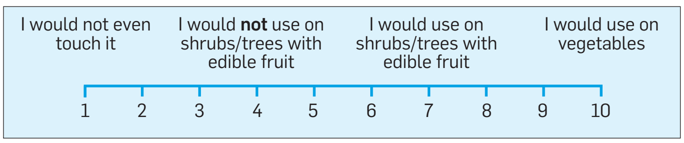

Figure 1. Willingness-to-use scale presented in the questionnaire.

Based on the questionnaire data, we found that more than half would be willing-to-pay and apply both types of composts on their food crops, which might indicate a potential market for biosolids compost in Kaikōura. We also found that vermicompost had a higher level of acceptability as 70% of respondents stated they would buy and apply vermicompost to vegetables and fruit trees, compared with 59% for open air compost (Figure 2). About 20% of participants said that they would not apply either type of compost to fruit trees, but they would be prepared to apply it on ornamental trees and plants on their garden. A small proportion of respondents (less than 20%) were not willing-to-use either of these composts on their garden.

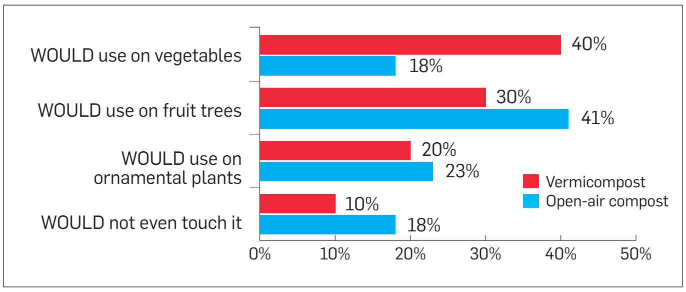

Figure 2. Results of the survey of 23 participants on their willingness-to-use two types of biosolids compost on their gardens.

Respondents who would be willing-to-use those composts were then asked how much they would likely pay for a trailer load of each type of compost (figure 3).

- [ ] I would pay a premium price for it (at least $40 per trailer load)
- [ ] $30 per trailer load
- [ ] $25 [ ] $15 [ ] $5
- [ ] Other amount, please specify $____per trailer load
- [ ] Free – expect you to give it away
- [ ] You would have to pay me to take it away!

Figure 3. Options provided to respondents to elicit their willingness/unwillingness to buy biosolids composts.

Results suggest that the largest proportion of respondents (52%) would be willing-to-pay about $15 per trailer load for open air compost. For vermicompost, the largest proportion (38%) would pay about $25 per trailer load. This suggests a price premium for the compost that had undergone further processing. About 19% would pay $30 for vermicompost compared to only 5% for open-air compost.

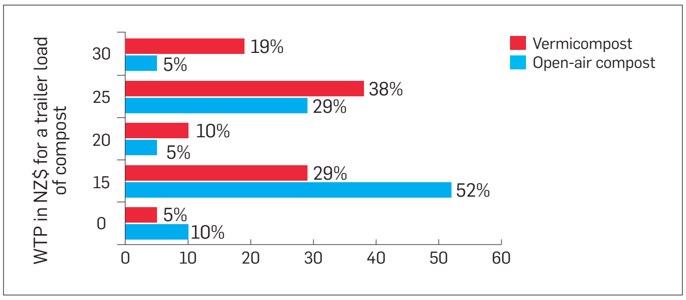

Figure 3. Willingness-to-pay of respondents for a trailer load of biosolids compost.

Respondents were asked, including those not wanting to use biosolids compost, about their perceived willingness-to-pay for compost by the wider community. They were again provided with the eight options listed in Figure 3. Respondents perceived that the wider community has a slightly higher willingness-to-pay for a trailer load of compost than their own willingness-to-pay (Figure 4). However, these values represented only about half of the price ($40 per trailer load) of the regular compost produced from green waste without biosolids sold by Innovative Waste Kaikōura (IWK) to the community. The price of a trailer load in 2012 remains the same in June 2014.

We also calculated the average and median willingness-to-pay for the two composts (Table 1). Respondents were made aware of the

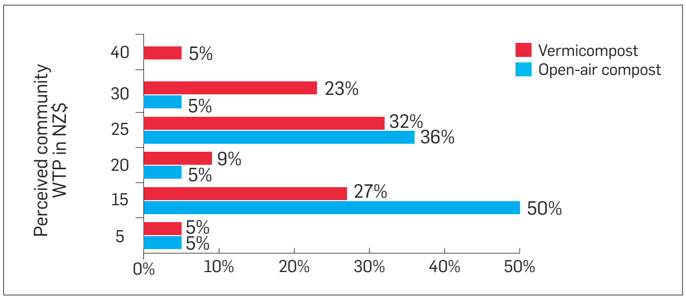

Figure 4. Respondents' perceived willingness-to-pay of other community individuals for a trailer load of biosolids compost.

additional processing that occurs in vermicomposting. This could be a reason why respondents indicated a greater median 'personal willingness-to-pay' ($25 per trailer load) for vermicompost rather than open-air compost ($15 per trailer load). In addition, they anticipated that the community would be prepared to pay a marginally higher amount based on the average 'community willingness-to-pay' compared to the average 'personal willingness-to-pay'.

Table 1: Personal and community willingness-to-pay for biosolids vermicompost compared to open air compost.

	Personal willingness-to-pay			Community willingness-to-pay		
	Mean	Median	(min-max)	Mean	Median	(min-max)
Open air compost	$17	15	$0 – 30	$19	15	$5 – 30
Vermicompost	$21	25	$0 – 30	$23	25	$5 – 40

The above results suggest a potential market for biosolids compost in Kaikōura. The majority of respondents indicated some level of acceptance to use open-air compost in the garden, while vermicompost received a higher level of acceptability. However, the sample of respondents might be too small to provide a sufficient assessment of the market potential of biosolids compost in the community. A more comprehensive study (i.e. a large sample size (at least 200 respondents), a more detailed and carefully designed questionnaire, use of up to date econometric models) would need to be conducted to have a more robust analysis of preferences and estimation of willingness-to-pay. It is also important to note that we used a hypothetical market to elicit the willingness-to-pay values. Hypothetical estimates may represent twice the amount of the actual amount that a person is prepared to pay based on the empirical work by Christie (2007). Therefore, instead of $25 per trailer load of vermicompost, the median respondent might actually be prepared to pay only $12.50 per trailer load. We suggest that a future study on marketing of different types of biosolids compost, including biosolids and organic waste material open-air compost, should account for the difference between actual and hypothetical willingness-to-pay to provide estimates that can be incorporated in future policy decision making.

It is also important to note that the production and selling of biosolids compost is not new to New Zealand. The Rotorua District Council had successfully produced and sold this type of compost for several years. Perhaps some of the lessons learned from that case can be used to provide insights for studying the feasibility of biosolids compost production in Kaikōura and in other New Zealand communities.

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UPDATE FROM THE SOIL SCIENCE TEAM

Long-term impact of repeated biosolids application on the accumulation and movement of heavy metals in the soil

By Jianming Xue

The CIBR soils team collected soil samples of four layers (0-25, 25-50, 50-75 and 75-100 cm) from the long-term biosolids research trial at Rabbit Island in Nov 2013 and now has completed all litter and soil chemical analyses. The results showed that land application of biosolids significantly improved soil fertility of a radiata pine plantation at Rabbit Island and there is a low risk that the biosolids derived heavy metals would to be leached out of the soil into the groundwater.

Biosolids from the Nelson regional wastewater treatment plant have been applied to a 1000-ha *Pinus radiata* plantation at Rabbit Island since 1996. A research trial was established on the site in 1997 to investigate the long-term effects of biosolids application on soil and groundwater quality, tree nutrition and growth. Biosolids have been applied to the trial site every three years (1997, 2000, 2003, 2006, 2009 and 2012, respectively) at three application rates: 0 (Control), 300 (Standard) and 600 kg N/ha (High). Tree nutrition status and growth are monitored annually, soil properties every three years and groundwater quality quarterly. The latest soil sampling at the Rabbit Island biosolids research trial was completed in late November 2013 (Fig. 1). Here we update our recent findings on the impact of repeated biosolids application on the heavy metal accumulation and movement in the soil.

Fig.1 Soil samples of 4 layers (0-25, 25-50, 50-75 and 75-100 cm) were collected from the long-term biosolids research trial at Rabbit Island in Nelson

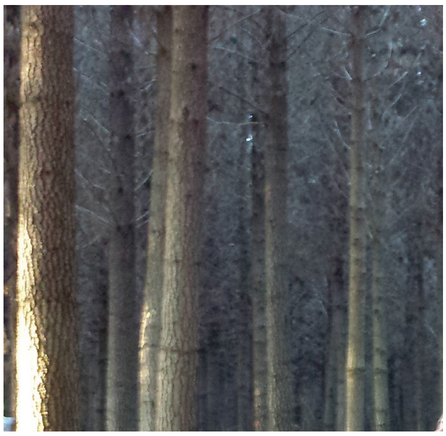
Biosolids application significantly increased the concentrations of Cr and Pb in the forest floor litter layer (Table 1). In the soil layer of 0–25 cm, there were no significant differences between biosolids treatments for the concentrations of all other heavy metals except Cr, which was only significantly higher in the High treatment than the Control (Table 1). In the soil layer of 25–50 cm, no significant differences were found between biosolids treatments for the concentrations of other heavy metals except Zn, which was only significantly higher in the High treatment (Table 1). In both layers of 50-75 cm and 75-100 cm, there were no significant differences between biosolids treatments for the concentrations of all measured heavy metals (Table 1). There were significant differences between the soil layers for the concentrations of As and Ni irrespective of biosolids treatments (Table 1). This indicates the downward movement of these two heavy metals through the soil profile was not related to the biosolids application.

Table 1. Effect of biosolids application on concentrations of total heavy metals in litter and soil.

Depth	Treatment	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
		mg kg^{-1}							
	Control	0.48 a	0.12 a	0.27 b	12 a	0.62 b	1.8 a	12 a	27 a
Littler	Standard	0.62 a	0.09 a	0.53 a	6.1 a	1.2 ab	2.5 a	13 a	16 a
	High	2.1 a	0.09 a	0.48 a	9.1 a	2.0 a	1.6 a	13 a	21 a
	Control	2.9 a	0.04 a	43 b	2.6 a	3.6 a	0.03 a	23 a	21 a
0–25 cm	Standard	3.3 a	0.03 a	41 b	4.1 a	3.9 a	0.04 a	23 a	23 a
	High	3.5 a	0.03 a	54 a	4.8 a	4.1 a	0.02 a	32 a	25 a
	Control	3.6 a	0.04 a	42 a	2.7 a	3.4 a	0.05 a	36 a	21 b
25–50 cm	Standard	3.7 a	0.03 a	45 a	3.1 a	3.5 a	0.02 a	34 a	22 b
	High	3.3 a	0.03 a	49 a	3.3 a	3.7 a	0.03 a	33 a	25 a
	Control	4.7 a	0.04 a	48 a	3.1 a	3.7 a	0.04 a	48 a	22 a
50–75 cm	Standard	4.2 a	0.03 a	45 a	3.3 a	3.6 a	0.05 a	45 a	22 a
	High	3.8 a	0.03 a	47 a	3.2 a	3.4 a	0.03 a	47 a	22 a
	Control	4.3 a	0.03 a	48 a	3.4 a	3.9 a	0.03 a	46 a	24 a
5–100 cm	Standard	4.0 a	0.04 a	57 a	2.8 a	3.6 a	0.04 a	47 a	21 a
	High	4.0 a	0.03 a	49 a	2.7 a	3.4 a	0.01 a	52 a	23 a

**For each depth, values within a column followed by different letters differ significantly at P = 0.05 (LSD test)*

Our study indicates that 6 applications of biosolids in 15 years on this forest site had minor impact on the accumulation of heavy metals in the litter and the top 50 cm soil layers. There is a low risk that the biosolids derived heavy metals would to be leached out of the soil into the groundwater. However, the longer term fate of biosolids derived heavy metals needs to be further monitored.



Rabbit Island Soil – how are carbon and nitrogen impacted by soil microbial processes?

Minhuang Wang, Jianming Xue & Alan Leckie

Foliage sampling in the upper canopy with a shotgun.

In July 2014, a field team of CIBR researchers collected soil samples at 0-10 cm depths, secondary branch foliage within the upper canopy, fine roots and forest floor litter from the long-term biosolids research trial at Rabbit Island, near Nelson.

Analyses of these collections will provide data for Minhuang Wang, a visiting PhD student from Fujian Normal University in China to complete field work for his studies. Jianming Xue is supervising Minhuang over the 12 month period he is studying at Scion and completing analyses at the ESR laboratory in Christchurch. Minhuang's doctoral thesis topic is on *'Impacts of forest succession and nitrogen (N) loads on soil carbon and N dynamics'*. His field site is at Rabbit Island where a biosolids to forest trial was established in 1997 in a six year old *Pinus radiata* stand. There are three biosolids application rates: 0, 300 and 600 kg N ha^{-1}. Biosolids were applied to the trial at three-year intervals; most recently in 2012, the sixth application. The aim of this study is to determine the inter-relationships between soil microbial processes, biochemical changes and their impacts on soil carbon (C) and N dynamics under different biosolids application rates.

Minhuang will specifically analyse $\delta^{15}N$ values of soil, foliage, roots, forest floor litter, microbial biota and soluble organic/inorganic N pools to trace the fate of ^{15}N enriched biosolids. When sewage sludge is treated at a wastewater treatment plant, changes to the isotopes (variants or types) of nitrogen occur, which induces a relative ^{15}N enriched residual biosolid. Nitrogen is usually measured in two forms; ^{14}N or "lighter" and ^{15}N or "heavier" forms. It is this change in the isotope levels or isotopic 'weights' between ^{14}N and ^{15}N that we are able to measure. Forest soils generally have negative ^{15}N values. When ^{15}N enriched biosolids is applied, the soil will have a uniquely higher level of ^{15}N nitrogen than soil where it is not applied. Therefore, any movement of nitrogen through the soil can be traced, measured and accounted for compared to soil where the biosolids have not been applied. As plants take up nitrogen from applied biosolids this ^{15}N level can be measured in new growth foliage, roots and future litter fall.

In addition, the soil samples will be analysed to determine the soil microbial community and functional enzymatic activities, while trying to elucidate the effects of biosolids application on plant-soil interactions and dynamics of soil organic matter. The root samples collected will provide data on root biomass, root morphology and internal nitrogen cycling. A follow-up sampling field trip in November provided further data to demonstrate seasonal changes of these biogeochemical processes in a pine forest ecosystem subjected to long-term biosolids loading. Research findings will be presented at the NZ Society of Soil Science conference in Hamilton in December.

Minhuang Wang, a visiting PhD student from China.

Collecting forest floor litter and soil samples.

Potential environmental and human health risks of greywater use in New Zealand

Morkel Zaayman

Many countries, including New Zealand, are investigating alternative water management practices to address increasing demands on freshwater supply. One such practice is the diversion and reuse of household greywater for irrigation. Greywater diversion also has the potential to increase the performance of old and underperforming septic tank systems, on which thousands of New Zealanders depend for sanitation.

Greywater is a complex mixture containing contaminants such as microbes and household chemicals. These contaminants may present an environmental and public health risk and has never been characterised in a New Zealand context.

One such an organic contaminant is triclosan (TCS; 5-chloro-2-[2, 4-dichlorophenoxy]-phenol). It has been reported that TCS is the most commonly used antibacterial compound in the United States. In New Zealand, such antibacterial compounds are found in many common personal care products including toothpastes, hand washes and in sports clothing. Once these compounds enter a domestic greywater stream where the water is reused, there is a direct route for TCS to the receiving environment, where it can continue its antimicrobial action.

We designed an experiment to assess the effects of TCS on a soil microbial community. A dose response experiment was conducted to assess the effects of increasing concentrations of TCS on various soil health indicators including substrate induced respiration (SIR), sulphatase activity, microbial biomass and the microbial metabolic quotient (qCO_2), a measure of microbial stress. Substrate induced respiration is a measure of the rate of substrate conversion to CO_2 by a unit mass of microbes and microbial biomass is a measure of the proportion of microbial carbon to soil mass.

Triclosan was dissolved in acetone (very low solubility in water) to create a stock solution and added in different quantities to soil samples in microcosms to yield final concentrations of 500ppm, 1000ppm, 1500ppm, 2500ppm, 5000ppm, and 7500ppm TCS (mg TCS/kg dry weight soil). A control sample spiked with acetone and no TCS was also included. The soil was incubated for 20 days at 25°C after spiking and samples were taken on days 0, 6, 10, 17, and 20 for SIR. Biomass, sulphatase activity and qCO_2 was measured on day 17.

From the SIR analysis it was evident that the microbial community recovered after initial TCS exposure. It has been reported in the literature that microbes acclimatise to a TCS-rich environment and may even use it as a food source. There was an upward trend for SIR over the course of the incubation period for all concentrations of TCS. Another reason for this upward trend could be that the unaffected microbes ingest the contents of dead microbes, therefore producing more CO_2 simply because there is a supplementary food source. The data gathered from this experiment, however, was not sensitive enough to derive an EC_{50}. An EC_{50} is the concentration of a contaminant or toxin that affects 50% of a particular function of a microbial population.

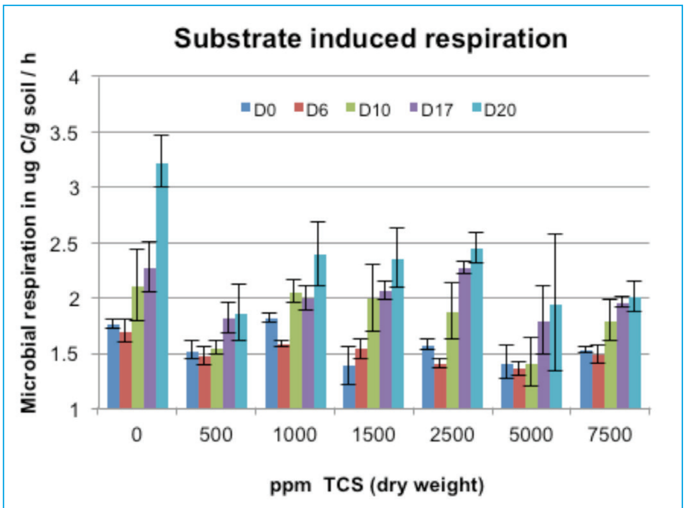


Figure 1: Substrate induced respiration (SIR) at investigated TCS levels

Sulphatase activity also was not sensitive enough to produce an EC_{50}; however the data from the microbial biomass measurement provided sufficient data to fit the model used for the calculation of toxicity.

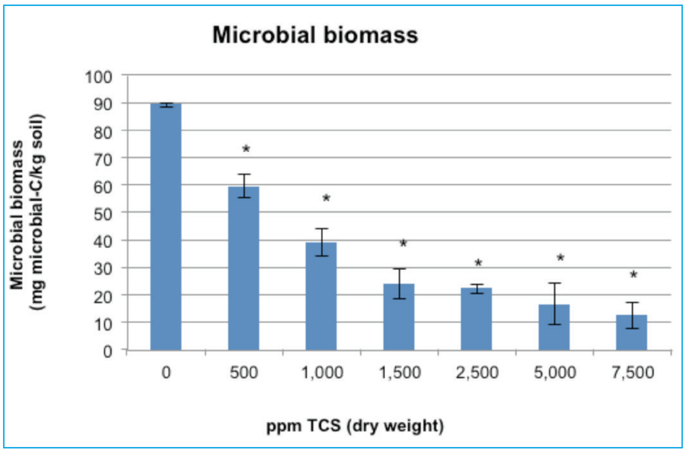


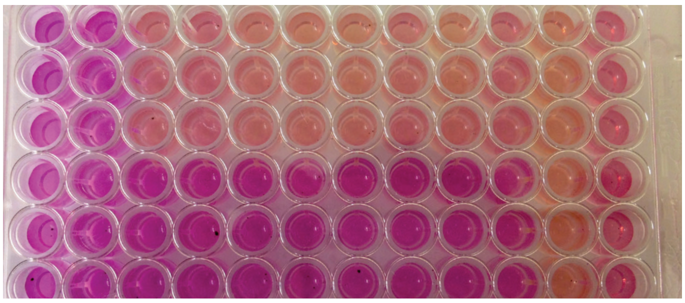
Figure 2: Microbial biomass at investigated TCS levels on day 17. Asterisk indicates difference of statistical significance ($p<0.05$) from the control calculated using Tukey's HSD test.

EC_{50} and EC_{20} values were calculated for TCS using microbial biomass and sulphatase as indicators of soil health and function. The EC_{50} and EC_{20} values for biomass carbon were 803 ppm TCS and 195 ppm respectively; considerably lower than the values for sulphatase (EC_{50} = 11326ppm, EC_{20} = 1737ppm). These results suggest that the numbers of soil microbes are significantly ($P<0.05$) impacted by the presence of TCS, perhaps not surprising as TCS is a generic anti-microbial.

The response of the soil microbial community to concentrations of TCS at 195ppm is of concern. A household using a TCS-containing toothpaste and mouthwash could be responsible for 450mg TCS entering the environment via greywater disposal over a period of 10 years. Assuming 50% microbial breakdown and a greywater receiving area of 10m x 10m, the total accumulated amount of TCS could approach 450ppm. This value exceeds the EC_{20} value of 195ppm determined by our study.

Triclosan has a negative effect on soil microbes at the concentrations investigated in this study by impacting on soil biomass and function. This study showed that an increase in TCS concentration can induce stress in the microbial community at concentrations as low as 195ppm (EC_{20} for biomass).

The EC_{50} value calculated from this experiment was used to inform the dosing rate for a lysimeter study where soil cores from three different locations in New Zealand was irrigated with two different qualities of greywater, and the fate and effects of TCS in the receiving environment was investigated.



A reading plate for substrate induced respiration (SIR)

Development of new toxicity assays to extend our understanding of the biological response associated with contaminants present in biosolids.

Jo Cavanagh, Kat Trought, and Caroline Mitchell (Landcare Research)

Thyroid dysfunction: Endocrine disruption is a primary sub-lethal toxicological effect of concern for contaminants. The focus is often on disruption associated with sex hormones; estrogens and androgens. The thyroid, which is responsible for the release of hormones that control our metabolism, is also part of the endocrine system and there is an increased concern about the effects of contaminants on thyroid function. We have used an acellular assay developed by Montano *et al* 2012 that measures the extent to which contaminants bind to a protein, transthyretin or TTR. This protein transports the thyroid hormone thyroxine or T4 around the body, and if a reduced number of binding sites are available –for example due to the binding of contaminants – then that transport is disrupted.

We tested a range of individual chemicals (triclosan, bisphenol A, carbamazepine, technical nonylpheno, bis-phthalate, and galaxolide –a polycyclic musk) known to be present in biosolids, and extracts from 17 different biosolids. We found that nonylphenol, bisphenol A, triclosan and carbmazepine binds to TTR although galaxolide and bis-pthalate do not (e.g. Figure 1). We also observed that unidentified compounds in the biosolid extracts also bind to TTR (Figure 2).

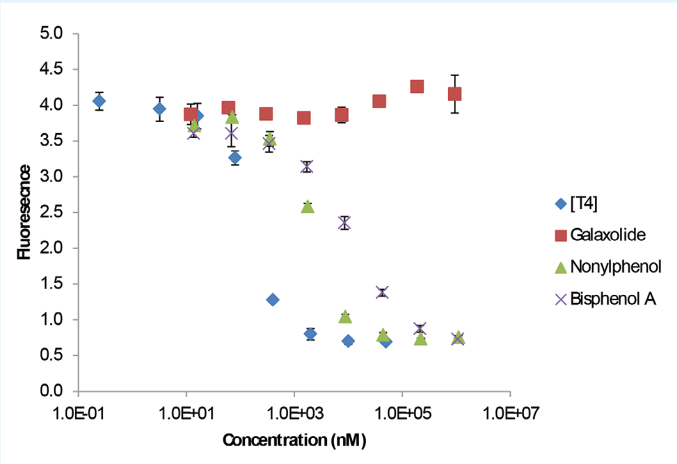


Figure 1. Binding of the standard T4, and individual chemicals to TTR. Galaxolide does not bind to TTR at the concentrations tested.

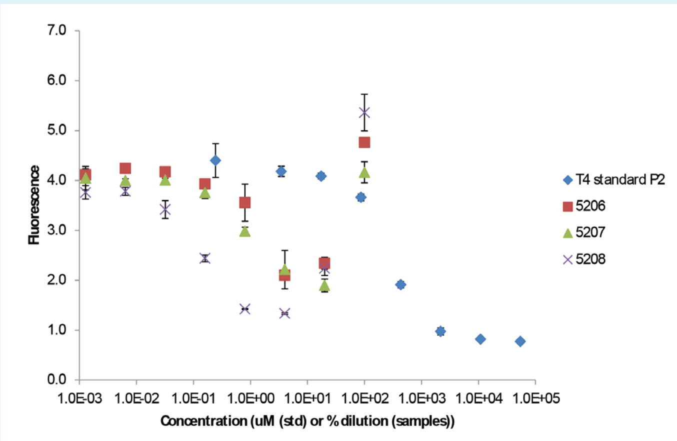


Figure 2. Binding of T4 (std) and contaminants in selected biosolids extract. Note increased fluorescence at higher concentrations in sample extracts is due to the colour present in these samples.

Early in 2015 we will be involved in an international inter-laboratory comparison of biological assays to assess thyroid dysfunction, which will provide an opportunity to compare the results of tests run in our laboratory with the same test run in another laboratory, as well as to compare the response of this assay to different measures of thyroid dysfunction.

Oxidative stress: Increasingly oxidative stress is recognised as a primary mechanism of toxicity, and it has been implicated in the development of a number of diseases including Parkinsons' disease and heart disease. Oxidative stress arises from a cellular imbalance of reactive oxygen species (ROS) and biologically generated anti-oxidants. This imbalance can be caused by ROS generated within the cell (endogenous ROS) in response to contaminants or ROS present in the external environment (exogenous ROS) that are absorbed into the cells.

Used extensively for assessing the oxidation potential of air particulate matter, we have applied an acellular assay based on Akhtar *et al* (2010) to test the oxidative potential of individual chemicals or biosolids extracts that may led to the production of ROS. We found no oxidative potential associated with any of the individual chemicals listed above, however the majority of biosolids extracts elicited a response (Figure 3). This indicates there are components other than those tested, that are giving rise to the oxidative potential in the biosolids extracts.

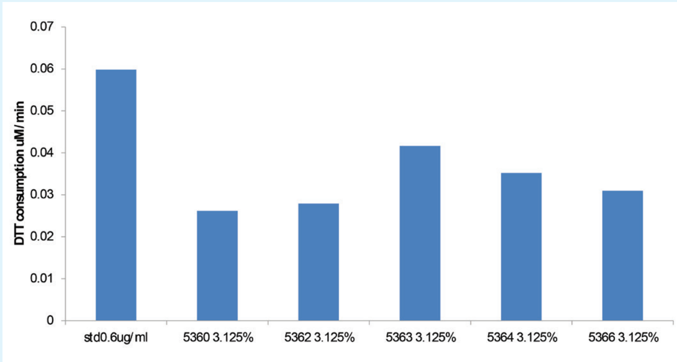
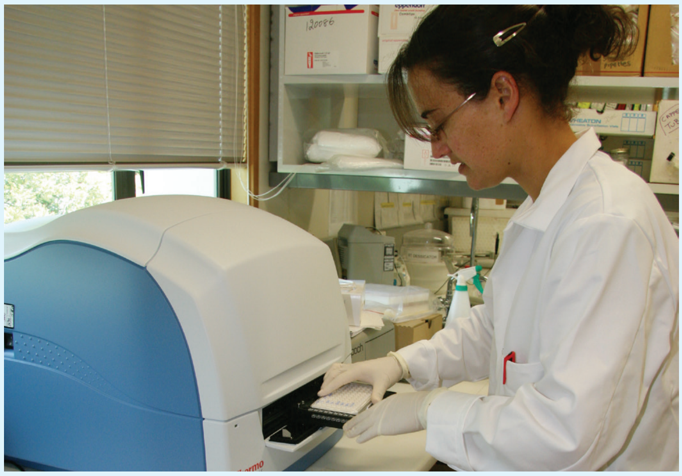


Figure 3. Measure of oxidative stress of selected biosolid extracts, compared to a standard. No response was observed for individual chemicals tested.

These assays enable us to extend the range of mechanisms of toxicity we can assess to provide a comprehensive assessment of different biological responses associated with biosolids and associated contaminants.



Kat Trought running the acellular assay

References:

Akhtar US, McWhinney RD, Rastogi N, Abbatt JPD, Evans GJ, Scott JA (2010). Cytotoxic and proinflammatory effects of ambient and source-related particulate matter (PM) in relation to the production of reactive oxygen species (ROS) and cytokine adsorption by particles. Inhalation Toxicology 22(S2): 37–47.

Montano M, Cocco E, Guignard C, Marsh G, Hoffmann L, Bergman A, Gutleb AC, Murk AJ 2012. New Approaches to Assess the Transthyretin Binding Capacity of Bioactivated Thyroid Hormone Disruptors. Toxicological Sciences 130(1): 94–105.

ADVISORY GROUP FEATURE

An interview with David Horne

The Advisory Group provides guidance into the long-term direction of the programme. They are a panel of industry, Government, and non-Government representatives with a keen interest and/or expertise in the biowaste field.

What is your interest in the biowaste programme?

I research and teach in the area of land application of wastes including dairy and municipal effluents. I also have an interest in grey water re-use. We have a large research project at Massey investigating ways that dairy farmers can reduce their environmental footprint while increasing profitability. At one of the university's dairy farms we have built a free-stall barn. These types of structures allow farmers to harvest and store large quantities of the dung and urine that is excreted by their cows. As this slurry can then be applied back to pastures in a timely manner, this practice approximately halves nitrogen leaching. I have also been involved with Horizons Regional Council in the development of a model that simulates combined land-water discharge of town effluent. In addition, we have a PhD student studying the ability of tephra soils to adsorb phosphorus from wastewaters. These soils are showing great potential for use as filters. Furthermore, I was fortunate enough to be involved with Morkel Zaayman's Master's thesis in which he looked at the fate and effect of antimicrobial triclosan in soils.

How do you see the information produced being useful to you and to NZ?

New Zealanders need to reduce the impacts of their waste materials on the environment that they inhabit. These biowastes also often contain nutrients and other valuable chemicals which need to be recovered or recycled. Good information and research in the sustainable management of our waste streams is an imperative. For example, the information that is produced in the biowaste programme is very valuable to members of the LTC, many of whom are practitioners and so get to apply this knowledge in very practical ways in the workplace.

What else would you like to see in the programme?

Perhaps there could be greater emphasis on exploring and developing technologies that help us recover or reuse the valuable chemicals that we are currently losing to our environment. While the emphasis to date has rightly been on mitigating environmental impacts of our waste streams, it may be time to think more strategically about reuse of some of their valuable constituents.

If you had a million research dollars, how would you spend them?

Following on from above, I think that the one of the most pressing needs is to recover the phosphorus that is contained in many of our effluents. There is a finite reserve of this nutrient, and given our dependency on agriculture, we are particularly exposed to threats associated with dwindling supply. Uncoupling nutrient cycles, whereby much of the phosphorus we consume or use is washed out to sea and lost to us does not seem wise to me. I would research the potential for humankind to start salvaging much of the phosphorus and other valuable nutrients that they currently place back into the environment so indiscriminately.

Andrew van Schaik (pictured right) left the CIBR group this month after more than 18 years of service at ESR. Andrew has provided very valuable technical expertise over his time with us and will be sadly missed. We are sure many readers will have come across him at some stage, we wish him all the best in his future endeavours.

STAFF CHANGES

Rob Lei has recently joined the CIBR team to take up the Business Leader role which supports the Programme Manager to grow new opportunities for CIBR. This role will include the coordination of a newly formed business development working group consisting of representatives of each of the core CIBR partners (Jacqui Horswell -ESR, Louis Tremblay-Cawthron, Kim McGrouther-Scion, Christine Harper-Landcare). This group is tasked with supporting the CIBR science teams in the continued building of strong end-user relationships and growing new revenue opportunities.

Rob is a Business Development Manager at Scion with considerable environmental technology experience in NZ and the UK. His background covers a wide range of positions and responsibilities from operational engineering to process design and project management. He has played a lead role in recent technology developments such as TERAX™ and previously managed the Clean Technology team at Scion.

Staci Boyte has joined the CIBR team at ESR. Our newest research technician, Staci, moved to Wellington from Palmerston North to be with us and we are very pleased to welcome her. Primarily involved in the biowaste and greywater projects at ESR, Staci is currently learning the ropes and will be kept busy with plenty of upcoming lab work as well as finishing off her Post Graduate Diploma in Soil Science through Massey University.

CIBR Produces Science Excellence

Every year Environmental Science and Research (ESR) accepts nominations for excellence awards in three categories; Chair's Award for Excellence, Science Excellence Award and Support Excellence Award. These are presented to individuals or teams within the organisation who demonstrate significant progress towards ESR's key outcomes, and are a means to recognise and celebrate achievements. In August this year the CIBR team at ESR were proud to take out two awards in the 2013/14 Science Excellence category.

- Dr Jacqui Horswell was awarded science excellence for her work in biowaste research and leadership of the Centre for Integrated Biowaste Research (CIBR).
- The ESR CIBR team as a whole; Jacqui Horswell, Alma Siggins, Sarah Quaife, Andrew Van Schaik, Jinny Baker, Morkel Zaayman and Jen Prosser (pictured left) received highly commended for their work in 'improving the safety of fresh water and ground water resources for human use and the safer use of biowastes'

These awards are considered to be prestigious within the organisation, and receiving two reflects the outstanding work undertaken by not just our ESR team members but that of CIBR as a whole, attributing credit to the diligence and dedication within the centre.

The ESR CIBR team members from left to right.

Top: Morkel Zaayman, Sarah Quaife, Andrew van Schaik and Jinny Baker. Bottom: Jen Prosser, Jacqui Horswell and Alma Siggins

Conference diary

Dedicated to improving and communicating technology for the land treatment of waste products

New Zealand Land Treatment Collective Annual Conference 2015

25th - 27th March. Edgewater Resort, Lake Wanaka

ecobiorefinery 2015 | IWA the international water association

1st IWA Conference on Lignocellulosic-Based Biorefineries and the Environment

Conference 30 August - 4 September, 2015. Novotel, Rotorua, New Zealand

SETAC Australasia Nelson 2015 25 to 28 August

Conference 25–28 August, 2015. Rutherford Hotel, Nelson

Image courtesy Tuaropaki Trust

Condolences for the late Ngaire George

He kōtuku rerenga tahi

The white heron is a bird of one flight, a rare visitor

Tēnā koutou katoa,

Among her many roles in the community, Ngaire George was a Trustee for the Tuaropaki Trust, a mentor for our work with the Mokai Marae and community, and a member of the CIBR Advisory Group.

We are shocked and saddened to hear of the sudden passing of Ngaire. Her vision, passion and commitment to all of life; people and the environment, the past and the future was truly inspiring. Ngaire was a woman of great insight and foresight, but more than having fantastic ideas, she did the hard work and long hours to follow through. Her ability was enormous in leadership, strategising, planning, connecting, and organising people. In this way she was one of those special people in the world that could actually make all the wonderful possibilities become real. Ngaire was truly one of a kind in her ability to span a huge breadth of vision and aspirations with her knack for grounding and growing real and tangible outcomes. Her spirit and character were truly mighty. Her endless stamina, kindness and commitment to nurturing, discovering opportunities and seeking excellence in all endeavours was outstanding and inspirational to all.

The CIBR Team are very privileged that Ngaire sponsored our work with the Mokai community. Ngaire's contribution, hospitality and encouragement were wonderful and very memorable. Indeed she was the glue, the backbone and the wings of this project. We feel very lucky that she touched our lives, and are deeply saddened by her passing. She will be missed by us all.

We give our heartfelt thoughts to all who have been part of Ngaire's life, and are touched by such a great and sudden loss.

Our tears flow, and our very deepest sympathies with Eru, family and friends at Mokai.

Arohanui The CIBR Team

If you would like further information on the programme or have any questions, please see our website www.cibr.esr.cri.nz or contact a member of the Science Leadership Team:

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